

Taiwan Stress Test National Report for Nuclear Power Plants

This national report is provided by the Taiwan regulatory body, as part of the stress tests program applied to Taiwan nuclear power plants in response to the Fukushima-Daiichi accident

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1. General data of site/plant

In Taiwan, there are currently three operating nuclear power plants (NPPs), namely, Chinshan, Kuosheng and Maanshan, which are also named the first, second and third NPPs, respectively. In addition, there is another one nuclear power plant under construction, the Lungmen NPP. Each of these four NPPs is equipped with two identical nuclear power units. All the nuclear power plants in this country are owned and operated by a state-owned utility, the Taiwan Power Company (TPC).

The following figure 1-1 shows the locations of the four existing NPPs in Taiwan.

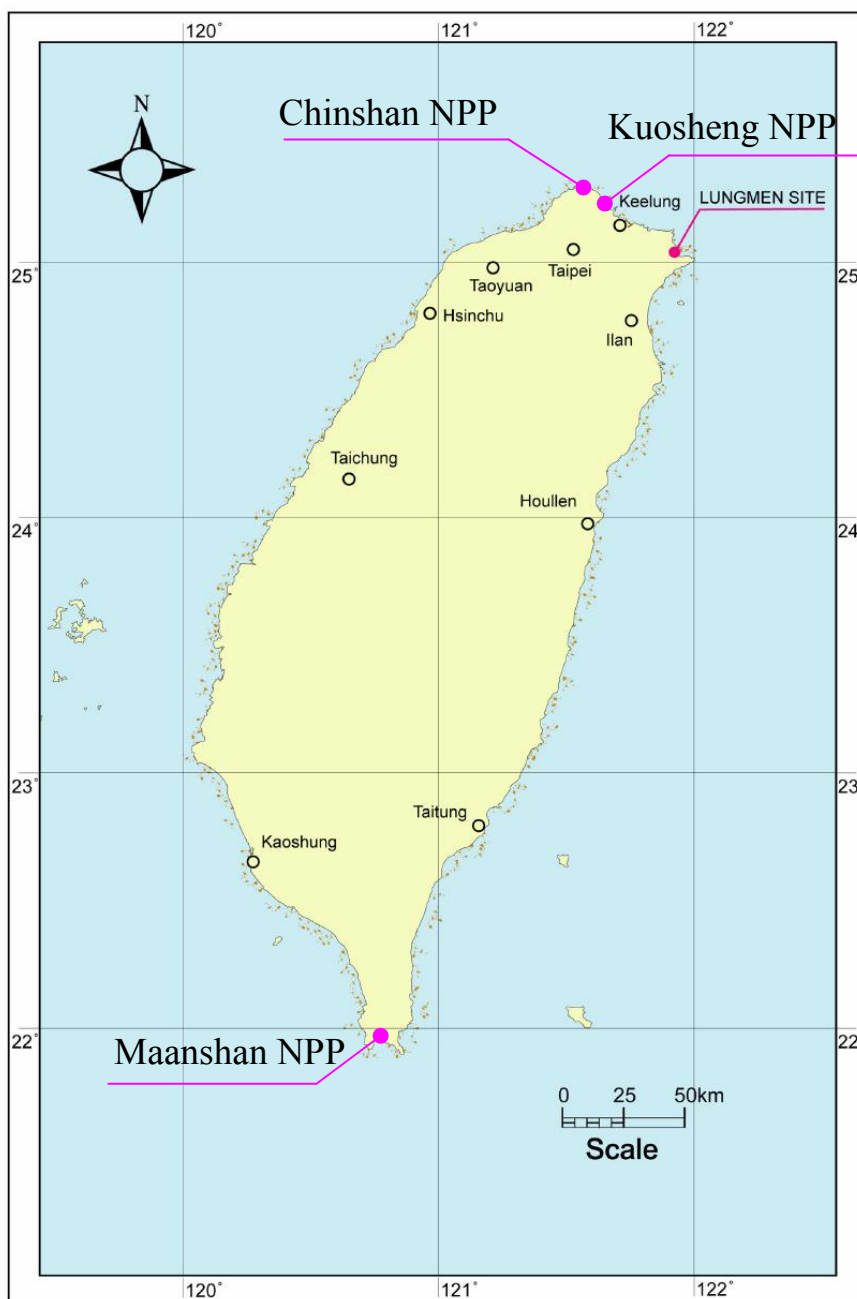


Figure 1-1 The site locations of NPPs in Taiwan

1.1 Site characteristics

Chinshan NPP

Chinshan Nuclear Power Plant (CSNPP) is located at the north end of Taiwan facing East China Sea. CSNPP is about 28 km away from Capital city Taipei. There is a ChanHua Creek adjacent to the side of the plant. The plant site spreads about 200 meters from east to west and 1.5 kilometers from south to north with total area about 20 hectares. The elevation of the entire plant is about 5 to 20 meters above sea level and is about 500 m from the shore. There are mountain ridges along the east and west sides of the CSNPP. The southern side of the plant is the so-called Da-Tun Mountains.

Kuosheng NPP

Kuosheng Nuclear Power Plant (KSNPP) facing East China Sea is located at the north end of Taiwan. The site elevation is about 10 to 20 meters above sea level and is about 500 m from the shore. It is close to Keelung city and is about 22 km away from Taipei. CSNPP is about 12 km west to this site. There is no creek passing through the site but do have two creeks passing by. One is Yuantan Creek which is on the west side of the plant and is about 1.5 km away. The other one is Mashu Creek which is on the east side of the plant and is about 4.5 km away. Both creeks flow to the ocean and are separated from the plant by the mountains.

Maanshan NPP

The Maanshan Nuclear Power Plant (MSNPP) is located at Southern tip of Taiwan Island and is about 300 meters from shore. The plant occupies 329 hectare and is 5 km from Hengchun, 15 km north of Cape Eluanpi, and 110 kilometers south of Kaohsiung city. There are no rivers or dams in and close to the plant. There is a Lake located less than 1 km at north of the plant.

Lungmen NPP

Lungmen Nuclear Power plant (LMNPP) facing Pacific Ocean is located at an inward bay area of northeast Taiwan. Most of the site elevations are about 12 to 30 meters above sea level and is about 600 m from the shore. The site is approximately 40 kilometers east of Taipei city. The Lungmen NPP site is located along the coast and approximately 68% of the area within a 50 km radius of the site is open water. The eastern part of the site is the reserved plant area with elevations varying from 8 to 15 m above Mean Sea Level (MSL).

The western part of the site is a mountainous district with elevations varying from 15 to more than 170 m above MSL.

Figure 1-2 shows the arrangement of the LMNPP facilities in the site. The Lungmen NPP includes all buildings which are dedicated exclusively or primarily to housing systems and the equipment related to the nuclear system or controls access to this equipment and systems. Major buildings included within the scope of the Lungmen NPP are:

- (1) Reactor Buildings (including containment)
- (2) Access Control and Unit Administration Buildings
- (3) Control Buildings and Control Building Annexes
- (4) Turbine Buildings
- (5) Radwaste Building and Radwaste Tunnel
- (6) Auxiliary Fuel Building

- (7) Reactor Building Service Water Pump House
- (8) Circulating Water Pump House
- (9) Switchgear Buildings

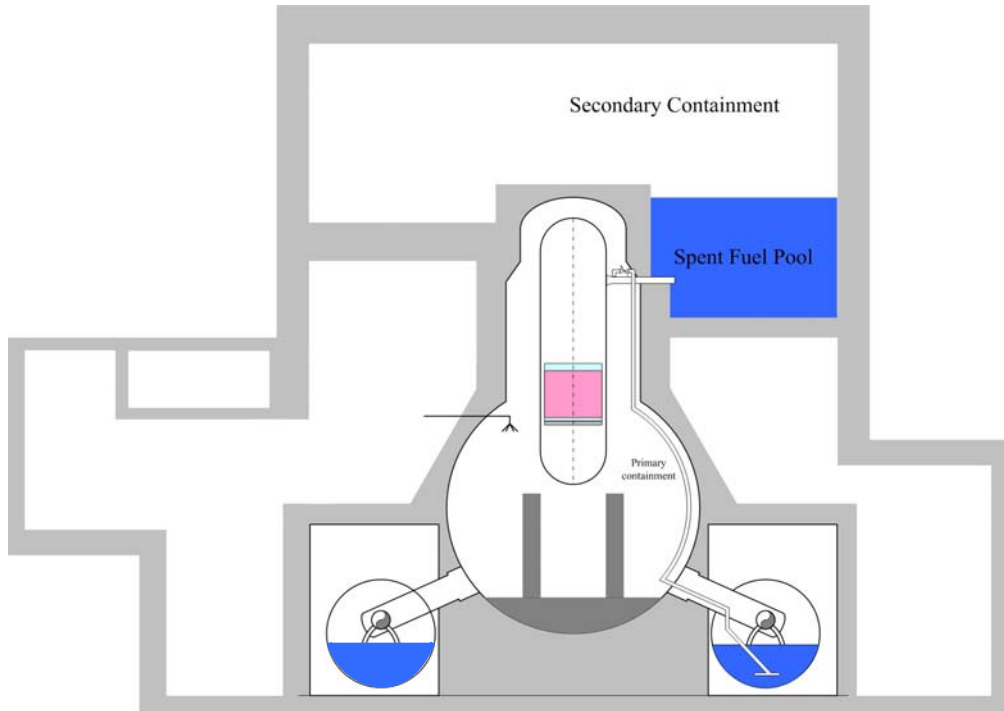
As to the geology and seismology of the site, both tectonic provinces and geologic structures as well as the seismicity are considered in the evaluation of the maximum earthquake potential at the site. No active faults were found near the site, although some shears ranging in thickness from a few centimeters to several meters were found, most of them are either localized, or are at depths substantially below structure base levels and hence have no influence on the foundation properties. The major geologic structure that does affect the site is the subducting slab in northeastern Taiwan. The site is primarily a rock site, the foundation rocks of the site are mainly consisting of indurated argillite with sandstone and arkosic sandstone with siltstone or shale. The overburden soil in the site consists mainly of organic and inorganic clay, silt, and sand with minor amounts of gravel, cobbles, and boulders.



Figure 1-2 Bird's View of LMNPP

1.2 Characteristics of units

[Chinshan NPP](#)



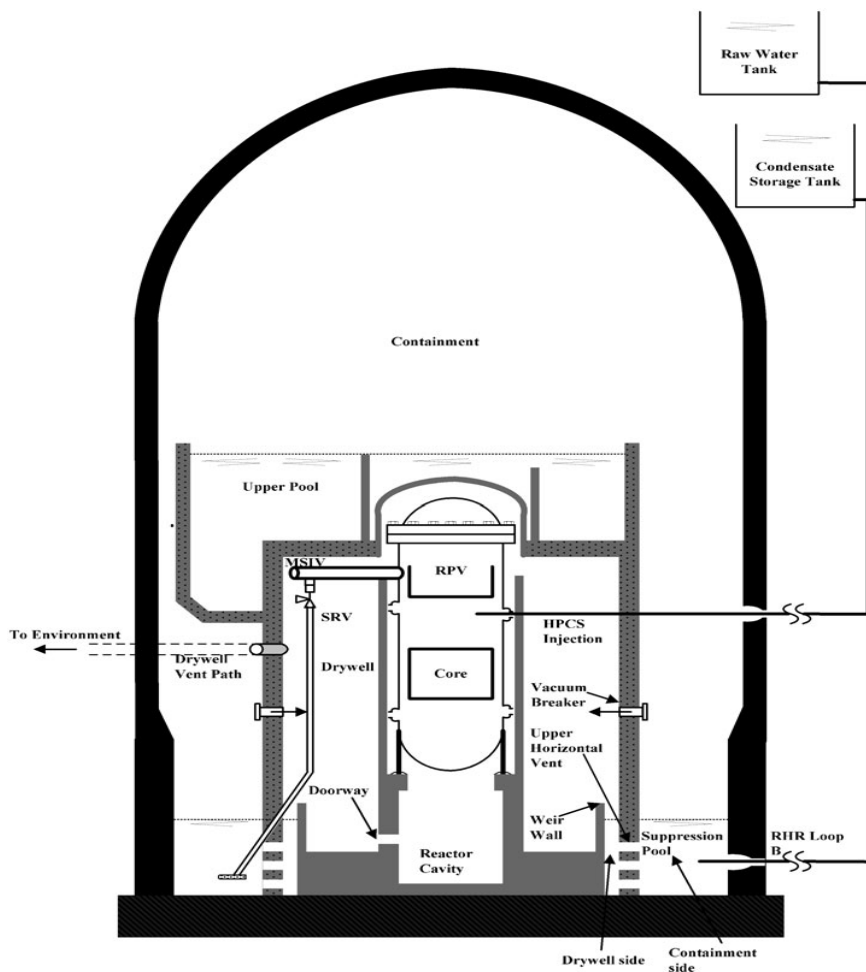
There are two BWR-4 reactors each rated at 1775 MWt installed in CSNPP. These two BWRs were supplied by GE. Unit 1 and unit 2 reached their initial criticality on 10/16/1977 and 11/9/1978 respectively. After completing the measurement uncertainty recapture power uprate for unit 1 and unit 2 on 2/24/2009 and 7/9/2008 respectively, the rated power was slightly increased to 1804 MWt.

Unit Design Operating Parameters

Number of Fuel bundles	408
Number of Control Rods	97
RPV Height (Internal) in	815
RPV Diameter (Internal) in	203

CONTAINMENT	
Type	Mark I, Steel Drywell and Pressure Suppression Pool
Leakage Rate, % vol/day	0.5
Drywell:	
Construction	Light Bulb Shape, Steel Vessel
Internal Design Temperature, °F	340
Maximum Internal Pressure, psig	56
Total Free (air) Volume, ft ³	130,000

Suppression Pool:	
Construction	Torus, Steel Vessel
Internal Design Temperature, °F	340
Internal Design Pressure, psig	56
Water Volume, ft3	78,000
Total Free (air) Volume, ft3	87,200



The KSNPP is equipped with 2 GE BWR-6 reactors, with rated power 2894 MWt installed in each unit. Unit 1 and unit 2 reached their initial criticality on 2/1/1981 and 3/26/1982 respectively. KSNPP also completed the measurement uncertainty recapture power uprate for both units. The rated power was slightly increased to 2943 MWt.

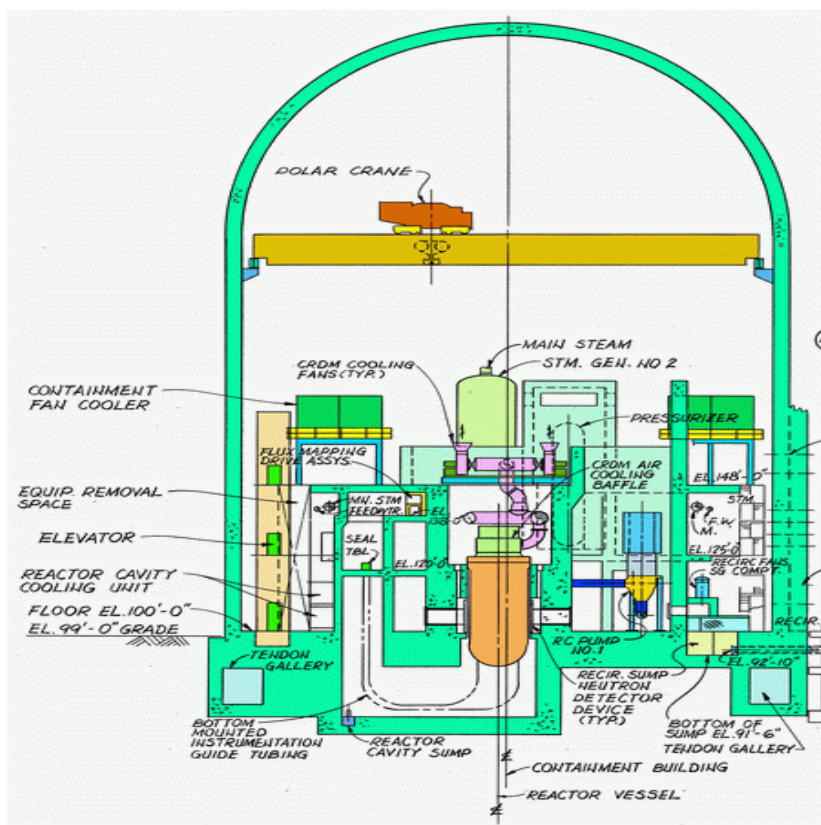
Unit Design Operating Parameters

Number of Fuel bundles	624
Number of Control Rods	145
RPV Height (Internal), in	838
RPV inside Diameter, in	218

CONTAINMENT	
Type	Mark III, Reinforced Concrete Containment with Pressure Suppression and Reactor Building Enclosing Drywell and Suppression Pool

Leakage Rate, % vol/day	0.45
Reactor Building Construction	Reinforced Concrete Cylindrical Structure with Hemispherical Head and Steel Liner
Internal Design Temperature, °F	200
Design Pressure, psig	15
Total Free (air) Volume, ft ³	1.43 x 10 ⁶
Drywell:	
Construction	Reinforced Concrete Unlined; Basically Cylindrical; Steel Head
Internal Design Temperature, °F	330
Design Differential Pressure, psig	
Internal	27.5
External	21
Total Free (air) Volume, ft ³	238,000
Suppression Pool:	
Construction	Reinforced Concrete, Steel Lined and Cylindrical
Internal Design Temperature, °F	200
Design Pressure, psig	15
Water Volume (at high water level), ft ³	113,950

[Maanshan NPP](#)



There are two 3-loop pressurized water reactors in MSNPP, which are designed and manufactured by Westinghouse. The rated power of each reactor is 2775MWt/ 951MWe. The initial criticality time of unit 1 is March 30, 1984 and that of unit 2 is Feb. 1, 1985. Measurement uncertainty recapture power uprate was conducted to unit 1 on July 7, 2009 and to unit 2 on Dec. 2, 2008. The rated power of each is raised to 2822 MWt/960MWe after power uprating. The reactor and its associated systems are enclosed in a pre-stressed reinforced concrete containment.

The design operating parameters of RCS

Normal operating pressure, Psig	2235(157 kg/cm ²)
Total system volume (including pressurizer (PZR) and surge line), ft ³	9410(266.3 m ³)
The system fluids volume at the maximum guaranteed operating power, ft ³	8833(250 m ³)
Maximum spray rate of pressurizer(PZR), GPM	700(44.1 l/s)
Capacity of the PZR heater, KW	1400
Heat power of the primary side, MWt	2834
Heat power of the reactor, MWt	2822
The flow volume of one loop under RCP operation (thermal design flow), GPM	97600 (unit 1) 92600 (unit 2)

Temperature at reactor outlet nozzle, °C	327.4
Temperature at reactor inlet nozzle, °C	290.1
Feedwater temperature of the steam generator, °C	228.1

CONTAINMENT	
Type	Steel-Lined Pre-Stressed Post-Tensioned Concrete Cylinder, Hemispherical Dome
Leakage Rate, % vol/day	0.1 (24 hr), 0.05 (after)
Internal Design Pressure, psig	60
Total Free (air) Volume, ft ³	2.0 x 10 ⁶
Diameter, ft	130
Height, ft	195

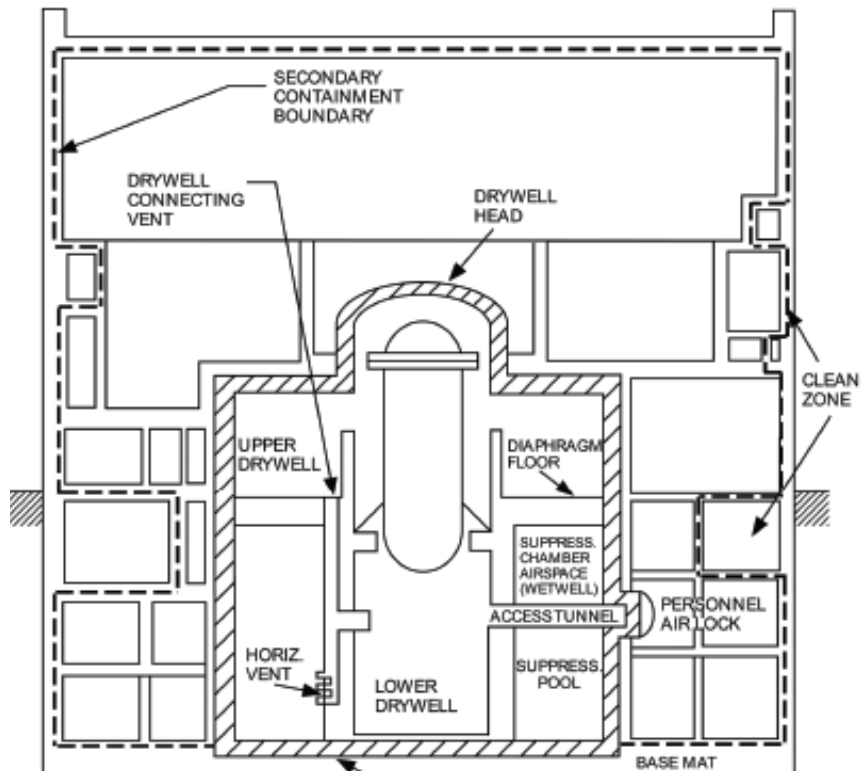
Lungmen NPP

There are two Advanced Boiling Water Reactors (ABWR) installed in LMNPP. The ABWR nuclear island is designed and manufactured by General Electrical Co. (GE). The turbine generator is manufactured by Mitsubishi Heavy Industry(MHI). The radwaste system vendor is Hitachi. The following table shows the fundamental design parameters of the plant. The containment vessel is a cylindrical steel-lined reinforced concrete structure integrated with the Reactor Building. The reactor building provides a secondary containment around the primary containment vessel. The containment nomenclature is specified in the following figure.

Design Specification and Parameters of LMNPP

Reactor	ABWR
Containment	Reinforced Concrete Containment Vessel (RCCV)
Rated Power	3926 MWt
Fuel Bundle	872 bundles
Number of Control Rod	205 rods
Reactor Pressure Vessel	Height(inside): 1770.3 cm · Internal Radius : 711.2 cm
Primary Containment	Height: 36 m (Measured from the top of containment base to the top of drywell cover) Internal Radius: 30 m
Spent Fuel Storage Capacity	Spent Fuel Pool : 3081 storage racks Auxiliary Fuel Pool : Up to 10,000 storage racks.
Safety Equipment	Reactivity Control related systems Control Rod and Fine Motion Control Rod Drive (205 control rods) Standby Liquid Control System (2 pumps)

Emergency Core Cooling related systems	High Pressure Core Flooding System (2 divisions) Reactor Core Isolation Cooling System (1 division) Automatic Depressurization System (8 safety relief valves) Residual Heat Removal system by Low Pressure Flooder mode (3 divisions)
related Radiation release prevention systems	Primary Containment Containment heat removal system, include RHR Suppression Pool cooling mode and drywell/wetwell spray mode.
Supporting Systems	Emergency Diesel Generator (3 sets) Reactor building cooling water system (3 divisions, 3 pumps/division) Reactor Building Service water system (3 divisions, 3 pumps/division)



ABWR Reactor Building

1.3 Significant differences between units

Chinshan NPP

Basically all the SSCs of the two units are identical. They are all designed based on redundancy, i.e., there are two trains of components and equipment for all safety related systems. Each train is completely isolated in space and independent on electrics from the other. Therefore any single component failure or malfunction will not affect the safety system operation. It is designed to achieve safe shutdown as long as one of the train is functional. The safety related systems of the two units are physically separated. The following is the safety related equipment shared by both units:

Besides the two diesel generators which are originally equipped for the two trains in each unit, one additional 4.16kV/4000kW air-cooled Emergency Diesel Generator (5th EDG) was installed to improve the plant safety in case of loss of offsite power event. So, the 5th EDG was initially designed to totally replace the two water-cooled diesel generators of either unit 1 or unit 2 when they are not available, but not both of them. However, after Fukushima Nuclear Accident, the Station Blackout Procedure 535 has been revised so that under appropriate control and management, the 5th EDG can supply power to the safety related 4.16kV Essential Bus of both units simultaneously.

Kuosheng NPP

Basically all the SSCs of the two units are identical. They are all designed based on redundancy. There are two trains (train A and train B) of components and equipment for all safety related systems. Each train is completely isolated in space and independent on electrics from the other. Therefore any single component failure or malfunction will not affect the safety system operation. It is designed to achieve safe shutdown as long as one of the train is functional. The safety related systems of the two units are physically separated. The following is the safety related equipment shared by both units:

Like the other NPPs, the 5th EDG with 4.16kV/3920kW capacity was also installed to improve the plant safety in case of loss of offsite power event. So, the 5th EDG was initially designed to totally replace the two water-cooled diesel generator of either unit 1 or unit 2 when they are not available, but not both of them. However, after Fukushima Nuclear Accident on 3/11/2011, the Station Blackout Procedure 1451 has been revised that under appropriate control and management, the 5th EDG can supply power to the Essential Bus of unit 1 and 2 simultaneously. (It was assured that the power generated by the 5th EDG is large enough to satisfy the basic power requirements of one operating division of both units simultaneously.)

Maanshan NPP

Basically all the SSCs of the two units are identical. The safety related systems of each unit are designed with redundancy as A and B loops. Components/equipment of each loop are installed separately and supplied with independent power source. Therefore any single component failure will not affect the function of the whole system. The redundant loops are designed that one single loop can accomplish the intended function of the system. Unit 2 is designed as a copy of unit 1, therefore, the major safety-related components/ equipment of unit 2 are the same as that of unit 1. However, there are some in common facilities for unit 1 & 2. The followings are the in common facilities for both units:

1. One air-cooled 4.16 kV/ 7000 KW emergency diesel generator (5th EDG). It can replace completely any one of the water-cooled emergency diesel generator in unit 1 & 2. But the 5th EDG can only replace one of the water-cooled emergency diesel generators. After Fukushima accident of 2011.03.11, new SOP 1451 is established. The 5th EDG can provide power to 2 safety related 4.16kV buses simultaneously, after the signals are cross over connected according to SOP 1451.
2. One NSCW building shared by both units. However, all systems or equipment of unit one and unit 2 in the building are separated.

Lungmen NPP

The safety related system of each unit has A, B and C three independent divisions. They are separated and isolated in space as well as in electrics and mechanics. So that any division fails would not affect the function of the safety related system. It is also designed that the unit can

achieve safe shutdown as long as any one of the division works. Basically the principal equipment of unit 2 are identical to unit 1. The safety related systems of the two units are identical and physically isolated. Still, there is some safety related equipment shared by the two units:

One set of air-cooled 4.16kV/7500kW emergency diesel engine generator (7th EDG): This EDG was designed to totally replace the water-cooled emergency diesel generator of either unit 1 or unit 2. After Fukushima Daiichi Accident on 3/11/2011, the new SOP 1451 allows the 7th EDG to simultaneously supply necessary power to the 4.16kV Essential Bus of unit 1 and 2. (Under proper loading management, the output of the 7th EDG is sufficient to supply power to operate one division of both units.)

1.4 Results of probabilistic safety assessments

Chinshan NPP

CSNPP has completed its living Probabilistic Risk Assessment (PRA) in 1995 and the PRA study is revised every three years. CSNPP has also established Reactor Power Operation Safety Assessment Model and Outage Safety Assessment Model. The Power Operation Safety Assessment Model is further divided into 5 categories, namely internal plant event, external earthquake, flood, fire and typhoon events. The conclusions of the most recent assessments are:

- (1) The total Core Damage Frequency (CDF) of reactor during power operation is $1.8E-5/R$. The total CDF of reactor during outage is $6.2E-6/R$.
- (2) The total LERF of reactor during power operation is $6.5E-6/R$.
- (3) Among the CDFs of reactor during power operation, 14.2% ($2.6E-6/R$) is due to internal plant event, 30.6% ($5.6E-6/R$) is due to earthquake, 0.2% ($3.0E-8/R$) is due to typhoon, 54.7% ($1.0E-5/R$) is due to flood, and 0.2% ($4.1E-8/R$) is due to fire.
- (4) Among the LERFs of reactor during power operation, 12.3% ($8.0E-7/R$) is due to internal plant event, 53.6% ($3.5E-6/R$) is due to earthquake, 0.2% ($1.4E-8/R$) is due to typhoon, 33.7% ($2.2E-6/R$) is due to flood, and 0.2% ($1.1E-8/R$) is due to fire.

Kuosheng NPP

KSNPP also completed its living PRA in 1995. Since then, four revisions of living PRA had been completed. KSNPP has also established reactor Power Operation Safety Assessment Model and Outage safety Assessment Model. The Power Operation Safety Assessment Model is further divided into 5 categories, namely internal plant events, external earthquake, flood, fire and typhoon. The conclusions of the most recent assessment are:

- (1) The total CDF of reactor during power operation is $2.549E-5/R$. The total CDF of plant outage is $9.55E-6/R$.
- (2) The total LERF of reactor during power operation is $1.617E-6/R$.
- (3) Among the CDFs of reactor during power operation, 37.90% ($9.659E-6/R$) is due to internal plant events, 32.29% ($8.231E-6/R$) is due to earthquake, 12.27% ($3.128E-6/R$) is due to typhoon, 1.23% ($3.144E-7/R$) is due to flood, and 16.30% ($4.155E-6/R$) is due to fire.
- (4) Among the LERFs of reactor during power operation, 12.42% ($2.008E-7/R$) is due to internal plant event, 76.07% ($1.23E-6/R$) is due to earthquake, 0.83% ($1.345E-8/R$) is due to typhoon, 0.12% ($1.956E-9/R$) is due to flood, and 10.56% ($1.708E-7/R$) is due to fire.

Maanshan NPP

The first version of MSNPP PRA report was finished in Oct. of 1987. Afterwards, the PRA was conducted every three years and the PRA report was updated accordingly. Since then, the PRA report has been revised 4 times up to now.

The PRA of MSNPP includes full power operation mode and shutdown mode. For full power operation mode, it is further divided into internal plant events, external earthquakes, typhoons, floods and fires event for analysis. The PRA conclusions in the most updated version are:

1. The total CDF of full power operation is $1.8E-5/R$; the total CDF of plant outage is $2.5E-5/R$.
2. The total LERF of full power operation is $1.2E-6/R$; no LERF analysis for plant outage.
3. For total CDF of full power operation, 27.2% ($4.9E-6/R$) is due to internal events, 44.4% ($8.0E-6/R$) is due to earthquakes, 8.3% ($1.5E-6/R$) is due to typhoons, 19.4% ($3.5E-6/R$) is from external floods, 0.8% ($1.4E-7/R$) from external fire sources.
4. For LERF of full power operation, the plant events are accounted for 56.2% ($6.6E-7/R$), 10.2% ($1.2E-7/R$) from earthquakes, 0.9% ($1.1E-8/R$) from typhoons, 31.5% ($3.7E-7/R$) from floods, 1.1% ($1.3E-8/R$) from fires.

Lungmen NPP

LMNPP had completed its PRA model setup and had reported the PRA results in 2007. Currently, the PRA is under peer review and is under continuous refinement. LMNPP has also established Power Operation PRA Model and Shutdown PRA Model. The Power Operation PRA Model is further divided into 4 categories, namely internal events, earthquake, flood, and fire. The Shutdown PRA Model is also divided into 2 categories, namely lower power operation, and refueling outage. The conclusions of the most recent assessment are:

1. The total CDF (Core Damage Frequency) of reactor power operation is $7.93E-6/R$. The total CDF of reactor shutdown is $1.61E-7/R$.
2. The total LERF (Large Early Release Frequency) of reactor power operation is $5.96E-7/R$.
3. Among the CDF of reactor power operation, 19.16% ($1.55E-6/R$) is due to internal events, 70.46% ($5.70E-6/R$) is due to earthquake, 7.59% ($6.14E-7/R$) is due to flood, 0.8% ($6.46E-8/R$) is due to fire.
4. Among the LERF of reactor power operation, 1.58% ($9.00E-9/R$) is due to internal event, 97.54% ($5.55E-7/R$) is due to earthquake, 0.08% ($4.76E-9/R$) is due to flood, 0.03% ($1.8E-10/R$) is due to fire.

1.5 Assessment and conclusions of the regulatory body

Building on the results of the stress test and insights from the actions being taken by other countries, the AEC established clear requirements to implement enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 5 November 2012. TPC may propose alternatives subject to AEC approval. The orders issued are listed below.

1. 10101: Requiring seismic hazard re-evaluations implementing the recommendation from the United States Nuclear Regulatory Commission (USNRC) Near Term Task Force (NTTF) Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.
2. 10102: Requiring flood hazard re-evaluations implementing the USNRC NTTF Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.

3. 10103: Requiring TPC to simulate the mechanism of seismic and tsunami hazards and the resulting risks based on comments from an AEC review meeting.
4. 10104: Requiring the enhancement of the water tightness of buildings (or build seawall, or tidal barrier) to a level of 6 meters above current licensing bases based on the actions being taken at Japanese NPPs and as referred to in the USNRC NTTF Report, to address the uncertainty from the original design basis tsunami height by adding 6 meters of protection.
5. 10105: Requiring seismic, flood and others external events walkdowns consistent with the USNRC NTTF Report Tier 1 recommendation 2.3 to conduct seismic and flood walkdowns
6. 10106: Requiring TPC to take actions to address station blackout (SBO) consistent with the USNRC NTTF Report Tier 1 recommendation 4.1 on SBO regulatory actions.
7. 10107: Requiring more than 2 emergency diesel generators (EDGs) to be in an operable state all the time even when the reactor is shut down so that if one unit is shut down with one EDG under inspection and the swing EDG is assigned to it according to the new requirement, the capability of the swing EDG to back up the other unit is restricted.
8. 10108: Requiring TPC to enhance emergency DC power supply to secure a storage capacity of at least 8 hours with the storage capacity of the batteries of one system without isolating the load and at least 24 hours after the unnecessary loads are isolated.
9. 10109: Requiring TPC to extend the SBO coping time to at least 24 hours based on specific issues for **Taiwan**'s NPP in that the original requirements of USNRC Regulatory Guide (RG) 1.155 do not include the effects resulting from earthquake and tsunami.
10. 10110: Requiring TPC to install a seismic qualified extra gas-cooled EDG at each NPP to address specific issues with electrical power supplies defence-in-depth for **Taiwan**.
11. 10111: Requiring TPC to install an alternate ultimate heat sink (UHS) consistent with recommendations from the ENSREG action plan.
12. 10112: Requiring TPC to implement the actions of the USNRC's Post-9/11 action (B.5.b) to stage response equipment on or near site to respond to extreme external events (see USNRC 10 CFR 50.54(hh)(2)).
13. 10113: Requiring TPC to address the USNRC NTTF Report Tier 1 recommendation 4.2 on equipment covered under USNRC regulation 10 CFR 50.54(hh)(2).
14. 10114: Requiring TPC to install reliable hardened vents for Mark I and Mark II containments and request the installation of filtration for all different containment designs consistent with the recommendation of USNRC NTTF Report Tier 1 recommendation 5.1 on reliable hardened vents for BWR Mark I and Mark II containments.
15. 10115: Requiring TPC to install spent fuel pool (SFP) instrumentation consistent with the recommendation of the USNRC NTTF Report Tier 1 recommendation 7.1 on SFP instrumentation.
16. 10116: Requiring TPC to strengthen and integrate the emergency operating procedures (EOPs), severe accident management guidelines (SAMGs), and extensive damage mitigation guidelines (EDMGs) with the ultimate response guidelines (URGs) developed by TPC following the accident at Fukushima Daiichi NPP consistent with the USNRC NTTF Report Tier 1 recommendation 8 on strengthening and integration of EOPs, SAMGs, and EDMGs.
17. 10117: Requiring TPC to perform a volcanic probabilistic risk assessment (PRA) for its NPPs and to study the impacts from ash dispersion based on comments during a high-level review meeting.
18. 10118: Requiring TPC to enhance the water-tightness of the fire doors of essential electrical equipment rooms based on specific concerns with the location of the equipment at **Taiwan**'s NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.
19. 10119: Requiring TPC to enhance the seismic resistant for the fire brigade buildings to

cope with beyond design basis earthquake (BDBE) conditions to address specific issues for **Taiwan**'s NPPs and on good practices from EU peer reviews.

20. 10120: Requiring TPC to improve the reliability of offsite power supplies to address specific issues for **Taiwan**'s NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.
21. 10121: Requiring TPC to improve the seismic resistance of raw water reservoirs at the NPPs and to consider the installation of impermeable liners to address specific issues for **Taiwan**'s NPPs and consistent with the measures being taken by TEPCO in Japan to install impermeable liners.
22. 10122: Requiring TPC to install passive autocatalytic recombiners (PAR) to prevent hydrogen explosions consistent with recommendations in the ENSREG action plan.
23. 101101: An Executive Order of the Yuan, requiring TPC to conduct an enhancement evaluation of safety related structures, systems and components (SSCs) for the Chinshan Nuclear Power Plant followed by the upgrading of the licensing basis safe shutdown earthquake (SSE) from 0.3g to 0.4g for specific SSCs relied upon to respond to an accident.
24. 101301: Requiring TPC to address the issue with the PWR reactor coolant pump (RCP) seal loss-of-coolant-accident leakage issue for Maanshan Nuclear Power Plant consistent with the ENSREG action plan.

In addition to the orders issued by the AEC's Department of Nuclear Regulation, there were three (3) orders issued by the Department of Nuclear Technology.

1. Requiring TPC to addressing staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions.
2. Requiring TPC to enhance the structure of the existing non-seismically qualified technical support centre (TSC) used for emergency response to address specific seismic concerns with the NPPs in **Taiwan**.
3. Requesting TPC to consider building a seismically isolated TSC building based on the practice being implemented in Japan in light of the accident at Fukushima Daiichi NPP and consistent with guidance provide by the International Atomic Energy Agency.

Furthermore, TPC should finish the integrated PRA analytical model based on ASME PRA standard.

2. Earthquake

2.1 Design basis

2.1.1 Design basis earthquake (DBE) of the plant

2.1.1.1 Characteristics of the DBE

[Chinshan NPP](#)

The threat of design basis earthquake to Chinshan NPP is evaluated based on an assumption that the most destructive earthquake, a (local) magnitude 7.3 earthquake which occurred in Western fault zone in 1909 since the earthquake data became available from 1900, hypothetically happened along the Hsinchuang fault, the nearest fault at distance of about eight (8) kilometers to the CSNPP, although Hsinchung fault was believed to be an inactive fault. A horizontal peak acceleration value of 0.3g for the DBE is inferred based on the attenuation law. 1/2 of the DBE value, 0.2g, is used for the Operating Basis Earthquake (OBE).

[Kuosheng NPP](#)

The determination for the DBE for Kuosheng NPP is the same as the approach used for the CSNPP, the only difference is the epicenter distance of the Magnitude 7.3 earthquake. The resulting peak acceleration is 0.4g/0.2g respectively for Kuosheng NPP's SSE/OBE. It's assumed that earthquake of intensity VIII+ in Modified Mercalli scale (MMI scale) happened in Kuosheng site due to the 1909 earthquake. Based on this assumption, the corresponding peak ground acceleration in Kuosheng site is 0.25g ~ 0.35g. Therefore, 0.4 g is selected as the peak ground acceleration for SSE in Kuosheng site and 1/2 of the 0.4g is selected for OBE.

[Maanshan NPP](#)

The DBEs for Maanshan are: (1) SSE: 0.4g, (2) OBE: 0.2g.

These two values were determined according to the geological characteristics of the site and the surrounding earthquake area. Based on Tectonic Province approach, the governing province for the Maanshan NPP is South Eastern Taiwan-Western Philippine Sea tectonic Province, and the governing historical earthquake is the 1941/12/17 M=7.1 earthquake. With the assumption of maximum potential magnitude M=7.5 for that province, the peak ground acceleration at the MSNPP site was determined to be 0.39 g, and 0.4g was therefore selected for PA for SSE and PA for OBE is 0.2g which is half of the SSE value.

[Lungmen NPP](#)

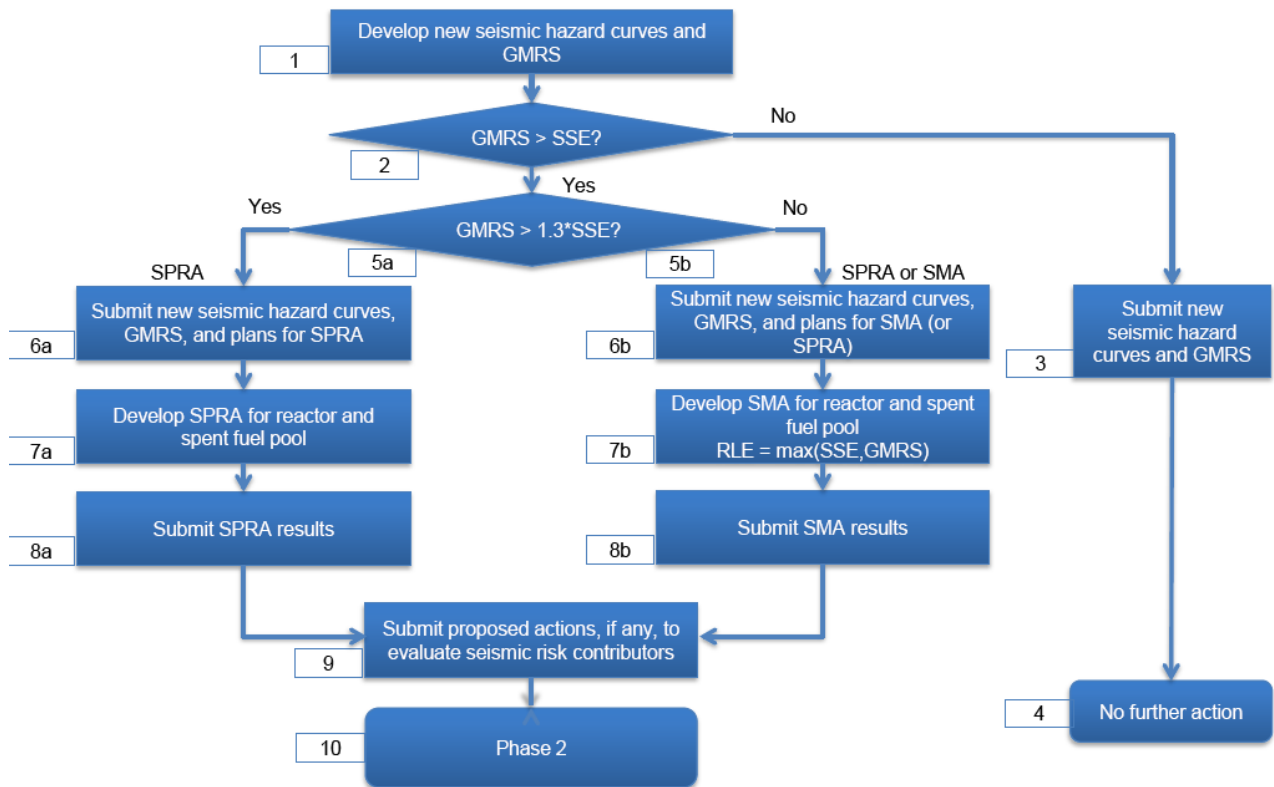
The seismic design of LMNPP basically follows the US rules and regulations. Accordingly, the historical earthquake records in the past 400 years of the area within 320-kilometers radius of the site was collected in 1992 to determine the LMNPP DBE. The DBE was determined conservatively and separately according to the geologic structure and the earthquake distribution in this area. It was determined based on the assumption that an earthquake of local magnitude of 7.3 which occurred in east of Taiwan in 1908, happened at the seismotectonic province boundary, 5 kilometers east of the site. The peak ground acceleration (PGA) of safe shutdown Design Basis Earthquake (DBE or SSE) is determined to be 0.4g conservatively. The PGA of Operating Basis Earthquake (OBE) is half of the DBE, i.e., 0.2g.

2.1.1.2 Methodology used to evaluate the DBE

Based on the definition in 10CFR100 Appendix A, the active faults are those faults which

have ever been activated at least once in 35,000 years, or have the evidence of moving of more than once in past in 500,000 years. The SSE of the plant was determined from all the active faults within 320 km from the site. The historically maximum magnitude or higher value was used to evaluate the maximum vibratory ground motion.

However, recent reports (special issue 19 and 23) from Central Geological Survey (CGS) stating that the pre-identified Shanchiao fault and Hengchun fault are reclassified as active faults potentially impact the seismic safety to the three existing NPPs as they are so close to the NPPs. Therefore TPC has taken the steps similar to USNRC NTTF (see flowchart below) to re-evaluate the adequacy of the current DBE of the three operating NPPs.



Chinshan NPP and Kuosheng NPP

Per the special report No.19 issued by Central Geological Survey (CGS), Ministry of Economic Affairs in July, 2007, a nearby fault, called the Shanchiao fault (a normal fault) is determined to be a category II active fault. The fault trends SSW to NNE, and the fault length is found to be at least 34 km long. The latest activated time of this fault may be back to 10,000 years from today. Based on this, TPC performed the impact evaluation for both plants, the preliminary result shows the free ground acceleration at foundation level of the Reactor Building of the plants, caused by Shanchiao fault, is 0.19g and 0.30g respectively, which is below the design basis earthquake value of 0.3g/0.4g for Chinshan/Kuosheng NPPs (see Table Nos.2-1 and 2-2).

Table 2-1a Shanchiao fault parameters

Fault	In-land Length	Length under the Sea	Depth of Epicenter	Scale(M _L)
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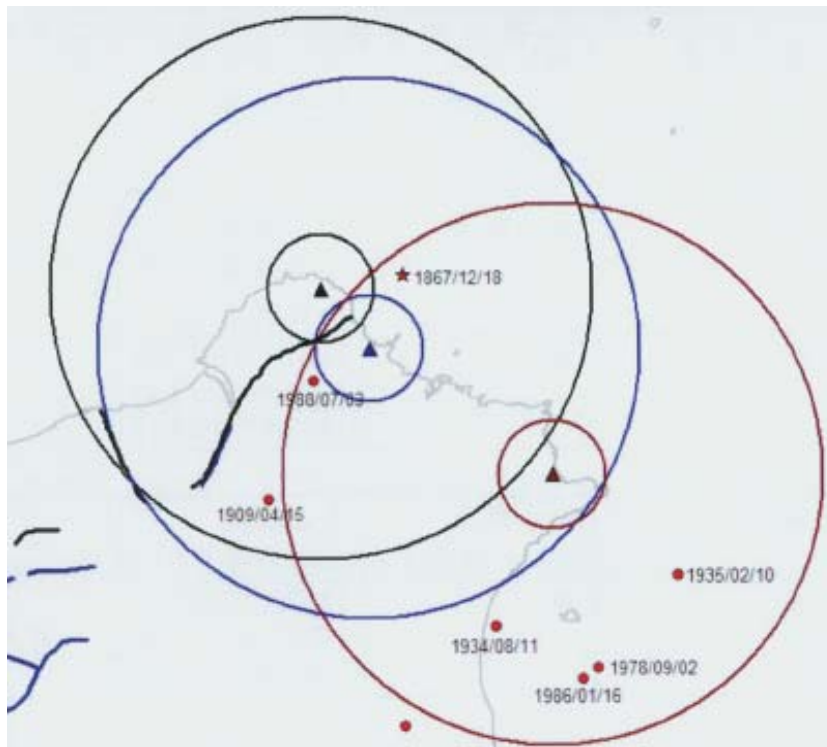
Shanchiao Fault	34 km	16.6 km	10 km	6.8
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Table 2-1b Maximum probable peak acceleration caused by Shanchiao fault

Location	Chinshan NPP	Kuosheng NPP
The calculated peak ground acceleration at grade surface	0.34g	0.56g
The calculated peak acceleration at foundation free surface	0.19g	0.30g
The site design acceleration at foundation free surface	0.30g	0.40g

Therefore, it is concluded that the DBE value of 0.3g and 0.4g is still adequate for Chinshan NPP and Kuosheng NPP respectively.

The following figure shows the new recognized active fault between CSNPP (the black triangle) and KSNPP (the blue triangle). Some major historical earthquakes within 8 kilometers and 40 kilometers radius were also included in the figure.



Maanshan NPP

Since the construction of this plant, the site has experienced two island wide strong earthquakes, namely the 921_Chi-Chi Earthquake in 1999 (M=7.3) and the 1226_Hengchun Earthquake (M=7.0) in 2006. However, the seismic intensity at the site did not reach plant's OBE (0.2 g) level during these two earthquakes.

Recently in Dec. 2009, the CGS reclassified 16 km long Hengchun fault as a category II active fault which was originally recognized as a suspicious fault. Accordingly, TPC reassessed the impacts of the Hengchun Fault to the DBE of the plant. The preliminary result shows the free ground acceleration at free foundation level of the Reactor Building of Maanshan NPP, caused by Hengchun fault, is 0.22g, which is below the DBE value of 0.4g of

the plant (see the following tables)

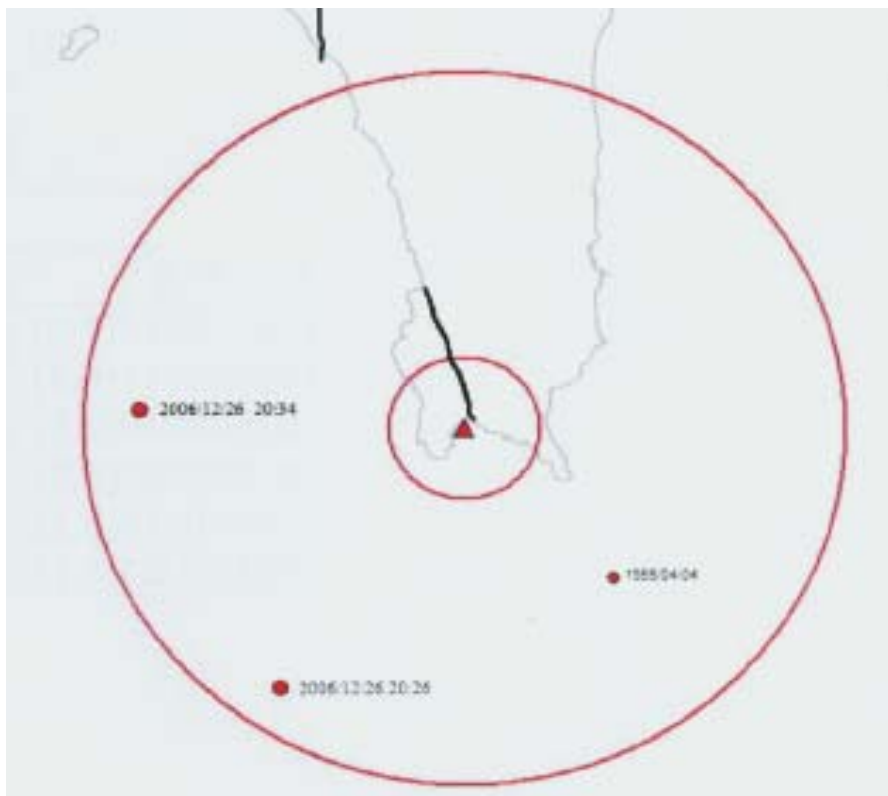
Table 2-2a Hengchun fault parameters

Fault	In-land Length	Length in Ocean	Depth of Epicenter	Scale(ML)
Hengchun Fault	16 km	-----	10 km	6.4

Table 2-2b Maximum probable peak acceleration caused by Hengchun fault

	MSNPP
Calculated peak ground acceleration at grade surface	0.38 g
Calculated peak acceleration at the foundation level	0.22 g
DBE acceleration at the foundation level	0.4 g

The following figure shows the new recognized active Hengchun fault close to Maanshan NPP (red triangle). Some major historical earthquakes within 8 kilometers and 40 kilometers radius were also included in the figure.



Lungmen NPP

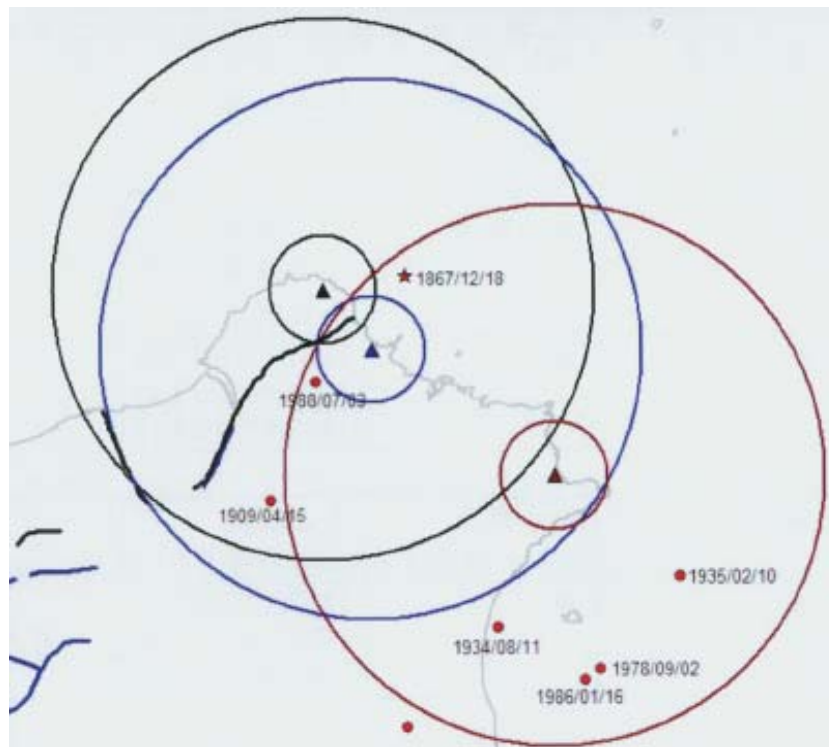
Design earthquake 0.4g for SSE was determined by Tectonic Province Approach, which conservatively assumed that the maximum potential earthquake could happen anywhere within its tectonic province, the calculated average peak ground acceleration is 0.33g (ranging from 0.23~0.41) and 0.4g is adopted as SSE.

In 2001, the result of a report “Summarization and Evaluation of the Geologic structure and seismic records near LMNPS Site” carried out by College of Earth Science, National Central University reassured that the DBE of Lungmen NPP is adequate.

In 2004, the Taipower company also contracted a project “Re-analysis and evaluation of Earthquake Threats to the LMNPS Site” to National Center of Research on Earthquake Engineering to study the possible earthquake hazards to LMNPS. The results also showed that the 0.4g DBE as well as its response spectrum of LMNPS is still adequate.

Furthermore, according to the latest Taiwan Building Code (issued by Ministry of Interior in July, 2005), the design horizontal acceleration near Lungmen site is 0.28g. It is also well below the design basis of safety shutdown earthquake, which is 0.4g of LMNPS.

The following figure shows the major historical earthquakes within 8 kilometers and 40 kilometers radius.



2.1.2 Provisions to protect against the DBE

2.1.2.1 Key SSCs required to achieve safe shutdown state after the earthquake

Chinshan NPP

1. The safety related SSCs are summarized as follows:
 - A. Structure: combination structure where reactor is enclosed, essential pump house, 5th D/G building, EDG oil day tank, CST
 - B. The key systems and their supporting systems:
 - a. Emergency Core Cooling System (ECCS): including LPCI, HPCI, ADS, CS
 - b. Reactor Core Isolation Cooling System (RCIC)
 - c. EDG (Nos.1~4 and 5th D/G)
 - d. Combination Structure Cooling Water System (CSCW)
 - e. Essential Service Water System (ESW)

- f. Essential Chilled Water System
 - g. Residual Heat Removal System (RHR)
2. The spent fuel pool located in 5th floor of R/B is reviewed as follows:
- (1) A fixed type 90 ton (main hosting load) overhead crane with single-failure-proof design feature is designed to be II over I, to ensure not to collapse during the SSE.
 - (2) The fuel storage pool structure which is made of reinforced concrete with a stainless steel liner. The water level in the pool is maintained as high as at least 7.88 feet above the top of fuel element. This will assure that the spent fuels are well protected with adequate water to prevent them from being damaged due to earthquake.

Kuosheng NPP

1. The safety related SSCs designed against for DBE are listed below:
- (1) Structure: Reactor Building, Control Building, Auxiliary Building, Diesel Generator Building, Emergency Circulating Water Pump House
 - (2) Systems: Emergency Diesel Generator (EDG) (Div. I / II / III and 5th), Emergency Core Cooling system (ECCS):RHR A/B/C, HPCS, LPCS, Reactor Core Isolation Cooling (RCIC), Automatic Depressurization System (ADS), Emergency Chilled Water System (ECWS), Emergency Circulating Water System (ECW)
 - (3) The safety related tanks are CST and ACST
2. The Spent Fuel Pool can maintain the water level 8 feet higher than the storage height of fuel elements to assure that the spent fuels are well protected with adequate water to prevent them from being damaged due to earthquake.

All the relevant equipment to the spent fuel pool operation were designed as seismic category I. Although the spent fuel pool cooling system is not designed as seismic category 1, its necessary cooling can still proceed via seismic category I RHR spent fuel pool cooling mode in case that it is damaged due to earthquake so as not to result in loss of its cooling function.

Maanshan NPP

The followings are the safety related SSCs:

- (1) Building Structures: Containment building, Control building, Auxiliary building, Diesel generator building, Emergency pump room, Fuel building.
- (2) Systems and Components
 - 1. Emergency diesel generator
 - 2. Emergency core cooling system ECCS (RHR 、 CCP)
 - 3. Reactor coolant system (RCS)
 - 4. Containment spray system
 - 5. Component cooling water system
 - 6. Essential chiller system
 - 7. Nuclear service cooling water system (NSCW)
 - 8. Chemicals and volume control system
 - 9. Auxiliary feed water system

Since all SSCs listed above is seismic category I, the SSC can assure its operability to achieve safe shutdown after design basis earthquake.

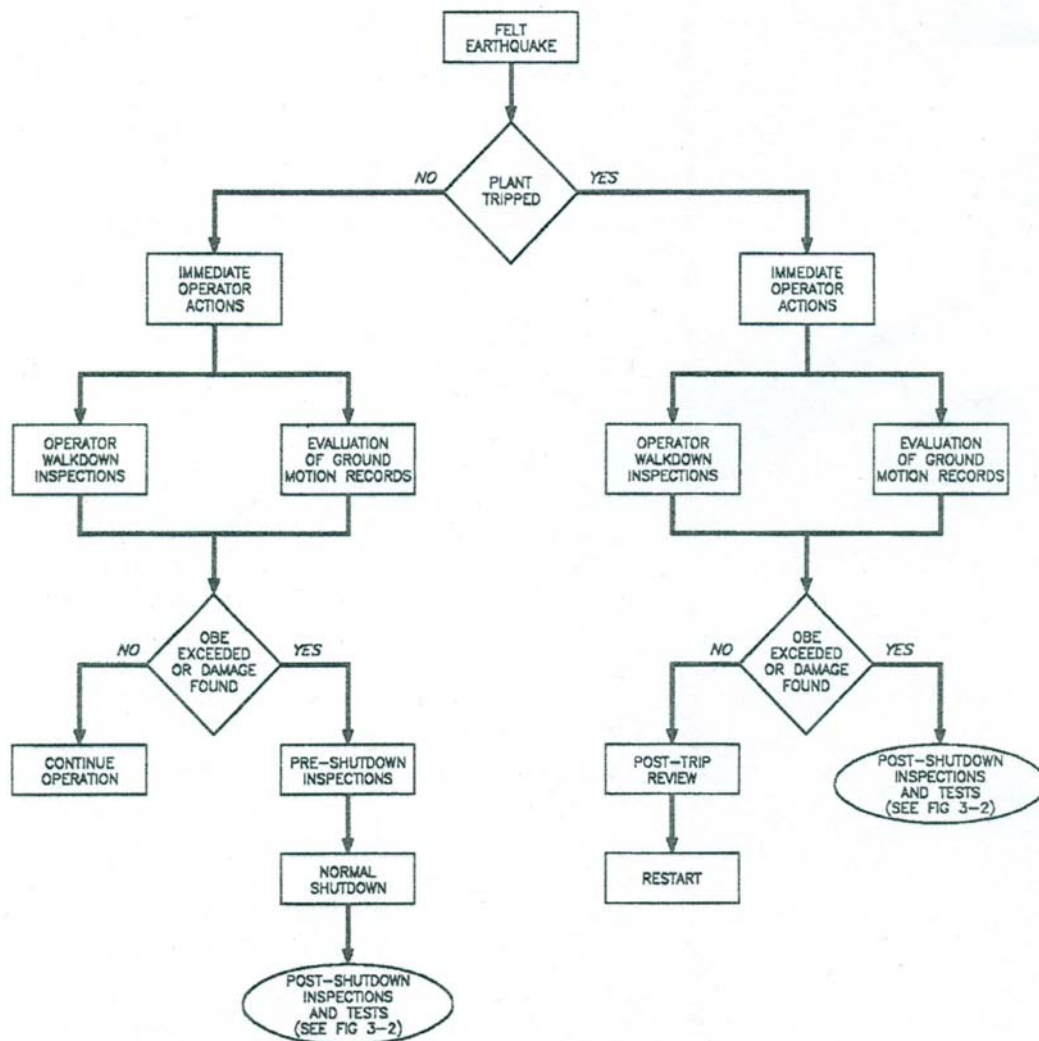
Lungmen NPP

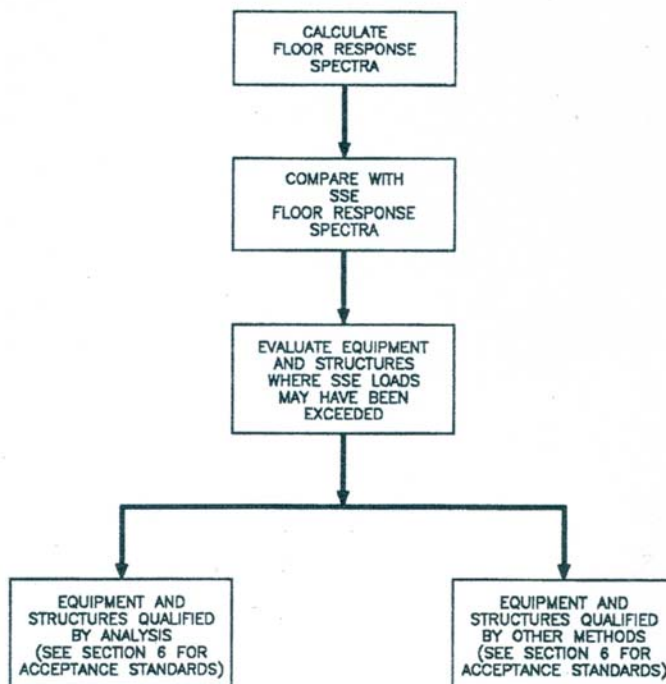
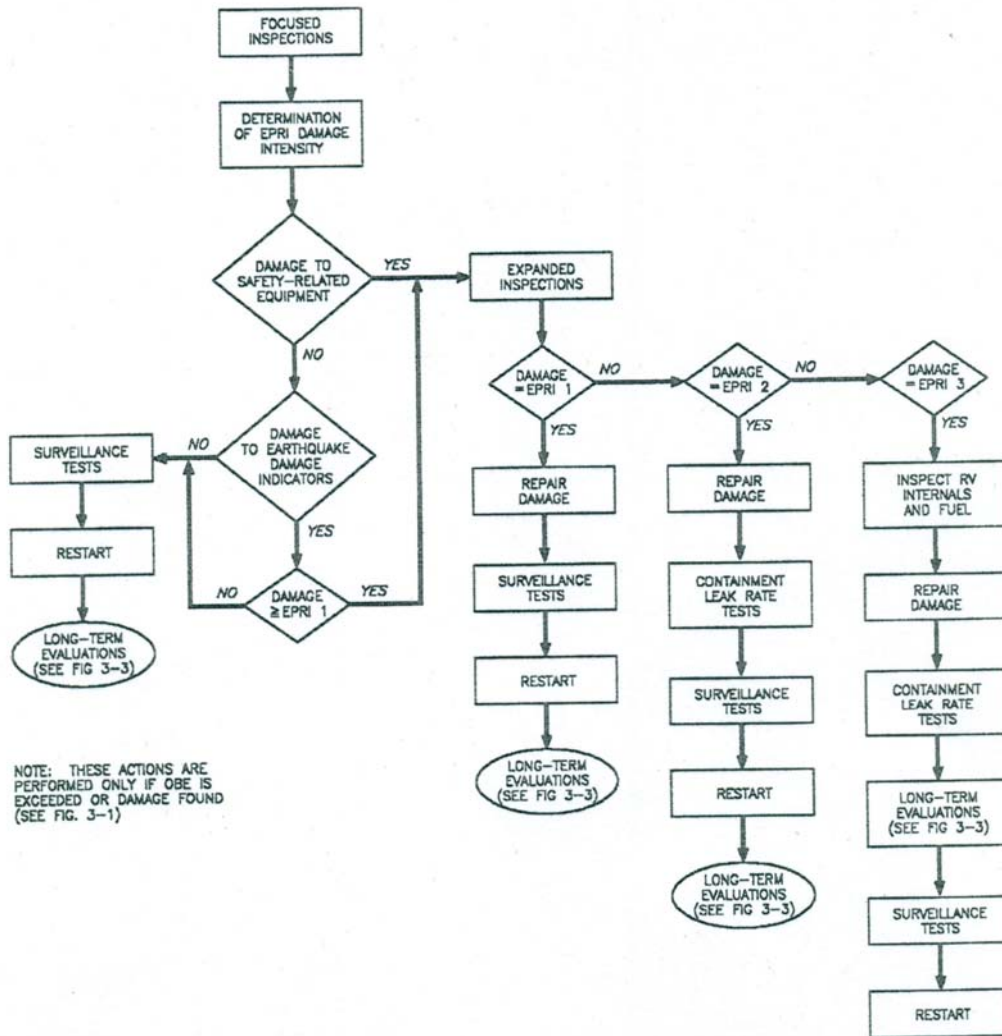
The safety related Structure, System, and Components (SSCs) are:

1. Building Structures: Control Room, Reactor Building, Service Water Pump House Auxiliary Fuel Building
2. Systems and their Supporting Systems
 - (1) Emergency Diesel Generator (DIV I/II/III and the 7th)
 - Emergency Diesel Generator Fuel Storage and Transfer System
 - Emergency Diesel Generator Lubrication Oil System
 - Emergency Diesel Generator Cooling Water Subsystem
 - Emergency Diesel Generator Startup Air System (Valves and Pipes)
 - Emergency Diesel Generator Startup Air System (Air Storage Tank)
 - Emergency Diesel Generator Intake and Exhaust system
 - (2) Emergency Core Cooling System ECCS (HPCF B&C, RHR A,B,&C)
 - Power (EDG)
 - Cooling Water Supply Source (RBCW)
3. Reactor Core Isolation Cooling System (RCIC)
4. Automatic Depressurization system
5. Reactor Building Cooling Water System
6. Reactor Building Service Water System (RBSW) in Sea Water Intake Structure

2.1.2.2 Main operating provisions

Basically, all the 4 NPPs followed the US practices/procedures after a NPP was hit by an earthquake. The following chart from EPRI NP-6695 is adopted for the post-earthquake flowchart to assure the plant safety after earthquake. Besides, if the calculated stresses from the actual seismic loading conditions are less than the allowable for emergency conditions or original design bases, the item is considered acceptable, provided the results of inspections and tests show no damage. An engineering evaluation of the effects of the calculated stresses on the functionality of the item should address all locations where stresses exceed faulted allowable and should include fatigue analysis for ASME Code Class 1 components and systems.





Chinshan NPP

The major operating provisions for protection of the Reactor Core or Fuel Storage Pool from being damaged after an earthquake event are based on the EPRI report NP-6695 (1989) "Guideline for Nuclear Plant Response to an Earthquake", they are

- (1) Procedure No. 512.1 "Post earthquake emergency response procedure"
- (2) Procedure No. 512.2 "Post earthquake overall plant inspection procedure"
- (3) Procedure No. 512.3 (Post earthquake inspection of overall plant key structures and equipment before restart)

The NP-6695 had been endorsed by NRC RG 1.166 "Pre-Earthquake Planning and Immediate NPP Operator Post Earthquake Actions" and RG 1.167 "Restart of a NPP Plant Shutdown by earthquake."

Besides, each unit has the Automatic Seismic Trip System (ASTS) installed in main structure building.

Kuosheng NPP

Similar to Chinshan NPP, the Kuosheng NPP procedure 575 "Emergency procedure for earthquake" for post earthquake action also followed EPRI's 6695 report.

Each unit in Kuosheng also has the ASTS.

Maanshan NPP

SOP 582 and AOP 582.1 referred to EPRI report NP-6695 are

- (1) Operating Procedures after Severe Earthquake SOP582
- (2) Equipment Inspection Procedure after severe earthquake AOP582.1
- (3) Each unit in Maanshan also has the ASTS.

Lungmen NPP

All safe shutdown related SSCs including reactor and spent fuel pool are designed per DBE requirements. The SSCs are designed for SSE and thus wouldn't fail after DBE earthquakes. The crew will follow procedure 528.01.01 "Emergency Operating Procedures for Earthquake" and procedure 528.01.02 "Reactor Restart Assessment Procedures after Earthquakes bigger than DBE" to conduct necessary walkdown. These operating procedures had been revised per EPRI report NP-6695(Dec.1989) "Guideline for Nuclear plant Response to an Earthquake". The following explains the major operational guides and requirements in the operations:

2.1.2.3 Indirect effects of the earthquake taken into account

Chinshan NPP

1. An earthquake induced in-plant flooding:

The main sources for the in-plant flooding event are the ruptures of the water containing facilities such as the pipe, tank body inside the buildings. Based on these flooding events, TPC has analyzed the consequence of the flooding for the combination structure and the turbine building. It was concluded that the postulated flooding event did not have any adverse effects to the safe shutdown capability of Chinshan NPP.

In light of the Fukushima event, Chin-Shan NPP has installed removable flood protection

facilities at the entrance of the building to protect the EDG's from being damaged resulting from flooding accompanied with the earthquake.

2. An earthquake induced fire event:

The fire protection facilities located in the safety related regions are all of seismic category I, and they are separated by different fire compartments and fire barriers; where the remaining non-seismic qualified equipment will be enhanced, such as:

- a. To replace the original buried raw water pipes and fire protection pipes with trenched ones.
- b. To upgrade the seismic resistance capability of the raw water reservoir structure and the related pipes.
- c. To install the interconnecting pipe between the upper and lower reservoirs (with 100,000 tons of water in total) to serve as a back-up cooling water source.
- d. The eight newly purchased large size fire water pumps can take water from various back-up sources.

3. During a loss of offsite power event: each unit is equipped with two EDGs and additional 5th EDG.

4. When the earthquake causes outside environment to prevent or delay the personnel and equipment to arrive at the plant site:

(1) When the event occurs in the office hours:

The trainees in the Simulator Center, the operators in the standby shift with enough members, the vendor under long term contract, and the in-plant fire brigade will serve as the back-up operation, maintenance, as well as emergency back-up manpower to take over and assist the operation of the units.

(2) When the event occurs in the off-duty hours:

More than 100 people with operation/maintenance expertise are resided in the plant and near by off-duty dormitories. They can be called in, to provide assistance in supporting the plant work. Besides, the vendors under the maintenance contracts with TPC residing in nearby regions, can take a prompt response to an urgent request for providing the equipment repairing services. The plant fire brigade and stationed policemen can be ready to take a quick response in case of an urgent event.

Kuosheng NPP

1. Flooding impact to building:

The Flooding accident impact analysis showed that the building has at least 6" margin to be flooded. The equipment compartments of the potential flooding buildings are all installed with water-tight doors and floor sump pumps. During normal operation, the floor sump water level can be overlooked from Main Control room and sump pump shall be automatically started to pump floor sump water out if there is abnormal water level condition so that it can meet the adaptable response need for abnormal water level condition.

Besides, procedure 577.1 "Operating procedure for Emergency water drainage in buildings" is added to immediately dispatch person to check if sump pump is in operation or not in case of flooding event occurred inside a certain building. If sump water level in any essential equipment room is more than "maximum safe operation level", unit power shall be reduced and maintained in safe shutdown condition per emergency operating

procedure EOP-500.6.

2. Loss of off-site power

In case of LOOP during earthquake, two sets of seismic category I emergency diesel generators in each unit are to provide the necessary power to safely shutdown the reactor. Moreover, the station is also equipped with one seismic category I (i.e., the 5th) air-cooled emergency diesel generator which is common to both units as the backup.

Furthermore, the 4 sets safety related battery sets have been upgrade from 8 hours to 24 hours.

The station has already completed the review of load shedding response measures in case of beyond DBE. Please refer to chapter 5 “Loss of power and loss of ultimate heat sink” for its relevant contents.

3. The required manpower and facilities are delayed to arrive at the site resulted from off-site road blockage due to earthquake:

The accident occurrence time can be divided into normal work time period and holiday time period which are respectively described as follows:

(1) When the event occurs in the office hours:

Similar to Chinshan NPP, the trainees in the Simulator Center, the operators in the standby shift with enough members, the vendor under long term contract, and the in-plant fire brigade will serve as the back-up operation, maintenance, as well as emergency back-up manpower to take over and assist the operation of the units.

(2) When the event occurs in the off-duty hours:

Emergency mobilization shall be initiated in no time according to the procedure 1407 “TSC Mobilization and Response process”, and the procedure 1409 “HPC Mobilization and Response process”. If off-site road can't be accessed due to earthquake, the station shall report to National Nuclear Emergency Response Center for providing the necessary help so as to restore the road access or request to utilize helicopter to transport the personnel and materials for emergency repair or deliver the medical first aid. The maintenance personnel who live in the standby-duty dormitory and nearby area will be mobilized for emergency repair of the damage equipment. The on-site fire fighting station manpower could also be of help.

4. If an earthquake induced fire event:

All the equipment in different safety divisions are separated by different fire compartments and fire barriers so that the equipment in different divisions will not be simultaneously burn out.

The station also installed an extra water supply system to take fire water from fire water reservoir in case that the existing fire water supply pipe is broken. Furthermore, the 12” cast iron underground fire water pipe has been upgraded to carbon steel above-ground pipe and seismic category I design, so as not to impact fire water supply in case of earthquake.

The existing station fire fighting brigade has also been enhanced after Fukushima accident. Moreover, the station already signed the “mutual support for fire fighting and first aid agreement“ with New Taipei City Fire Bureau for emergency support. For fire fighting facilities, the station is allocated with large scale trolley type powder, CO₂, and Halon fire extinguishers; fire water reservoir truck; and chemical fire engine. The plant oil storage tanks are designed with fire protection wall to prevent it to damage the nearby equipment in case fire accident happens.

Maanshan NPP

1. Loss of off-site power:

In the LOOP case, the ESF Bus will be supplied by train A and/or train B seismic category I emergency diesel generators (EDG). Besides, there is the 5th EDG, which is also seismic category I, will take over to supply power to the safe shutdown related equipment if any of the EDGs is not available. In case all AC powers were lost, the reactor will scram and NPP will be in the SOP 570.00 stage followed by SOP 570.20 Station Blackout stage.

2. Personnel and equipment can not reach the plant due to road blockade caused by earthquake:

(1) Use every possible means to obviate the blockades.

(2) If the events happen during office hours:

The personnel in simulator center, the maintenance/contract supporting personnel, and the firemen can be of help.

(3) If the events happen during off-duty hours:

All standby maintenance personnel in nearby dormitories as well as the on-site firemen/police could come to help.

3. Response to earthquake induced fire:

As all important oil tanks have overflow walls, the oil would not spread to threaten the safety related equipment or affect the fire fighting activities.

In light of 2007 Japan NCO earthquake experience, MSNPP is carrying on an upgrading program to move the underground reactor raw water fire water pipes to above ground and to improve the seismic resistance of the system tank and pipes.

The plant has its own firefighting team and firefighting trucks. They can obtain necessary firefighting water from various water sources.

4. Although the cranes inside the plant buildings have no fixed parking positions according to the operating procedure, every crane does have its own parking place in practice. MSNPP has inspected and assured that even if the crane falls during earthquake, it will not damage any safety related equipment nearby. Each crane parking position had redefined in related operating procedures.

5. Excavation and backfill

During construction period, surface accumulation layer and weathered mudrock were excavated and plant structure is rested directly on fresh mudrock layer. The buried piping and electric conduct pipe supporting frame have been checked to ensure the backfill after excavation will not affect plant structure and piping's seismic capability.

Lungmen NPP

1. Effects of flood inside the reactor building:

(1) There are built-in flood drain holes and drainpipes on every floor. These drain holes and drainpipes will eventually collect water into a sump. Even if the flood is beyond the drainage capacity, most of the flood will flow to the storage tanks at the basement of radwaste building. The radwaste building design will mitigate the flood influence and save more time to secure essential equipment.

(2) For the 6 ECCS pumping rooms located in Reactor Building bottom floor, the floor water

will drain to a sump exclusively for ECCS. These rooms also equipped with water-proof doors to isolate the rooms to avoid outside water flowing into the rooms. The flood prevention design can assure the integrity of ECCS equipment.

(3) If any circulating water pipe leaks, the sump warning signal and the leakage detection system will prompt to isolate and mitigate the leakage. The sitting base of safety equipment is 20 cm above ground to avoid flooding. The actuation of manual fire equipment and the limitation of water storage in the pipe/tank will also mitigate flooding in the plant.

2. Loss of off-site Power:

(1) Each unit of LMNPP is equipped with 3 safety grade emergency diesel generators. These generators are designed to provide power to the emergency cooling system if the off-site power was lost.

(2) The plant also equipped a safety grade air-cooling emergency diesel generator, named 7th EDG. This 7th EDG is commonly shared by the two units. It can replace the failed DEG of any unit.

(3) All the above mentioned EDGs were designed and manufactured to sustain DBE earthquake. Based on the Fukushima experience, the plant has planned to add flood barrier and enhanced soft rubber bands on entrance doors or metal rollup doors of all essential equipment buildings. The flood barrier and the rubber gasket shall be installed before the flood comes.

3 Personnel and equipment can not reach the plant due to road blockade caused by earthquake:

(1) If the events happened during office hours:

- a. In case the operator cannot reach the plant to take over the shift, the personnel in simulator center and the mobile supporting personnel (most of them are certified licensees) can take over or help the reactor operator.
- b. There will be constantly about one hundred personnel including maintenance staff and long term contract personnel. It is enough to support any urgent equipment maintenance.
- c. Normally there will be 8 firemen on duty. According to Station Emergency Response Organization, the plant can organize an emergency fire fighting team to help.

(2) If the events happened during off-duty hours:

- a. Most of the operators and maintenance people live in the plant/stand-by dormitory. They can support reactor operation/emergency equipment rescue at first priority. Besides, the plant has already decided to build family dormitories at Gong-Liao and Shuang-Xi. The personnel lived in these dormitories can also help the plant operation before the crew arrives.
- b. If off-site road can't be accessed due to earthquake, the station shall report to National Nuclear Emergency Response Center and apply for army engineers corps' (?) support for rush repair of the damaged road so as to restore the road access or request to utilize helicopter to transport the personnel and materials for rush repair or deliver the medical first aid.
- c. Support from the station firefighting crews.

4. The plant is equipped with seismic category I firefighting facilities and on-site firefighting station.

5. Excavation and backfill:

All safety related equipment and structure sit on a solid rock base, there exists no possibility of soil liquefaction. The earthquake wouldn't affect the plant safety due to soil liquefaction.

There are some excavations on the west side and south side mountain slopes. An operation procedure 1208 "Excavation and Back-fill Engineering" was issued to instruct and quality control all excavation and back-fill constructions. This procedure is to assure that any excavation and back-fill construction won't affect plant building structure and facilities.

2.1.3 Compliance of the plant with its current licensing basis (CLB)

2.1.3.1 Licensee's organization to ensure compliance

Chinshan NPP

The general procedures of periodic inspection, evaluation and remedy of the seismic category I SSCs, as well as the testing and maintenance for the equipment are covered in Procedure Nos. 5121, 5122, 5123, 600 series (periodic inspection procedures) and 700 series (maintenance operating procedures).

Kuosheng NPP

1. The general equipment test procedure is in Plant 600 series procedures and its test cycle is in accordance with the test requirements in Technical Specification.
2. The maintenance method and inspection period for the system and components are described in detail in 700 series "Maintenance Procedures". The inspection of systems and equipment shall be carried out in every outage in accordance with the station's 10 year Long Term Maintenance program.
3. The inspection and maintenance method for the building/structures and passive components are specified in procedure 173.7 "Maintenance rule of structural inspection and monitor". The safety related structures shall be inspected every five years or ten years depending on its importance.

Maanshan NPP

1. To ensure the compliance with the licensing base, the 600 and 700 series procedures are used to conduct the inspection, test, and maintenance of all safety related SSCs.
2. Procedure 582 is for the post earthquake inspection and test.

Lungmen NPP

1. The regular inspection and test periods for all systems and equipment are defined in the plant operating procedures. The test procedures and the acceptance criteria are described in the series 600 "Inspection and Testing Procedures".
2. The regular maintenance periods and test methods of the systems and components are described in the series 700 "Prevention and Maintenance Procedures". These procedures illustrate all details of disassembling and assembling, lubrication, replacement of parts (eg. oil seal, gasket, washer etc.), wrench torques of the equipment. The equipment must be inspected every reactor outage according to the 10-year long term maintenance program.
3. The inspection and maintenance method of structure is specified in procedure 152.07 "Maintenance rule of structural inspection and monitor". The inspection results will be categorized according to the regulations of structure, civil engineering, and passive components. The inspection periods are 5 years for high safety related structures and 10 years for less safety related

structures.

2.1.3.2 Licensee's organization for mobile equipment and supplies

Chinshan NPP

Learned from the Fukushima accident experience, two sets of large scale (4.16kV/1500kW) mobile container type power truck and 12 sets of medium scale (480 V/500kW or 200kW) diesel generators as well as many sets of small mobile gasoline/diesel generators, air compressors, combustion water pumps, etc. have been purchased. They are all included and listed in the station procedure 113.5.

In order to assure that the storage areas are accessible and equipment/facilities are easy to activate not subject to the impact by typhoon and tsunami, the storage areas for above-mentioned equipment and facilities are properly arranged considering its material / spare parts type or by disperse layout, and all are located in high elevation. The procedure 113.5 has been revised to reflect the storage management. And all these materials and facilities shall be inspected and tested periodically.

Kuosheng NPP

Similar to CSNPP, the KSNPP also prepared enough general supporting facilities and spare parts like mobile cranes, mobile pumps and mobile generators.

Maanshan NPP

Similar to CSNPP and KSNPP, the plant is also equipped with some supporting and standby equipment like mobile diesel generators and mobile pumps.

Lungmen NPP

The general rescue equipment shall be prepared before Jun. 30, 2011 as per operating procedure 186.01 "Focuses of disaster prevention and Rescue" .

2.1.3.3 Deviations from CLB and remedial actions in progress

Chinshan NPP

There is no deviation from CSNPP's FSAR commitment. If there is any deviation, the station shall follow the following relevant procedures to carry out safety evaluation and take corrective actions:

1. The shift engineer shall issue the repair request per procedure 1102.01 and determine whether the deviation will impact unit safety or not. If yes, operator shall announce it to be inoperable and take corresponding actions to put the unit in LCO. The station shall follow the station procedure 113.1&113.2 to report to AEC.
2. The NCD (nonconformance notice quality document) as per procedure 1115.01 "Nonconformance Disposition control process" will be issued in case that nonconformance items of SSCs are found. The station shall report the NCD to TPC headquarters and AEC in case that the NCD involves 10 CFR 21.

Kuosheng NPP

TPC has already established a complete quality assurance program which is complied with US NRC 10CFR50 Appendix B in his NPPs. All working processes in NPPs such as organization, design, procurement, fabrication, installation, operation, and maintenance etc

shall be controlled and supervised by following quality assurance program in order to assure all SSCs can perform its intended functions. Any deviation can also be found in time and is evaluated if it is necessary to take the required corrective actions in order to minimize or to eliminate its impact to unit safety.

The seismic design of the plant SSCs does not deviate from the commitment of FSAR. If there is any deviation of SSC from the commitment, the plant will conduct safety evaluation and corrective measures according to related procedure.

Maanshan NPP

1. According to SOP 192 “Procedures of rescue equipment maintenance and management”, mobile equipment including mobile diesel generators, gasoline engine water pumps, etc. must be inspected, tested, and properly maintained to operable conditions.
2. If any fixed equipment related to safety protection system was deviated from its normal condition, the related procedures must be conducted.

Lungmen NPP

Up to now, the design and construction of LMNPP meet all the commitments in the FSAR. If any deviation is found in the future, the plant will conduct the safety assessments and equipment modifications as per the plant procedures.

2.1.3.4 Specific compliance check already initiated by the licensee

Chinshan NPP

1. The station has completed several seismic enhancement items in response to Fukushima accident:
 - (1) “Install an additional above-ground Fire Water Piping system”.
 - (2) “Upgrade the EDG Day Tank oil makeup piping to seismic category I”.
 - (3) “upgrade the SFPACS Cooling Tower CT-15A/B associated piping to seismic category I”: This can provide the alternative cooling for the reactor, drywell, suppression pool, and spent fuel pool heat removal system in case that compound disaster accident happens.
2. The enhancement work by TPC

In response to new evidence found in Shanchiao fault, TPC has accelerated the seismic enhancement work, including detailed geophysical survey of the in-land and the sea area surrounding the site, Seismic Margin Assessment (SMA), Seismic Probabilistic Risk Assessment (SPRA) (to be completed by end of Dec. 2013). In addition to that, Seismic and Tsunami warning System were also setup.

Kuosheng NPP

1. The following enhancements have been implemented in response to Fukushima accident:
 - (1) “Raw water pipe enhancement”: to assure the water supply from extra water sources of 37,000 tons Raw Water Reservoir in higher elevation to reactor and fuel pool via gravity.
 - (2) “Installation of additional RHR backup injection pipe and shutoff valve”: to provide an additional water injection path of RHR system from ECW tunnel, water reservoir, or the nearby water source via mobile pump or fire fighting truck.

- (3) “Installation of additional baffle gate in A & B tunnels”: to provide the enclosure function of A & B tunnels to store the water from the tunnel upstream river and the outlet where the water can be pumped by means of mobile pump.
 - (4) “Installation of additional fixed transfer pipe from the outside bridge to the station entrance”: to pump the sea water from outlet to the station entrance by means of mobile pump.
2. In response to new evidence found in Shanchiao fault, TPC has accelerated the seismic enhancement work, including detailed geophysical survey of the land and the sea surrounding the site, Seismic Margin Assessment (SMA), Seismic Probabilistic Risk Assessment (SPRA) (to be completed by end of Dec. 2013). In addition to that, Seismic and Tsunami warning System were setup.

Maanshan NPP

1. In response to the evidence found on Hengchun Fault, TPC has accelerated the seismic enhancement work, including detailed geophysical survey of the land and the sea surrounding the site, Seismic Margin Assessment (SMA), Seismic Probabilistic Risk Assessment (SPRA) (to be completed by end of Dec. 2013). In addition to that, Seismic and Tsunami warning System were setup.
2. The following actions will be executed after MSNPP loss of its offsite power:
 - (1) If both EDG of train A and train B failed, then after disconnecting the electrical interlock, the 5th EDG will supply power to one ESF Bus of both unit 1 and unit 2 simultaneously. If one of the EDG of train A or B is functional, the functional EDG can also supply power to the ESF Bus of the other unit after disconnecting the electrical interlock.
 - (2) If all the AC power supply can not be recovered in a short time period, then following SOP 1451 “Reactor Ultimate Response Guideline”, the mobile diesel generators will be applied to the equipment that need AC or DC emergency power.
3. The following actions will be executed if the offsite roads were blocked due to earthquake and it was during off-duty hours. (1) Mobilize the 103 registered personnel with special skill (include operators) in Hengchun area to help plant operation. (2) Mobilize contract vendors’ workforce to help the plant equipment maintenance. The contract vendors’ workforces are also registered in the list according to their expertise.
4. All cranes in essential plant buildings must be anchored at their specific positions defined in the related SOP. MSNPP has also installed locking devices between the crane and the horizontal trail to avoid its movement during earthquake.
5. After a comprehensive review of potential accompanied accidents after earthquake, MSNPP has procured necessary equipment and materials (e.g. mobile generators, extra fire fighting trucks, diesel water pumps) to mitigate the accident effects.

Lungmen NPP

1. After the Fukushima Accident, The LMNPP initiated a reinforcement action plan (RAP) to improve the equipment seismic resistance and its operability under severe earthquake. For example, RAP-LM-04-03-002 is to make sure the fire water supply and fire system are available under SSE; RAP-LM-04-03-001 is to assure the above ground water pipe between the raw water reservoir and the fire system can be inspected and repaired as soon as it has any damage; RAP-LM-03-04-001 is to install extra seismic category I make-up water pipe and sprinkler pipe on the reactor building. These pipes, connecting the ground

floor of reactor building to the water source, are exclusively used to make up and sprinkle water to the spent fuel pool; RAP-LM-03-05-001 is to modify the ultrasonic water level meter G41-LT-0012A/B to extend its range to the effective fuel height. This meter is powered by essential AC power (R13). Besides, the measuring depth of the thermometer G41-TE-0013 is also modified to extend its monitoring range to the effective fuel height.

2. The general rescue equipment already existed before Fukushima accident and the procurement of additional equipment after Fukushima accident have been prepared.

2.2 Evaluation of margins

Seismic event trees analysis developed from the PRA analysis is used as the tool to evaluate the seismic margin as well as the cliff-edge effects.

2.2.1 Range of earthquake leading to severe fuel damage

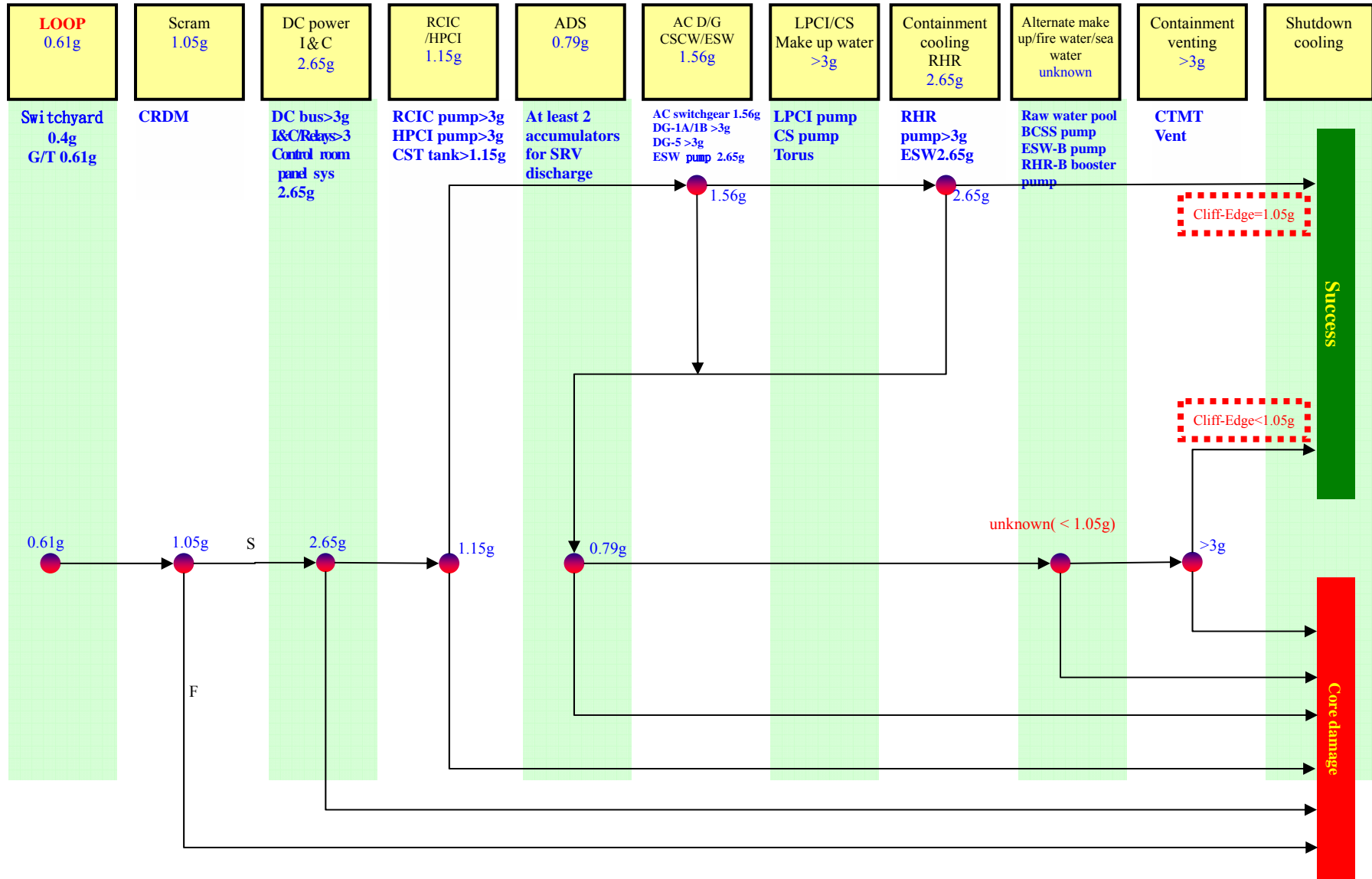
2.2.1.1 Weak points and cliff edge effects

[Chinshan NPP](#)

The seismic margin analysis is adopted as the tool for this evaluation. The event tree analysis is used to find out the cliff edge and safety margin of the plant. Assuming the off-site power is lost (LOOP) during earthquake, the two plant success paths are:

- (1) Reactor scrammed and long term high pressure reactor water makeup (including containment cooling) are all successful.
- (2) Reactor scram and low pressure alternative reactor water makeup (including containment venting) are all successful but long term reactor water makeup is failed.

The following figure is the Seismic Event Tree used for the seismic margin as well as the Cliff-edge evaluation. From the figure, the cliff edge values for the 2 successful shutdown paths are 1.05g, <0.79g respectively.



The safety margin and cliff-edge of each successful path is described as follows:

- (1) The safety margin of successful path 1 is found to be 1.05g. The cliff-edge, as defined by taking the minimum safety margin of each headline, is found to be 1.05g.
- (2) The safety margin of successful path 2 is expected to be less than 1.05g because the seismic fragility of long term alternative reactor water makeup is the lowest and its seismic medium value is less than 0.79g, so its expected minimum value of cliff-edge is less than 0.79g.

Therefore, the safety margin of successful path is 1.05g because the cliff-edge as defined in this case for each successful cooling path takes the maximum safety margin 1.05g of the seismic intensity of each headline as representative. It means that the station can achieve the goal of Core Shutdown Cooling until the PGA is greater than 1.05g.

The table below listed the most vulnerable SSCs in the CSNPP seismic event tree analysis. It will be provided the plant HCLPF as the result of cliff edge assessment.

Structure/Equipment	Fragility (medium, PGA in g)
Offsite Power	0.4
Gas Turbine	0.61
Air Accumulator	0.79
Power Center Transformers	1.03
Core Support Structure	1.05
Gas Turbine MCC	1.08
Condensate Storage Tank	1.15
5th D/G	1.20
Reactor Vessel Support Skirt (Ring Girder)	1.22
4.16-KV Switchgear (Structure Failure)	1.56
Fuel Assembly	1.7
Recirculation Pumps	1.77
Diesel Oil Storage Tank	2.1

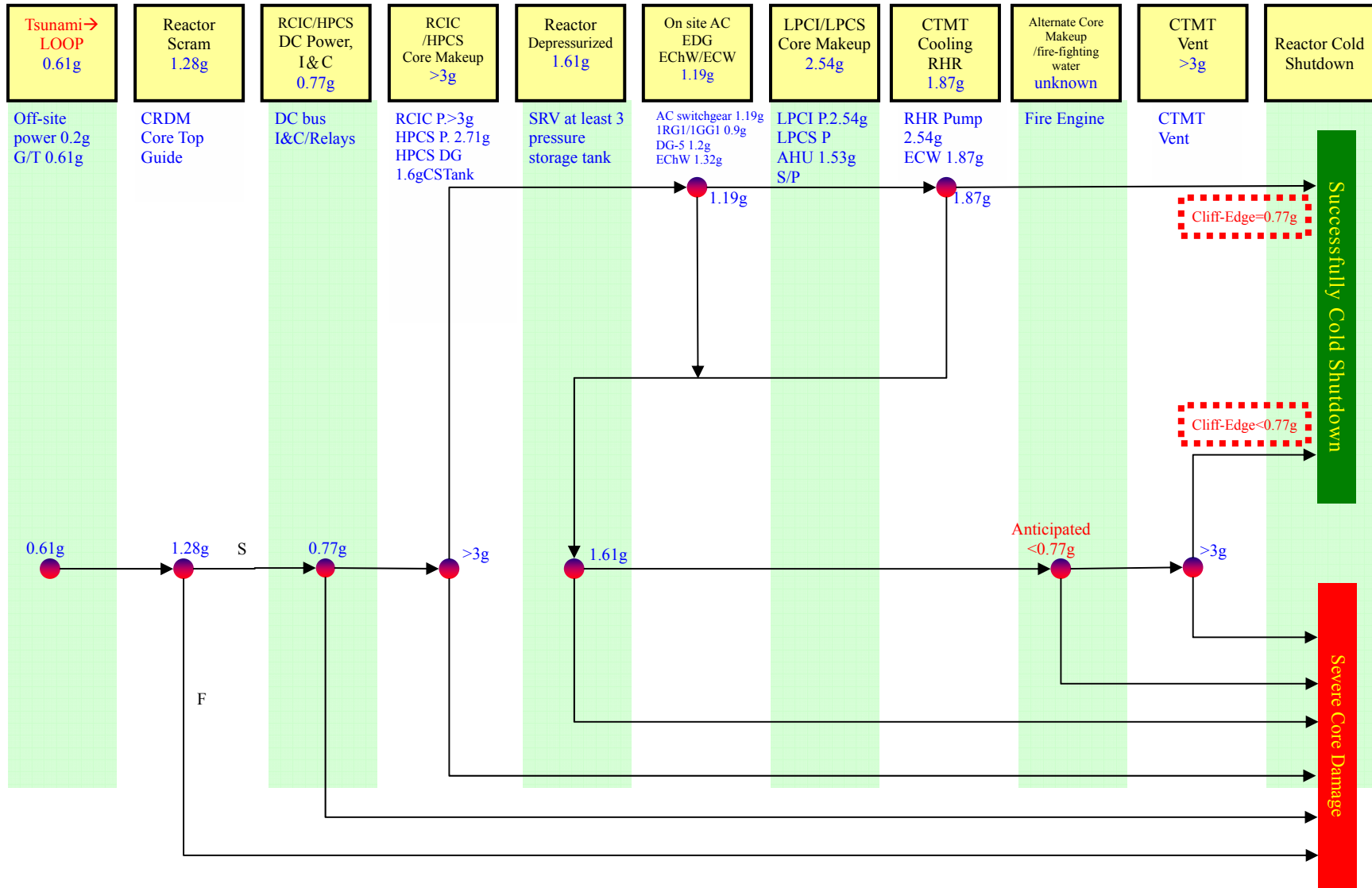
[Kuosheng NPP](#)

The seismic margin analysis is adopted as the tool for this evaluation. The event tree analysis (based on 1995 living PRA analysis result) is used to find out the cliff edge and safety margin of the plant. Assuming the off-site power is lost during earthquake, the two plant success

paths are:

- (1) Reactor scrammed and long term reactor water makeup (including containment cooling) are all successful event sequences.
- (2) Reactor scrammed but long term reactor water makeup failed, long term alternative reactor water makeup is the successful event sequence.

The following figure is the Seismic Event Tree used for the determination of seismic margin as well as the Cliff-edge evaluation. From the figure, the cliff edge value for the successful shutdown paths is 0.77g.



The safety margin and cliff-edge of each successful path is described as follows:

- (1) The safety margin of successful path 1 is found to be 0.77g. The cliff-edge as defined takes the minimum safety margin 0.77g of each headline as representative.
- (2) The safety margin of successful path 2 is expected to be less than 0.77g due to its long term alternative reactor water makeup not yet checked-up so that its expected minimum value of cliff-edge is less than 0.77g.

Therefore, the safety margin of successful path is 0.77g because the cliff-edge as defined in this case for each successful path takes the maximum safety margin 0.77g of the seismic intensity of each headline as representative.

The table below listed the most vulnerable SSCs in the KSNPP seismic event tree analysis. It will be provided the plant HCLPF as the result of cliff edge assessment.

Structure/Equipment	A _m (g, medium, PGA)
1. Offsite Power	0.20
2. SBLC Operation Heater	0.39
3. SBLC Instrument Panel	0.39
4. SBLC Transformer	0.58
5. Static Inverters(5KV)	0.67
6. 125 VDC Switchgear	0.77
7. Lube Oil Sump Tank(Main D/G System)	0.90
8. 4.16 KV Switchgear (Turbine &Control Bldg)	0.91
9. 480 V MCC (Auxiliary Bldg)	0.93
10. 480 V MCC (Diesel Generator Building)	1.05
11. 4.16KV Switchgear (Aux. Bldg)	1.19
12. Top Guide (Reactor Internals)	1.28
13. ECHW Pump	1.32
14. RHR Booster Pump	1.32
15. Reactor Recirculation Pump	1.42
16. Main Control Room Emergency Cooling Unit	1.42
17. SBLC Test Tank	1.51
18. LPCS Pump Room Cooling Unit	1.53
19. HPCS D/G Auxiliary Equipment	1.60
20. ADS Accumulator	1.61
21. Diesel Generator Bldg (Silencer Room Walls)	1.70
22. Fuel Oil Tank(Main D/G System)	1.80
23. Fuel Oil Tank (HPCS D/G System)	1.80
24. ECW Sluice Gate	1.87
25. ECW Traveling Screen	1.87

26. Emergency Pump House	1.90
27. Reactor Building	2.00

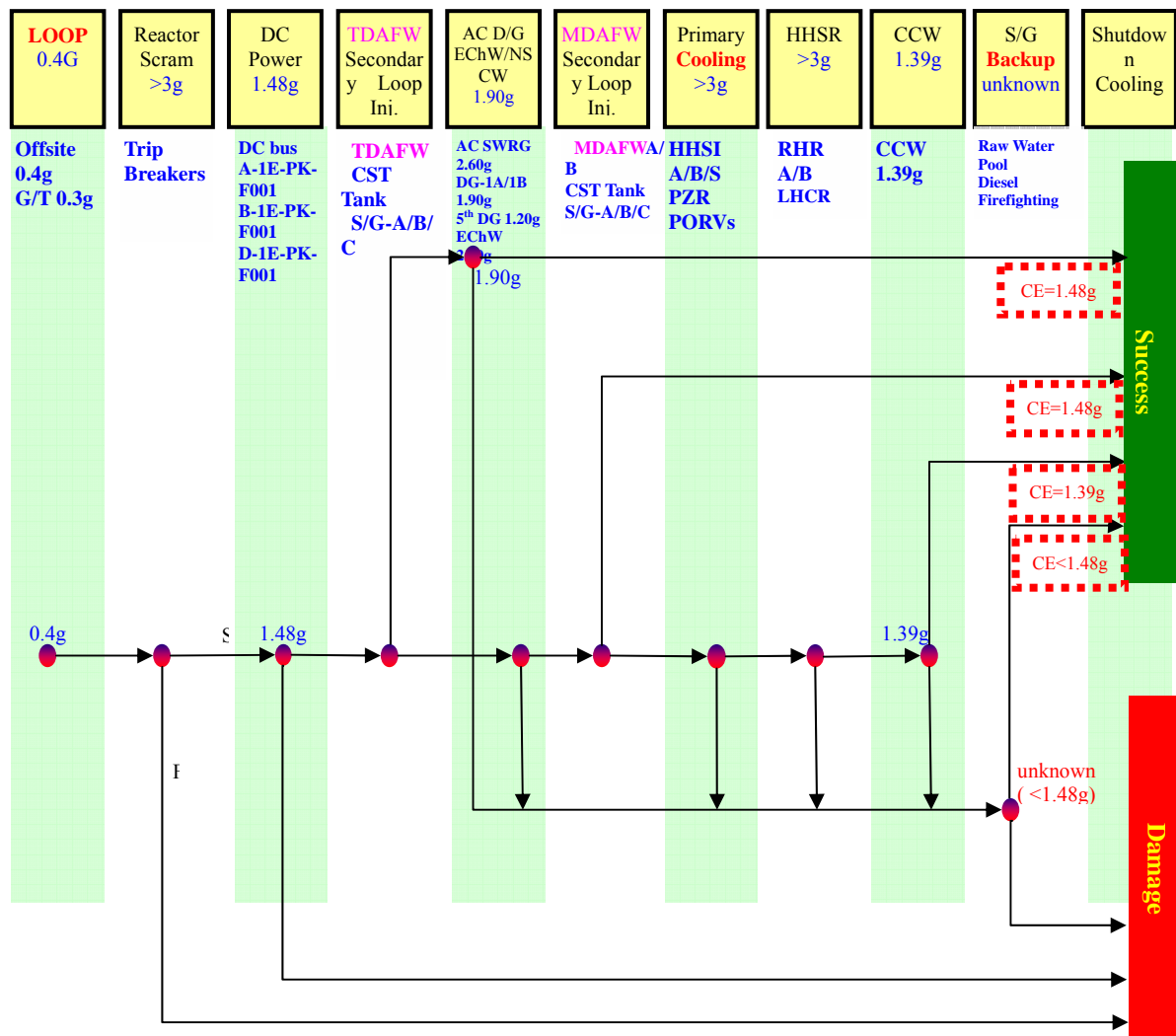
Maanshan NPP

The seismic margin analysis is adopted as the tool for this evaluation. The event tree analysis (based on 1995 living PRA analysis result) is used to find out the cliff edge and safety margin of the plant.

Assuming the off-site power is lost during earthquake, the two plant success paths are:

- (1) If offsite power was lost due to earthquake → reactor scram → use DC controlled gas turbine to drive AFWP to remove heat → If on site AC power was established (DC power can continue to supply power) → Successful Cool down.
- (2) If on site AC power was established → use AC motor to drive AFWP to remove heat → Successful Cool down.

The following figure is the Seismic Event Tree used for the seismic margin as well as the Cliff-edge evaluation. From the figure, the cliff edge values for the 4 successful shutdown paths are 1.48g, 1.48g, 1.39g, and unknown respectively.



Based on the definition of cliff edge, the cliff edge level is represented as the lowest item number of the maximal safety margin of all the successful cooling paths, i.e., the 1.48g of success path (1) or (2).

In summary, from the path of successful event tree along with the safety margin of associated event and Cliff Edge, the following two enhancements will be implemented.

- (1) Enhance the strength of the coupling cap screws of G/T to upgrade the seismic resistance of initial events.
- (2) Enhance the strength of water pipe between S/G and firefighting hydrant to the safety margin of path 4.

The table below listed the most vulnerable SSCs in the MSNPP seismic event tree analysis. It will be provided the plant HCLPF as the result of cliff edge assessment.

Structure/equipment	Fragility (g, medium, PGA)
Gas turbine	0.30
Offsite power	0.40
5 th Diesel Generator	1.20
Component cooling water pump	1.39
125-V DC distribution panel	1.48
480-V MCC	1.55
Diesel fuel-oil storage tank	1.90
480-V load center chatter	1.96
Auxiliary/control building	2.00

Lungmen NPP

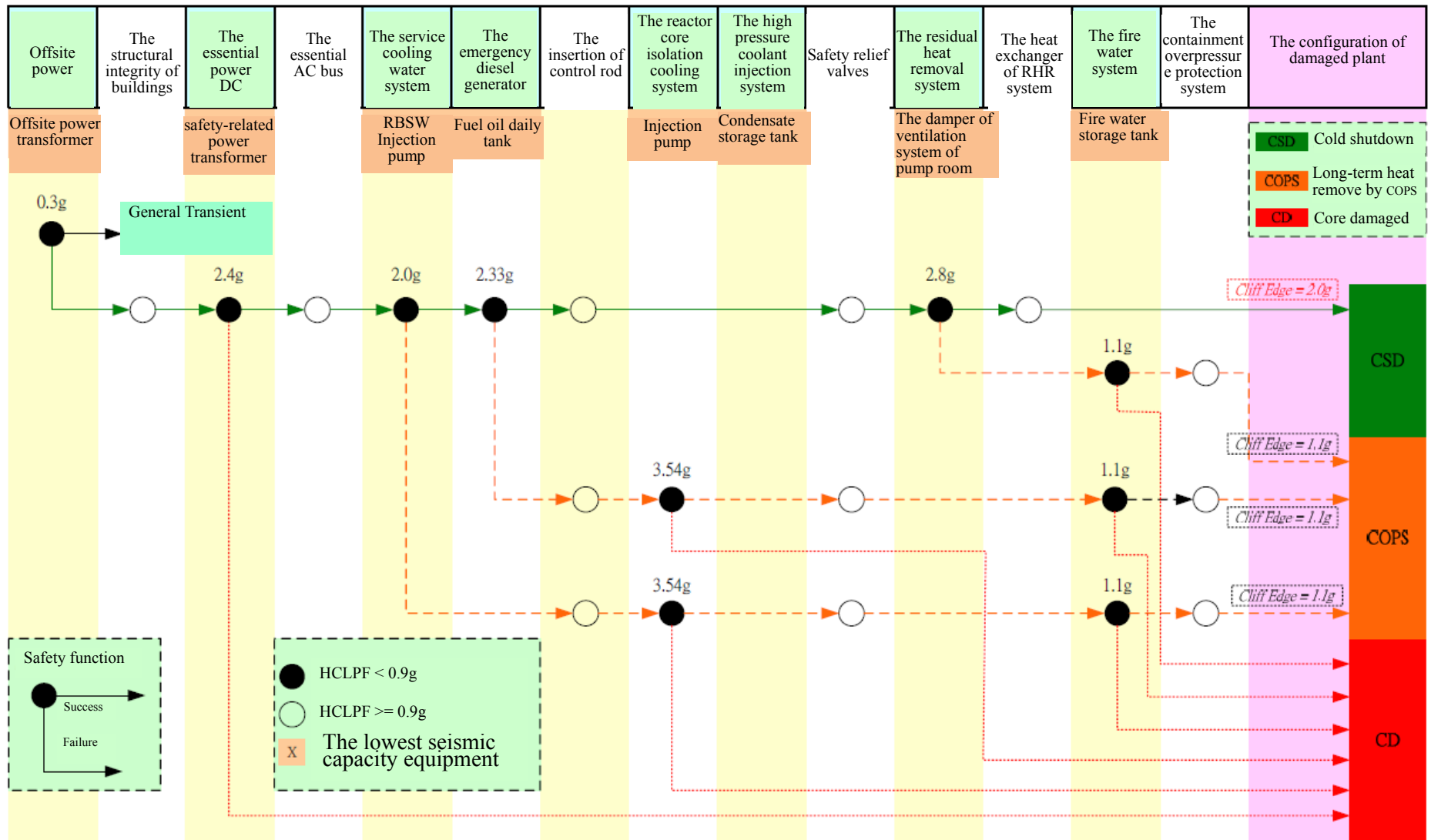
The purpose of this assessment is to find out the minimum withstanding value for the required equipment and facilities which can maintain unit safe shutdown via probability risk assessment (PRA) event tree methodology and evaluation of equipment and facilities seismic withstanding extent when earthquake happens. It means that once seismic degree reaches the extent that all the above-mentioned equipment and facilities which is unable to withstand the seismic degree are assumed to lose their intended function and further to impact of unit safe shutdown. The PRA event tree methodology applied to find out the required first aid equipment and facilities of the minimum vibratory withstanding value for the successful first aid path is the cliff-edge defined in this section.

According to the equipment seismic capability assessment information in Appendix AC.3 of Lungmen FSAR, the plant has 97 structures, systems and component may affect the integrity of the reactor after earthquake. Based on the characteristics of the design, installation and spatial interaction, the individual seismic capability was assessed. The medium seismic withstanding value of each equipment are different (comparing to the Peak Ground Acceleration (PGA) of the base rock), from the 0.3g of the offsite power supply to the 13.13g of the duct of the air-conditioning systems. Because there is a large number of the equipment on the list of seismic equipment and the seismic withstanding values vary, so the screening of the seismic withstanding capability was executed before the seismic cliff edge effect analysis, in order to focus on the equipment that have significant impact on the maintenance of the integrity of the fuel.

It requires HCLPF = 0.5 (elastic equipment) or 0.57 (inelastic equipment) as the screening value of the equipment seismic withstanding capacity in EPRI-1002988, but it also requires a more conservative screening values for the nuclear power plants located in high seismic risk

zone. Considering that Lungmen nuclear power plant is located in a high seismic risk zone, the SSE value at the foundation level free surface is 0.4g, HCLPF = 0.9g was selected conservatively as the screening value to be used in the seismic cliff edge effects event tree.

According to the above screening analysis requirements, the plant has only 13 equipment must be included in the subsequent cliff edge effects analysis. A detailed list of equipment and seismic capacity parameters evaluated in the FSAR is shown in the following table.



The equipment included in the seismic cliff edge effects detailed analysis. It will be provided the plant HCLPF as the result of cliff edge assessment.

Structure 、 System 、 Equipment	Am(g, medium, PGA)
Offsite Power Transformer	0.3
Condensate Storage Tank	1.1
Fire Water Tank	1.1
Fire Water Pump	1.9
Reactor Building Service Water Pump	2
Buried Piping	2
Fire Water Buried Piping	2
Fire Protection House	2.3
EDG Fuel Oil Day Tank	2.33
SDG Fuel Oil Day Tank	2.33
Safety Related Transformer	2.4
HVAC Damper	2.8
Air Handling Unit	2.95

Based on the existing design of the safety functions and the operating procedures, the plant has conducted seismic cliff edge effects assessment using the medium seismic withstanding value listed in the table above. The following figure seismic cliff edge effects event tree of the Lungmen nuclear power plant. When the plant lose offsite power due to earthquake with intensity that is greater than 0.3g. There are four successful paths to achieve reactor core long-term heat removal.

Successful path (1): All the necessary safety functions for the unit normal cold shutdown paths can be successfully performed. The related safety functions include: the essential DC power to start the emergency diesel generator; the service water system to cool the emergency diesel generators and safety injection system and to provide cooling water for the heat exchanger of the residual heat removal system; the emergency diesel generators to provide the AC power for the important equipment; the residual heat removal system to execute safety injection and a variety of heat removal functions.

Successful path (2): When the residual heat removal system is unavailable due to earthquake, the fire water system can provide the reactor core long-term cooling. The containment bypass pathway provided by the containment overpressure protection system can release the energy accumulated in the containment to achieve the purpose of long-term heat removal of the reactor core.

Successful path (3): When the emergency diesel generator is unavailable due to earthquake, the RCIC can provide the reactor core short-term water makeup functions. The fire water system can provide the reactor core cooling. The containment bypass pathway provided by the containment overpressure protection system can release the energy accumulated in the containment to achieve the purpose of long-term heat removal of the reactor core.

Successful path (4): When the service water system is unavailable due to earthquake, the rescue path the same as successful path (3) can achieve the purpose of long-term heat removal of the reactor core.

The safety margin and cliff-edge of each successful path are described as follows:

Successful path (1): The seismic withstanding value of the service water system is the lowest, in which the RBSW pumps and the underground buried piping are the key equipment. The medium seismic withstanding value is 2.0g.

Successful path (2), Successful path (3), and Successful path (4): The seismic withstanding value of the fire water system is the lowest, in which the fire water storage tank is the key equipment. The medium seismic withstanding value is 1.1g.

The cliff edge in this case is defined as the lowest seismic withstanding value (listed on the heading of the event tree sequence) of the highest safety margin path among all the successful cooling paths. Therefore, after evaluation, the cliff edge of Lungmen nuclear power plant due to earthquake that can result in core fuel damage is 2.0g of successful path (1).

2.2.1.2 Envisaged measures to increase robustness of the plant

Chinshan NPP

1. According to the seismic LOOP event trees analysis, the plant fragility medium value is 0.61g. The critical component is skid anchor bolt of Gas Turbine which will be incorporated in to the Gas Turbine seismic enhancement program
2. According to seismic event tree analysis, fuel support structure is damaged due to the cliff-edge of 1.05 g earthquake so as to result in reactor unable to scram. In this condition, ATWS shall be automatically actuated and boron shall be immediately injected into reactor by means of its relevant essential power. After Fukushima accident, additional boron is procured and its mobile injection measure was already prepared and incorporated in the station procedure. After this enhanced measure, reactor can be put in subcritical condition and the station's cliff-edge will be changed from fuel support structure 1.05g to Condensate Storage Tank 1.15g.
3. According to the seismic event tree analysis, one of the successful reactor cooling path is that reactor shall be able to relieve the reactor pressure in order to assure that low pressure water injection can provide with sufficient cooling capacity. The fragility of reactor pressure relief is 0.79g and its critical component is its accumulator. The station already prepared sufficient nitrogen gas bottles and mobile air compressors after the safety reassessment so as to provide SRV emergency backup gas sources to maintain reactor pressure relief function in case of the accumulator damaged after earthquake.
4. According to seismic event tree analysis, one of the successful reactor cooling paths is mobile water injection via BCSS or RHR system by raw water pump, fire water pump, or fire water truck. Its relevant water injection path and water source was already programmed in Overall Checkup Program Item 4 "Review of Ultimate Heat Sink" and its relevant operation process was also incorporated in unit URG procedure. Moreover, except for seismic enhancement of raw water reservoir as well as raw water pipe to be above ground, the seismic enhancement of RCIC and RHR B injection paths are evaluated in connection with the new evidence of Shanchiao fault.

Kuosheng NPP

1. According to the LOOP initiating events of seismic event trees, the medium plant fragility is 0.61g. The critical component is skid anchor bolt of Gas Turbine which will be incorporated into the Gas Turbine seismic enhancement program.
2. According to one of successful reactor cooling path as per seismic event tree analysis, the DC power for steam-driven RCIC system or its instrumentation control power as well as

the DC power for HPCS pump driven by HPCS Diesel Generator or its instrumentation control power is the reason of cliff-edge effect (0.77g). The station already prepared its enhancement measures including that for response to the new evidence of the Shanchiao fault and RCIC system (including I&C and control power) is selected to enhance its overall seismic capability. Moreover, the operation process for manual startup of RCIC in case of loss of RCIC control power was included in “URG” and it is demonstrated to be feasible. Seismic margin will be upgraded from 0.77g to 1.119g after above-mentioned relevant enhancement measures put into practice.

3. According to seismic event tree analysis, one of the successful reactor cooling paths is mobile water injection via RHR B system by raw water pump, fire water pump, or fire engine. In plants ultimate response program, raw water reservoir, raw water piping system, RCIC and RHR B injection paths have all been upgraded to deal with the potential movement of the nearby Shanchiao fault.
4. The station also procured 3 sets of small air compressors for the air operated valve emergency operation, to assure that the compressed air supply can be available for AOV operation. In addition to that, two sets of mobile diesel-driven air compressors which have also been procured for SRV emergency operation. Furthermore, installation of an additional emergency air charging pipe with connector in the outside building for standby use in order for mobile diesel-driven air compressor with booster pump to provide compressed air via this additional emergency air charging pipe.

Maanshan NPP

In order to enhance the defense and rescue capability facing various compound disasters, MSNPP has revised and improve related procedures and hardware/equipment. MSNPP has also upgraded seismic fragility for its gas turbine generator. After the enhancement, MSNPP can upgrade its overall resistance to seismic events.

Lungmen NPP

- Shorten the time needed to establish fire water flow path

Operator must manually open at least two isolation valves, they are E11-BV-045C and E11-BV-046C (located in equipment channel division C of the reactor building, the building room number 335), to establish the fire water system based on current system design. When loss of AC power, in addition, operator must manually open the E11-MBV-0005C electric valve (located in the ECCS division C valve room of the reactor building, the building room number 431, locked during normal operation). Operator need to spend more time to do that because the locations of the three valves are not in open space, and there will be considerable obstacles in field during manual operation. If some kind of modification can be made, the time to establish the flow path can be shortened. In addition, the decision-making timing to establish the flow path by on duty operator in the control room is also an important key factor in the accident. If there are clear procedures guidelines with training, it can also help to shorten the time needed to establish the fire water flow path.

- Upgrade the seismic capability of raw water system

Raw water reservoir has various design functions. Therefore the upgrading of the seismic capability of raw water system mainly focus on the pipes and valves related to the provision of fire water and the hillside which is adjacent to the raw water reservoir and the plant boundary. Therefore, the raw water system can provide a stable water supply to fire water system after earthquake.

- Intake from raw water system through fire water pump

Because the seismic capability of fire water storage tank is low, and the feasibility of substantial improvements is also low. However, we consider to modify the interface of fire water system and raw water system. The raw water can be introduced directly into the intake pipe of fire water pump using fixed or unfixed pipes if necessary. Therefore, the fire water system can still perform its functions after the failure of fire water storage tank.

2.2.2 Range of earthquake leading to loss of containment integrity

[Chinshan NPP](#)

Based on the seismic fragility analysis, the medium fragility for the reactor building is found to be greater than 5.6g.

[Kuosheng NPP](#)

Based on the seismic fragility analysis, the medium fragility for the reactor building is found to be greater than 3.5g.

[Maanshan NPP](#)

Based on the seismic fragility analysis, the medium fragility for the reactor building is found to be greater than 5.8g.

[Lungmen NPP](#)

Based on the seismic fragility analysis, the medium fragility for the reactor building is found to be greater than 5.5g

2.2.3 Earthquake exceeding the DBE and consequent flooding exceeding DBF

2.2.3.1 Physically possible situations and potential impacts on the safety of the plant

[Chinshan NPP](#)

Chinshan NPP site area surrounded by small mountain can be divided into two subareas (East side and West side) and they are separated by a hill and are connected through a tunnel. In east side, there is a 4 km long stream flows into East Sea and the major facilities located in this district are some not-important facilities. In west side, there is a 8 km long Chien-hwa stream, and the stream path is changed into artificial drainage trench in downstream portion with jetty, protection slope and it also flows into East Sea. The major structures and facilities are all located in this district. During the plant construction period, the ground elevation are all filled to 12m above mean sea level to prevent from site area flooding in case of natural incidents.

There are three uphill raw water reservoirs with capacity of 2000 metric ton, 1000 metric ton, and 600 metric ton respectively. In case these water reservoirs were damaged due to earthquake, the water from these damaged water reservoirs are evaluated not to cause the flood to the plant facilities.

Both streams were evaluated with the result of no mudslide potential.

[Kuosheng NPP](#)

The consequent flooding exceeding DBF resulted from earthquake is caused by tsunami. It is described in chapter 3 “Flooding including tsunami”.

There is no stream across the site area but there are two streams nearby the site. Both of them are separated by a hill from the station, and both streams were evaluated with the result of no mudslide potential.

Maanshan NPP

There is no creek, no water dam, and no potential mudslide inside plant site. Although the highest water level 16.5m of nearby Lung-luan pond is 1.5 m higher than the site elevation of 15 m, it would not overflow to Maanshan site because of high mountain separation in between. Therefore there is no concern of water overflow or mudflow from Lung-luan Pond during earthquake.

There are two 50,000 ton raw water reservoirs in the northwest side of the site. The elevation of the two reservoirs is about 51 m and is 36 m higher than the site. However, it is shielded and separated from the site by high lands. Therefore, there is no concern of water overflow or mudflow from the raw water reservoirs during earthquake.

On the east side of the site, there is a firefighting water tank with a 5000 ton capacity. However, since it is 500 m away from NPP, there is no concern of flood due to its collapse during earthquake.

In conclusion, exceeding DBF flood will not occur even the seismic intensity is above DBE.

Lungmen NPP

The Lungmen NPP site has a concave shoreline that faces the Pacific Ocean and the other side surrounded by hills. It is located at Yenliao Village, Gongliao District, New Taipei City, at an approximate longitude of 121°55'E and latitude of 25°03' N in the northeastern coast of Taiwan. It is about 20 km southeast of Keelung, 40 km east of Taipei and 33 km northeast of Yilan.

The plant site is on a coastal plain of the Shihting Creek and Shuang-Chi Creek. The Shihting Creek flows through the warehouse area and dormitory area located in the north side of the plant. The creek inside the plant is the rectified composite open channel. The Shuang-Chi Creek is located in the south side of the plant. There is a hill higher than 50 meters that blocks between the Shuang-Chi Creek and the plant site. The rise in Shuang Chi Creek water level will not affect the operation of the Lungmen NPP. This two creeks were not included in the list of potential mud flow areas determined by the Soil and Water Conservation Bureau of the Council of Agriculture, Executive Yuan. After many years of typhoon, rainstorm and earthquake, the plant does not have serious mud flow disasters. In addition, the excavation and site preparation area is maintained through good soil and water conservation engineering. Therefore the probability of mud flow disaster or changing course of Shihting Creek and Shuang-Chi Creek is very low based on the site natural conditions. Both of them are not considered as the flooding source of the plant due to earthquake.

The raw water reservoir is located on the west side flat hills with 116 meters of elevation, 112 meters long and 63 meters wide. The elevation of bottom plate is 116.6 meters. The elevation of full water level is 124.6 meters. The volume of water storage is 48,000 cubic meters. The base and walls are constructed using reinforced concrete structures. The tank is designed as Seismic Category IIA structure so it doesn't collapse during SSE. Moreover, the internal partitions of the reservoir can disperse and reduce the impact force due to water sloshing during earthquake. The foundation of the raw water reservoir is built on the base rock. The bearing capacity is much higher than the total weight of the reservoir body plus water storage. Therefore, there is no concern for the lack of soil bearing capacity or the liquefaction. In addition, the rock stratum of upper raw water reservoir hillside is south-north direction, with dip of slope towards south at about 14°. In order to reduce the safety concern of slope stability,

the slope of upper raw water reservoir and the slope between upper and lower reservoir were trimmed with slope (1V:4H). We also remove all blocks that may slip along bedding surface so that the hill layer will not be exposed. When the bedding surface extends to the lower slope, there is no concern of dip-slope landslide caused by excavation at the toe of slope. The whole section of slope is safe and stable. However, when earthquake occurs with the intensity exceeding the withstanding range of the raw reservoir structure, the raw water reservoir may collapse caused by structural crack damage and may affect plant safety.

2.2.3.2 Weak points and cliff edge effects

[Chinshan NPP](#)

Overflow of those close-by water reservoirs shall not result in flooding so as to impact the major essential building and its facilities. Moreover, after review of the condition of both Streams, the station shall not be impacted by mudflow event.

[Kuosheng NPP](#)

In case that the western reservoirs collapse, water will be dumped along valley line to Gas Turbine Building and Emergency Diesel Generator Building.

[Maanshan NPP](#)

There is no weak point and cliff edge effects due to earthquake induced flood in this plant.

[Lungmen NPP](#)

Although an “the Raw Water Pool Leakage Analysis due to Crack Damage” analysis revealed that if the earthquake with intensity exceeding the design basis, there will be a maximum peak leakage flow of 46.6 cms, the flow of sub-drainage Channel (No.III-1) is then attenuation to 31.6 cms, which is below the 57.0cms design flow, and the flood is transported to the downstream of marine outfall. Therefore, there is no weak point and cliff edge effects due to earthquake induced flood in this plant.

2.2.3.3 Envisaged measures to increase robustness of the plant

[Chinshan NPP](#)

The station already take the following enhancement measures to strengthen its protection capability based on that raw water reservoirs structure may be damaged so as to result in water overflow:

1. Raw Water Reservoirs Structural Damage:
 - (1) TPC had already upgraded the seismic resistance for the 100,000 metric ton and two sets of 3000 metric ton raw water reservoirs structures.
 - (2) The station also installed baffle plate on the entrance and exit in each essential building to avoid that flooded water crashes directly into essential building in case of reservoirs damage.
2. Mud flow protection:
 - (1) The station revised plant procedure to include the monitoring of the two Streams.
 - (2) The station shall announce mudslide warning alert according to Central Weather Bureau (CWB) criteria (i.e., daily rainfall 500mm is exceeded) and take proper actions in the plant procedures.

Kuosheng NPP

The station already installed baffle plate for the Gas Turbine Building and Diesel Generator Building in order to reduce water directly crashing into building to damage equipment in case of embankment collapsed.

Maanshan NPP

Although MSNPP has no concern on earthquake induced flood, the structures of the two 50,000 ton raw water storage reservoirs, the 5000 ton firefighting water tank, and the 2000 ton raw water reservoirs have been upgrade for their seismic resistance.

Lungmen NPP

Although the plant does not have to take enhancement measures to strengthen its protection capability due to earthquake induced flood. However, if the flood height exceeds the design basis height (greater than 12.0 meters), the plant will be flooded because the external gate of each building on ground floor have no watertight function. In addition to plant existing Sump Pump, to drain the water, we can also use pre-prepared temporary pump, to restore the function of the equipment located on the ground floor of the plant as soon as possible. Also, we will install baffle plates at the external gates on ground floor of each important building to upgrade the protection capacity against flood.

2.3 Assessment and conclusions of the regulatory body

Based on the 2007 Japan NCO earthquake experience, the newly confirmed active Shanchiao and Henchun faults, the 311 Fukushima nuclear disasters, the regulatory body AEC has required TPC to perform an updated and thorough seismic evaluation and to take every measure needed to fulfill the ENSREG stress test requirements.

For current operating six units, the approaches used to update the seismic hazard and to assess the plant seismic safety by SMA and by SPRA of the TPC's operating six units are all the same and are in conformance with the latest methodology defined and adopted by USNRC. **As to the LMNPP, TPC is also conducting the seismic hazard curve re-analysis to see whether the annual exceedance frequency of current SSE is adequate.**

TPC has also adopted a so-called ultimate response countermeasure to deal with the extreme unlikely event like Fukushima NPP.

Based on the review of TPC's reports and the supporting documents, the subsequent technical meetings, the AEC considers that the resulting action plan of this seismic reassessment is adequate. But the schedule should be more efficient and should be speeded-up, the AEC also identified additional recommendations for TPC to further improve the seismic robustness of the plant facilities:

1. Although the preliminary results showed the DBEs of the three plants remain some margin, the maximum potential earthquake caused by the Shanchiao fault and Henchun fault are still to be evaluated, as they are so close to the Chinshan/Kuosheng and Maanshan NPPs respectively.
2. There are too many spent fuels stored in spent fuel pools and the spacing to each other is too small to avoid collision during strong earthquake, so they are very vulnerable to the seismic impact. Therefore TPC should speed-up to move these spent fuels to ISFSI.
3. AEC required TPC to submit the seismic action items based on the requirements set forth in section 2.1 and 2.3 of USNRC NTTF report tier 1 recommendation.
4. Referring to the international nuclear safety actions in response to the Fukushima Daiichi

nuclear accident, AEC required TPC to accomplish the following items

- (1) Seismic/Tsunami hazard and event scenario simulation
- (2) Seismic enhancement for the non-seismic TSC structures
- (3) SSCs enhancement evaluation followed by the SSE upgrade from 0.3g to 0.4g for CSNPP
- (4) Functionality upgrade for emergency response facilities including adopting seismic base isolation or damping devices.
- (5) Seismic upgrade of plant fire brigade building structures.
- (6) Upgrade the raw water reservoir seismic resistance as well as its reliability.
- (7) Enhance the power durability of seismic monitoring sensors.

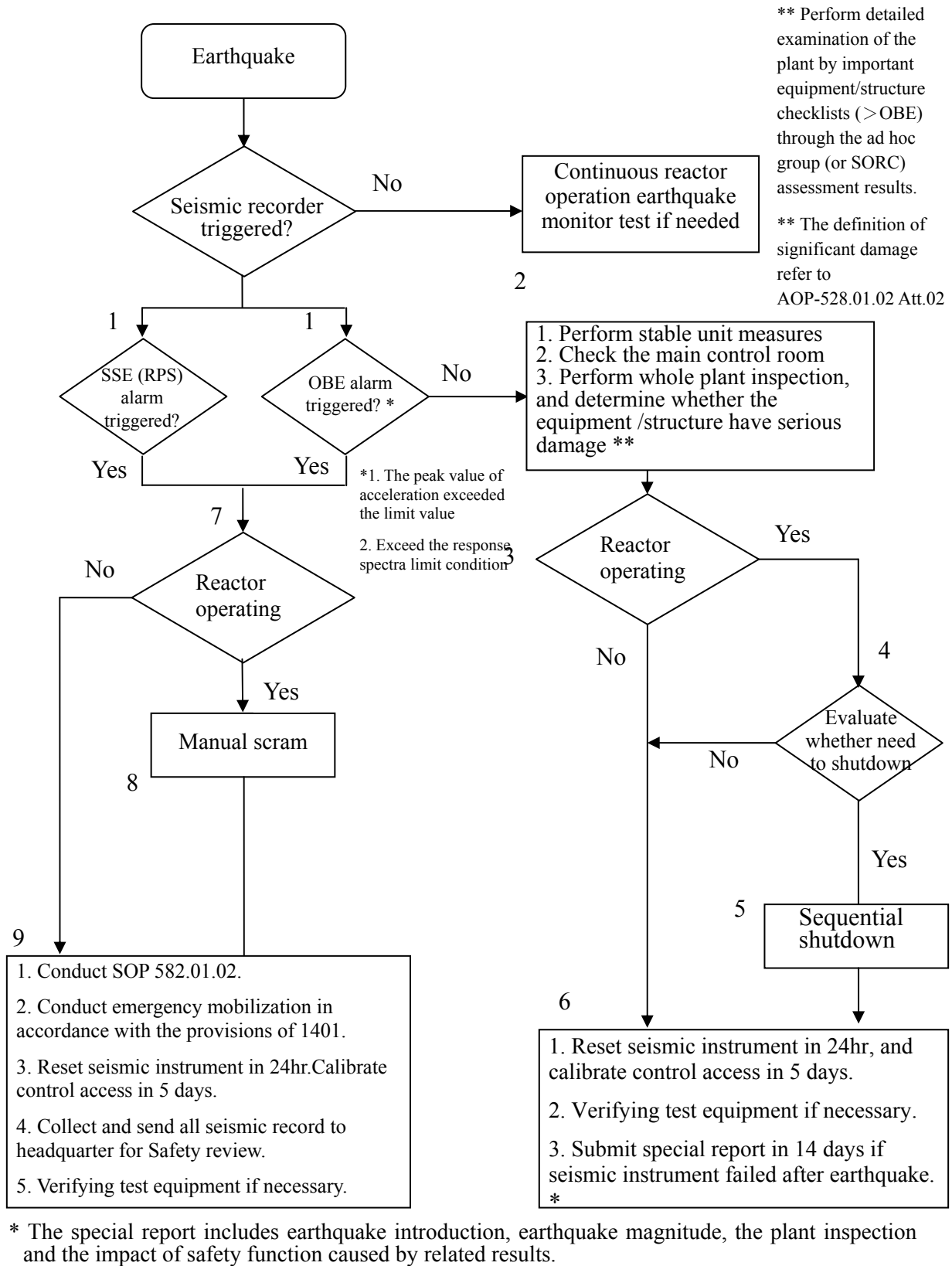


Figure 2-1 The emergency procedure flowchart of nuclear power plant after strong earthquake

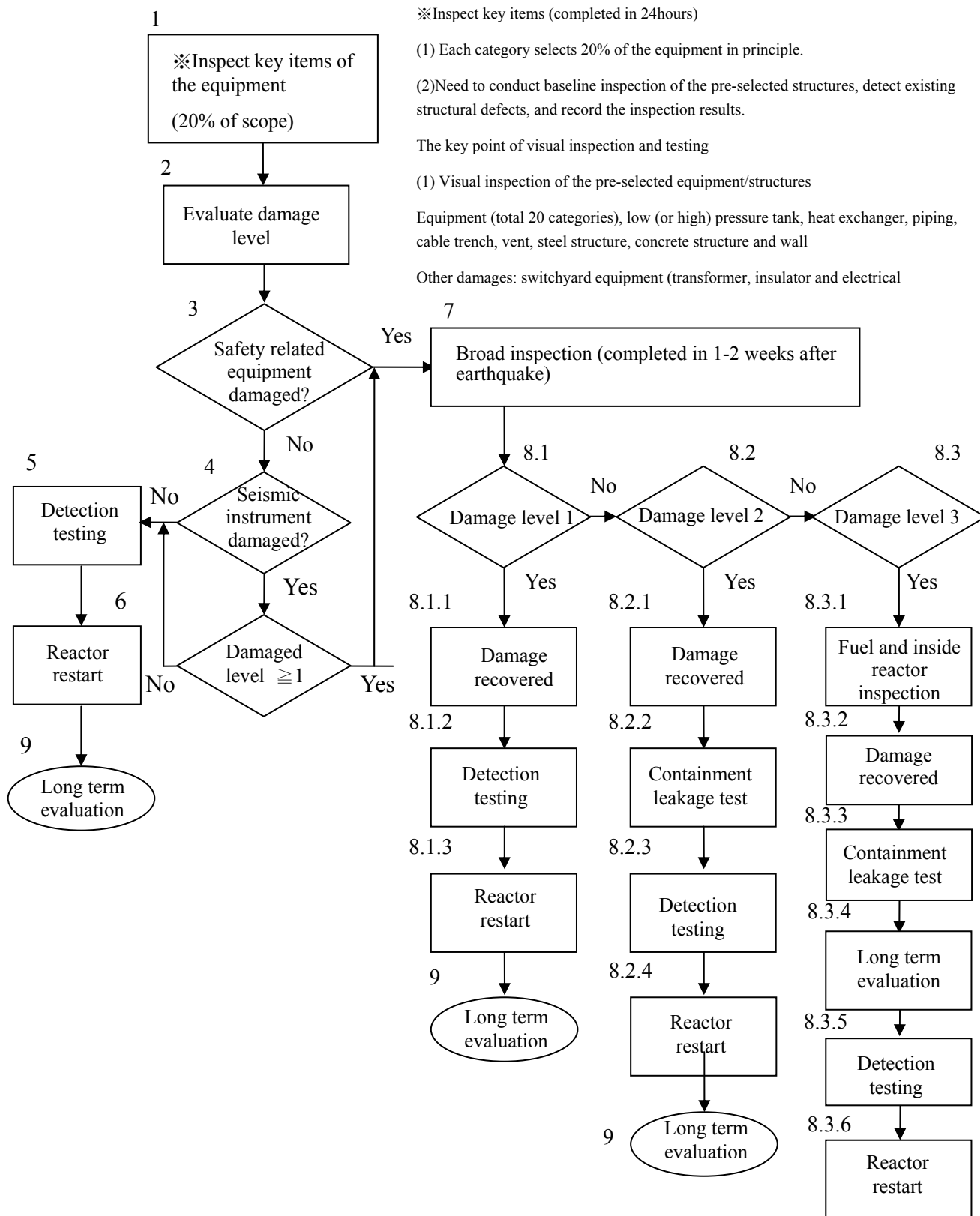


Figure 2-2 The evaluation flowchart of earthquake caused reactor shutdown inspection, testing and reactor restart

3. Flooding

3.1 Design basis

3.1.1 Flooding against which the plant are designed

3.1.1.1 Characteristics of the design basis flood (DBF)

Chinshan NPP

The design basis flood of Chinshan Power plant considers the influence of tsunami and storms on the site.

1. Tsunami:

According to the Final Safety Analysis Report (FSAR), Section 2.6.1.1, the potential maximum tsunami run-up height is 9 m. If the height of tide wave, 1.73 m, is also added, the total height is 10.73 m.

2. Flooding due to storms:

Chinshan Power Plant adopts the probable maximum precipitation (PMP) of 297 mm/h as the design basis flood, which complies with the requirement of flooding with a return period of 10,000 years. The data source of the statistic calculation is based on the historic storm record from 1943 to 1972 measured at both Danshui and Anbu weather stations, where the PMP reach 252 mm/h and 325 mm/h respectively.

Kuosheng NPP

Due to the characteristics of the Kuosheng nuclear power plant, its design basis flooding considers the influence of tsunami and storms.

1. Tsunami:

At the time the power plant was built, the maximum tsunami height was estimated from the historic tsunami records, influence of local climate, as well as the geographical landscape of the plant. According to the evaluation result of FASR, the maximum tsunami height is 7.78 meters. If tides and geographical landscape are taken into account, the maximum tsunami run-up will be 10.28 meters, which is still lower than the plant elevation of 12 meters.

2. Flooding due to storms:

Based on the 30 years historic record in the neighboring area before the construction of the power plant, the plant estimates that the probable maximum precipitation (PMP) with a return period of 10,000 years is 241 mm/h, in accordance with which, the drainage capability of the plant is designed to be 138 cms (m³/s) for trench A and 114 cms for trench B respectively.

Maanshan NPP

According to the FSAR of the plant, the design basis flood (DBF) considers the influence of tsunami and extremely heavy rain.

1. Tsunami:

The elevation of the plant is 15 m above sea level. The maximum tidal range in the historic record of the neighboring oceanic area is 4.0 m, which happened at Kaohsiung Port before. Based on the tsunami run-up height record of the neighboring oceanic region

as well as the oceanic stratum structure near the plant, it is estimated that the maximum tsunami run-up height near the plant is 12.5 m. Therefore, there is no concern of tsunami-induced flooding at the plant.

2. Flooding due to extremely heavy rain:

- (1) When the power plant was built, the plant used the precipitation data between 1940 and 1975 at the nearby Hengchun, Dawu, Taidong, and Kaohsiung Weather Stations, to estimate the once every 100 year maximum precipitation intensity. The mean of the precipitation intensities of the four weather stations, 120 mm/h, was used to be the 100-yearly PMP.
- (2) The plant chose the biggest estimate of the 10,000-yearly precipitation intensity from the four stations, which is 228 mm/h from Dawu Weather Station, to be the design basis PMP with a return period of 10,000 years.

Consequently, the plant has two DBFs: one is 120 mm/h, the 100-yearly precipitation intensity; the other is 228 mm/h, the 10,000-yearly precipitation intensity.

Lungmen NPP

Considering the geographic characteristics of Lungmen NPP, the DBF takes into account the influence of tsunamis and storms.

1. Tsunamis:

When estimating possible height of tsunami waves, the plant uses historic records as reference and considers influence of both climate and geographical landscape. According to the evaluation result of FASR for Lungmen NPP, the maximum tsunami height is 7.5 meters; if change of tides is also considered, the maximum tsunami run-up is at least 8.07 meters. Adding another 0.5 meters of freeboard, the elevation of the design basis for the plant protection against tsunamis is 8.57 meters, which is lower than the ground elevation of the main building area, 12 meters.

2. Flooding:

Lungmen NPP estimates the probable maximum precipitation (PMP) mainly based on the historic precipitation records measured at the Keelung Weather Station between 1901 and 1982. The resulting PMP at Lungmen NPP is 310 mm/h. The drainage system is designed to carry the run-off from a storm with **100-yearly return period**. The drainage capabilities of both channels, Channel II and III, are 81.57cms (m^3/s) and 137.2cms respectively.

3.1.1.2 Methodology used to evaluate the design basis flooding

Chinshan NPP

1. Design basis tsunami:

As described in Section 3.1.1.1, the height of the design basis tsunami is 10.73m. Therefore, FSAR recommends that the ground elevation of the plant buildings should be higher than 11 m. In the end, the elevation of the main area in the plant was set to be 12 meters.

2. Design basis flood:

Chinshan Power plant can be divided into two parts: the west part ChienHwa area, and the east part Xiaoken area. In between the two parts are mountain hills, and ChienHwa Tunnel connects the two areas. Xiaoken Stream flows from south to north through Xiaoken area and flow into East China Sea. Main facilities in this area are spare parts warehouses, the

office building for the Improvement Division, the Radiation Laboratory. ChienHwa area is the downstream valley of ChienHwa Stream. When the plant was built, the plant diverted the section of ChienHwa Stream that flew through the plant area by building embankment as well as revetment. The plant also constructed man-made drainage trenches to guide the water to flow from south to north through ChienHwa area into East China Sea. The main buildings and facilities of the power plant are located within ChienHwa area. The landscape of the plant descends from south to north. Furthermore, the ground of the reactor building and the levels at the exit of ChienHwa Stream were reclaimed to 12 meters (Sinotech Engineering Consultant Company re-measured and confirmed that it is still higher than 11 meters.). The purpose of these efforts is to prevent the main buildings from flooding if natural disasters happen.

The drainage system in the main area, ChienHwa area, of the plant comprises two parts:

- (1) Power Block area: Drainage of surface runoff is done by gravity. There are 5 pipes with various diameters in this area to drain water into ChienHwa Stream. Besides, there is also a trench to drain water out of the Power Block. The total drainage capacity is 5.6 cms.
- (2) The rest of ChienHwa area: Drainage of surface runoff in this area is also done by gravity. There are two drainage routes: one drains toward west into ChienHwa Stream and the other drains toward north into East China Sea. The water in this area is collected and drained by the man-made trenches at ChienHwa Stream. The drainage capability in this area is bigger than the 10,000-yearly PMP.

TPC has completed a map of the plant. According to the map, it is concluded that the inundation-prone area in the plant is the region between the north wall of the Power Block and the container area. There are trenches in this region to drain water into ChienHwa Stream and East China Sea.

Kuosheng NPP

1. Design basis tsunami:

Based on historic records, it has been concluded that tsunami originated from the central and western Pacific Ocean would not cause any damage. Therefore, design basis tsunami of the plant mainly consider potential tsunami threat from north of the site. From historic record of Central Weather Bureau, there were two severe tsunamis in Taiwan in 1867 and 1918. The tsunami happened at 134 km north of Keelung in 1867 is more serious, and it caused severe damage in Keelung area. As documented in historic record, the height of the tsunami wave is 7.5m. The maximum run-up height of tsunami is determined to be 10.28 meters by combining the height of the severe tsunami happened in 1867, the influence of season winds, the height of run-up at shore and the height of the highest tide (1.28 meters). Hence, the Kuosheng nuclear power plant is protected against tsunami by its 12 meters high ground elevation.

2. Design basis flood:

For the flooding design basis, the plant mainly considers probable maximum precipitation at the plant, and based on which, the plant designs its drainage capability against storms.

As stated in FSAR, precipitation intensity is directly related to elevation and geographic environment. To calculate the PMP, the plant used the historic precipitation data measured at the nearby Keelung weather station between 1947 and 1976. Based on statistics analysis, the plant uses 241 mm/h, the 10,000-yearly PMP, as the design basis of the drainage capability.

The drainage system of the plant consists of three parts—the main building area, west of the site, and east of the site:

- (1) The drainage system in the main building area is made up of on-site ditches, pumps, manholes, and pipes.
- (2) The drainage system in the west of the site area collects ground runoff from rainfall at the warehouse area, the power switchyard, and the hills in west of the main building area, and drains out through trench A.
- (3) The drainage system in the east of the site area collects ground runoff from rainfall at the hills in east of the main building area, and drains out through trench B.

The trenches A and B above are both open type of trenches, making water flow into ocean at a slope rate of 0.2% to 0.5%. The maximum drainage capabilities of both trenches are 138 cms for trench A (at the estuary) and 114 cms for trench B respectively.

Maanshan NPP

1. Design basis tsunami:

Because the plant faces south, its threat of tsunami is from Bashi Channel, Luson Strait, and South China Sea, which are induced by big earthquakes with shallow epicenters. Assuming an 8.0 (Richter scale) earthquake induces tsunami with 5m high wave at the epicenter location, the height of the tsunami wave at the coast of Maanshan will be approximately 11 m, and the tsunami run-up height near the plant will be approximately 8 m. Conservatively adding a 4.0 m typhoon surge wave and 0.5 m safety margin, the maximum tsunami run-up level at the plant is 12.5 m. Comparing to the ground elevation of the main building area, which is 15 m, the plant has enough protection against tsunami.

2. Design basis flood:

- (1) The elevation of the building area is 15 m above sea level, which is higher than the potential maximum tsunami run-up height, 12.5 m. Hence, there is no concern of tsunami-triggered on-site flooding.
- (2) There is no stream or dam near the plant.
- (3) Although the highest water level of Lungrung Lake, 16.5 m, is 1.5 m higher than the ground level (15 m) of the building area, there is a natural high land barrier at an elevation of 30 m between the lake and the plant. For this reason, there is no concern of the lake water entering the plant.
- (4) The plant has two 50,000 tons raw water reservoirs, whose ground elevation is 51.5 m. Even though these two reservoirs are 36.5 m higher than the ground elevation of the plant building area, a natural high land barrier separates the reservoirs and the building area. So, there is no concern of the water flowing into the plant.
- (5) High ground elevation around the building area, except for the southern part (facing the sea), serves as a natural flood barrier. Accordingly, the drainage system only needs to deal with the precipitation in the building area.

Lungmen NPP

1. Design basis tsunami:

FSAR of Lungmen NPP considers the possible threat by the tsunami induced by undersea earthquake in north or northeast of Taiwan when evaluating the design basis tsunami. According to the historic records, two severe tsunamis occurred in Taiwan in 1867 and 1918 respectively. The one that happened on June 11, 1867 at 134km north of Keelung

was more severe, and the height of the tsunami waves was approximately 7.5 meters. As described in Section 3.1.1.1, after considering the influence of tides and geographic factors, the height of the design basis tsunami is set to be 8.57m, which is still lower than the ground elevation of the main building area, 12 meters.

2. Design basis flood:

Lungmen NPP is situated in the northeast corner of Taiwan, where there is abundant rainfall all year round. The main causes of storms in this area is northeast monsoon, plum rains (East Asia rain season), and typhoons. According to FSAR 2.4.3.1, the probable maximum precipitation is the main consideration when evaluating the design basis flood. The plant adopts the precipitation records measured at Keelung Weather Station from 1901 to 1982, and obtains the PMP result of 310 mm/h after calculation. With the consideration of this PMP figure and the geographic landscape of the site, the plant designs its drainage system: four main drainage channels I, II, III, IV. The drainage system of the plant is divided into the following three parts:

The first part: drainage in the power block area. The runoff resulting from rainfall (100-yearly storms) in the power block area is released by the Yard drainage system, which includes ditches around buildings, collecting pools, manholes, pipes, underground trenches (e.g., drainage Channel IV), and etc.

The second part: drainage outside of the south fence of unit 1, in part of the bordering area between unit 1 and unit 2, and in switchyard area, is done by drainage Channel III. Besides, the runoff caused by rainfall on hills in south, southwest, and west of the main building area is also released by drainage Channel III.

The third part: drainage in east of the switchyard and runoff resulting from rainfall on hills in west of the power block area are released via drainage Channel II.

3.1.1.3 Conclusion on the adequacy of the design basis for flooding

After assessing the 22 earthquake origins of potential maximum tsunami in Taiwan, National Science Council (NSC) published a report “Influence of Tsunami Induced by Potential Massive Scale of Earthquakes on the Nuclear Power Plants in Taiwan” on Aug. 19 in 2011. The result shows that the potential tsunami run-up height at the four power plants in Taiwan is lower than the design basis tsunami elevations of these plants. [However, there are still significant uncertainties in tsunami run-up predictions due to the definition of tsunami sources.](#) Related design basis tsunami elevation and the design of the elevation of these plants are listed in the Table below:

Table 3-1 related design basis tsunami elevation and the design of the elevation of these plants

Site Name	Chinshan	Kuosheng	Maanshan	Lungmen
FSAR Tsunami run-up elevation (Note 1)	10.8m	10.3m	12.6m	8.1m
Site Elevation	11.2m	12.0m	15.0m	12.0m

Note1: The result of this analysis was done by both domestic and international professionals in related fields before the establishment of these power plants.

[Chinshan NPP](#)

1. The adequacy of design basis tsunami

After the Fukushima Accident, TPC completed an investigation on the oceanic and terrestrial geographic landscapes near the power plant and reviewed both the design basis against tsunami and the safety of plant facilities stated in the FSAR. The result shows that the elevation of Chinshan Power Plant is 11.2 m, which is larger than the maximum tsunami height 10.7 m. Thus, it is confirmed that important buildings and equipment would not be flooded by tsunami. [They will build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.](#)

2. The adequacy of design basis flood

- (1) The two units of the plant have been operated for more than 30 years. Based on the precipitation record from Anbu, Danshui and Fugui Cape Weather Stations between 1979 and 2011 (provided by the Central Weather Bureau), the maximum precipitation intensity near the power plant is 136 mm/h occurred at Anbu station on Sep. 5, 2001, which is lower than the design basis maximum precipitation intensity of the plant, 297 mm/h.
- (2) Using the historic records of the maximum daily precipitation measured from 1979 to 2011 by Danshui and Anbu Weather Station of Central Weather Bureau, the plant adopts Log Pearson type III analysis method to calculate the probable maximum precipitation with a return period of 10,000 years. The PMP results are 231 mm/h for Danshui area and 358 mm/h Anbu area. If we take the mean of these two results as described in FSAR, the PMP with a return period of 10,000 years is 295 mm/h, which is still smaller than the design maximum precipitation intensity, 297 mm/h.

[Kuosheng NPP](#)

1. The adequacy of design basis tsunami

In addition to the aforementioned NSC's report, TPC contracted Sinotech Engineering Consultants to conduct an investigation on both the oceanic and terrestrial geographic landscapes near the plant with the focus on the faults that may induce tsunami. Sinotech simulated and analyzed tsunami run-up height with fine grids in accordance with U.S.NRC (2009) "Tsunami Hazard Assessment at Nuclear Power Plant Site in the United State of America " and JSCE (2002) "Tsunami Assessment Method for Nuclear Power Plant in Japan. " Sinotech's study shows that the maximum tsunami height is 4.4 m. [However, there are still significant uncertainties in tsunami run-up predictions due to the definition of tsunami sources.](#) Both the results from NSC and Sinotech are smaller than the design basis used in FSAR. Because all the elevation of the important buildings and equipment is higher than 12 meters, they will [build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.](#)

2. The adequacy of design basis flood

By analyzing the daily probable maximum precipitation data measured at Keelung weather stations near the plant over the past 30 years, the plant estimates that the maximum daily precipitation at the site is 123 mm/h. Using Log Pearson type III method, the calculated value 208 mm/h is used for the PMP with a return period of 10,000 years, which is still smaller than the design basis PMP of the plant, 241 mm/h. Therefore, the design basis PMP for the plant is appropriate.

[Maanshan NPP](#)

1. The adequacy of design basis tsunami

The potential tsunami run-up height at Maanshan Power Plant is 12.5m in the FSAR of the plant. [However, there are still significant uncertainties in tsunami run-up predictions](#)

due to the definition of tsunami sources. They will build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.

2. The adequacy of design basis flood

Using the totally 32 historic records of the maximum daily precipitation measured in the past 30 years by Hengchun Weather Station of Central Weather Bureau, the plant re-calculated the maximum precipitation of storms with a return period of 100 years and 10,000 years respectively. The results are 169 mm/h for 100-yearly storm and 303 mm/h for 10,000-yearly storm. Both of these two figures are smaller than the design basis PMP, 325 mm/h, which is the maximum capacity of the trenches A and B in the plant. According to the analysis, the drainage trenches of the power plant can still sustain extremely heavy rainfall resulting from climate changes, so there is no concern of external flooding of the plant.

Lungmen NPP

1. Adequacy of design basis tsunami

The potential tsunami run-up height at Lungmen NPP is 8.1m in the FSAR of the plant. However, there are still significant uncertainties in tsunami run-up predictions due to the definition of tsunami sources. They will build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.

2. Adequacy of design basis flood

Even though the annual maximum precipitation data in recent years shows a slightly increasing trend, the maximum annual precipitation data in the last 40 years (happened on Sept. 23, 1980) is 107mm/h, which is still far lower than the design basis flood of the plant (PMP 310mm/h). Therefore, the design of the drainage capability for Lungmen NPP is adequate.

3.1.2 Provisions to protect the plants against the DBF

3.1.2.1 Key SSCs required to achieve safe shutdown state after flooding

Chinshan NPP

1. Main facilities of Chinshan Power Plant can be divided into two categories: nuclear safety related facilities (Safety Related) and not nuclear safety related facilities (Non-Safety Related). All nuclear safety related facilities comply with category 1 structure, including a combined structure building, cooling water storage tank (CST), the fifth diesel generator building, the building in which the emergency seawater pump room is located, the 850,000-gallon oil tank and the gaseous waste chimney. Non-safety related facilities and the rest of facilities do not comply with category 1 structure, such as gas turbine building, circulating cooling water pump building, gaseous waste building, dikes, and etc. All nuclear safety related facilities must be operable when the design tsunami attacks. In regard to non-safety related facilities, the safety of the nuclear plant would not be threatened if they are damaged by tsunami. The plant has reviewed the structures, systems, and components (SSC) needed for maintaining safe shutdown state in the event of design basis flooding. The conclusions are as follows:

- (1) The geographic landscape of Chinshan Power Plant descends from south to north. The ground elevation of important buildings/facilities, except normal intake pump house, is higher than 11 meters. Hence, when design basis tsunami hit, the important buildings/facilities (consisting of unit 1 and unit 2 gas turbine building, a combined structure building, emergency drainage pump rooms, the 5th emergency diesel

generator building, and etc.) can meet the requirement of the current design basis. Tsunami can be a threat to normal intake pump house, the building in which the pump house is located and its related equipment are non-safety related. Therefore, their failure will not affect the safe shutdown of units. In addition, with the assistance of Sinotech Engineering Consultant Company, the plant has confirmed that the flood gates, emergency drainage pump rooms and underground intake trenches would not be damaged by design basis tsunami.

- (2) The elevation of important water storage tanks and oil tanks are examined. The elevations of all storage tanks are higher than tsunami run-up height except the DST. The DST is located on the second floor underground (EL. -0.25 meters) in the combined structure building. Since the combined structure building is excluded from the threat of the design basis tsunami, so is the DST. Meanwhile, the ground elevation of CST is 11.2 m and CST is enclosed by 3.2 m height walls with ground elevation higher than 11 m, so the CST is adequately protected against the design basis tsunami.
 - (3) As described in Section 3.1.1.2, the designed drainage capability of the site is capable of draining heavy rainfall. Equipment in the ChienHwa area will not be affected by heavy rainfall. The most serious heavy rainfall at the site happened during the period of October 30 to November 1, 2000 when Xiangsane Typhoon invaded Northern area of Taiwan. The maximum hourly precipitation observed was 116 mm/h, and the precipitation level reached super heavy rainfall criteria. But, during that period, the drainage trenches did not overflow and buildings were not flooded.
2. After Fukushima Accident, Chinshan Power Plant immediately followed WANO SOER 2011-2 Recommendation 3 “Verify the capability to mitigate internal & external flooding events required by station design” to review flooding preventive measures and to conduct walkdown of related equipment/facilities. The result of the walkdown shows no abnormality and it is concluded that the original design provides adequate protection against the design basis flood.

Kuosheng NPP

1. The ground elevation of the station is 12 meters, which is higher than all potential height of tsunami mentioned above. [They promised to build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.](#)
2. As stated in FSAR, the site, except main buildings, has the design of trenches A and B to protect the power plant against flooding resulting from storms. The plant has re-examined the precipitation of the recent years and finds that no precipitation exceeds the PMP design basis. Therefore, the drainage system is still capable of dealing with flooding caused by storms and all facilities on-site will not be affected by the flooding.
3. In addition, after the Fukushima accident, the power plant immediately followed WANO SOER 2011-2 Recommendation 3 “Verify the capability to mitigate internal & external flooding events required by station design” to conduct walkdown to verify the adequacy of equipment and material needed to mitigate external and internal flooding. The verified items contain:
 - (1) Filling of the penetrators on floor levels above and under the ground in buildings.
 - (2) Sump pumps and water-proof doors in emergency equipment areas in auxiliary building.
 - (3) Fire-proof doors, emergency exits, and roller shutter doors of buildings that are direct accesses to the outside of the buildings.
 - (4) Building drainage capability and spare drainage equipment for flooding.

(5) Building drainage accesses.

This result showed that there is no deviated situation, and the facilities dealing with design basis flooding function as the way they were intended by design.

Maanshan NPP

1. In order to confirm that the important SSC required for safe shutdown can operate after flooding, the plant needs to verify that it has enough protection on the SSC against design basis tsunami and the probable maximum precipitation (PMP). The important SSC, except that the nuclear service cooling water system is outside of the pump rooms (the elevation of entrances/exits is 12.6 m.), are all in the building area of the plant at an elevation of 15 m, which is larger than the height of the design basis tsunami 12.5 m.
2. After the Fukushima accident, the power plant immediately followed WANO SOER 2011-2 Recommendation 3 “Verify the capability to mitigate internal & external flooding events required by station design” to conduct a walkdown to verify the adequacy of equipment and material needed to mitigate external and internal flooding. The walkdown consists of:
 - (1) Seal of the penetrators on and under the ground floor of buildings.
 - (2) The sump drainage pumps and water-proof doors in the area of buildings for emergency equipment.
 - (3) Fire-proof doors, doors at emergency exits, and roller shutter doors that connect to outside of buildings.
 - (4) On-site drainage routes.

The result of the inspection shows no abnormality and it is concluded that the original design provides adequate protection against the design basis flood.

Lungmen NPP

1. The ground elevation of the power block area is 12 meters, which is higher than all probable tsunami heights described previously, including the elevation of the design basis tsunami triggered by an undersea volcano estimated by the FSAR for Lungmen NPP. They promised to build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.
2. As the description in FSAR 2.4.2.2, areas in the plant, except power block area, utilize drainage channels Nos. II and III to prevent flooding caused by very heavy rain. Moreover, the plant reexamines the record of the precipitation in recent years and does not see any PMP that exceeds the design basis flood for the plant. Thus, the design of the drainage capability of the plant still has enough margins to deal with flooding caused by very heavy rain, and all onsite facilities would not be affected by flooding caused by storms.
3. After the Fukushima accident, Lungmen NPP immediately followed the Recommendation 3 in WANO SOER 2011-2 “Verify the capability to mitigate internal and external flooding events required by station design” to verify the adequacy of equipment and materials needed to mitigate external and internal flooding by walkdown inspection. According to FSAR 3.4, the protection against flooding for the safety related SSC can be divided into two types based on the origin of internal flooding: one is the flooding resulting from water outside of buildings and the other is flooding caused by leaking from damaged equipment in buildings:
 - (1) Main preventive measures against internal flooding resulting from water outside of buildings have been investigated. In general, structures of safety related systems as well as their components, and the water stops that offers water-proof function to

penetration holes are all 30 cm higher than ground floor. The design also considers possible rupture of storage tanks, so all entrances/exits of plant buildings are 30 cm higher than ground floor. Also, water originating from rupture of onsite storage tanks would be drained before it could enter any buildings to cause damage to equipment inside.

- (2) Preventive measures against internal flooding caused by leaking from damaged equipment in buildings are elaborated for reactor building, control building, radwaste building, access control building, reactor building service water pump house, turbine buildings and auxiliary fuel building.

Presently Lungmen NPP is under construction. After commissioning, all the flooding prevention equipment mentioned above will also be included in periodical testing and maintenance following quality control system and will be managed by MMCS.

3.1.2.2 Protection of the site against flooding

Chinshan NPP

1. The elevation of the coastal road in north of the plant is higher than 11 m, which can serve as a tsunami barrier of Chinshan Power Plant.
2. Man-made drainage trenches at ChienHwa Stream have flood gates to block tsunami and the elevation of all main buildings is higher than 11 m, so there is no concern of flooding.
3. Before Chinshan Power Plant was constructed, the site was prepared and filled with soil according to geographic landscape of area (descends from south to north). According to the record, the elevation of reactor building was 12 m higher than the estuary of ChienHwa Stream. The recently re-measured result by Sinotech Consultant Company is still higher than 11 m.
4. Drainage pipes/trenches in ChienHwa area are capable of handling the design basis PMP, and are thus capable of protecting the important buildings from being flooded.
5. Although the 1.5 km upstream of ChienHwa Stream (near its origin) has a medium level of mudslide potential, there is no record of occurrence of mudslide in the recent years. Chinshan Power Plant has modified procedure 104.37 "ChienHwa Stream mudslide monitoring procedure" to include ChienHwa Stream and Xiaoken Stream as the target of mud/rock slide monitoring.

Kuosheng NPP

1. Main buildings are situated on an elevation of 12 meters. This can prevent the plant from the impact of tsunami and rule out their direct influence on the safety systems.
2. Dealing with potential maximum storms, the plant rerouted and built drainage trenches to drain PMP and protect buildings against flooding.
3. Spent fuel building site is located at the elevation of 12 m which is higher than the possible flooding height induced by tsunami. Besides, the plant has planned to install flood barrier plate at the openings of buildings to enhance the capability of protection against storms due to extreme climate changes.
4. To prevent flooding from entering buildings, the plant has planned to install flood barrier plates or insert rubber packing at doors of all main equipment buildings. Besides, there are drainage system and sump installed in buildings. The capacity of the sump pump is 50 gpm, it is sufficient to discharge water that abnormally enters the building.

Maanshan NPP

The consideration about the protective design against the DBF of the plant can be divided into two parts: inside of buildings and outside of buildings (namely the building area), the detailed description is provided below:

1. Inside of buildings:

- (1) All penetrations on exterior walls and the penetrations underground are designed to be water-proof and sealed.
- (2) Base and walls of buildings that are underground are installed with water-proof synthetic rubber tapes at expansion joints and structure gaps.
- (3) Install door thresholds or watertight doors at emergency equipment rooms to prevent water from entering or flowing out of these rooms.
- (4) Accumulated water on all floors is gathered by drainage holes on the floor and delivered to the sumps of the buildings. Then, the water is extracted to liquid waste treatment systems via sump drainage pumps for treatment and drainage toward outside of buildings.

2. Outside of buildings (the building area):

- (1) The elevation of entrance and exit of the NSCW pump room is 12.6 m, which is higher than the potential maximum tsunami run-up height. This is to keep the NSCW pumps from flooding.
- (2) The first floor elevation of on-site buildings is 15 m. All doors or openings are at least 6 inches above the ground to prevent accumulated flooding from entering buildings. The ground elevation outside of building is 14.85 m above sea level.
- (3) The outside of buildings has a ground drainage system that is capable of dealing with probable maximum precipitation(PMP) intensity, and its ground surface has enough slopes to ensure no water accumulation. Drainage trenches outside of buildings has drainage capacity of 20 cms (325 mm/h), which is bigger than the volume flow rate of 14 cms resulting from the probable maximum precipitation intensity, 228 mm/h.
- (4) In the east, north, and west of the building area, there are high lands to isolate the area. It is also equipped with independent drainage system to prevent the surface flow in these regions to enter the building area.
- (5) Under the security fence on the south side of the building area, there are 6 emergency drainage outlets, 70 cm (height) ×235 cm (width), whose bottom elevation is 14 m. Their drainage capability is 20 cms, similar to the total drainage capability of the drainage systems in the east and west sides of the area. This can further ensure that there is no concern of external flooding.

Lungmen NPP

1. The elevation of main buildings in the plant is 12.3 meters, which is based on the total of the probable maximum tsunami run-up height and some reasonable margins.
2. In response to probable maximum storms, the plant builds drainage channels based on hydrologic analyses and reroutes streams in the aspect of design, in order to solve run-off in the plant and further to protect buildings from flooding.
3. Lungmen NPP is within the watersheds of Shiding Stream and Shuangxi Stream. Both streams are not mudslide-prone according to the record of Soil and Water Conservation Bureau (SWCB), Council of Agriculture. All excavations and developments in the plant

are examined and approved by SWCB. The landscape of Lungmen NPP area is relatively flat. Water and soil conservation work is done in areas that have been excavated and developed, so there should be no concern of mudslides.

3.1.2.3 Main operating provisions for flooding warning and consequence mitigation

Chinshan NPP

Normally when the plant is operating, emergency equipment areas have floor sump drainage pumps, and the operators in control room will monitor the sump water level all the time. When water level is abnormal, the plant automatically starts sump drainage pumps. However, in order to enhance disaster prevention and mitigate consequence, Chinshan Power Plant has established disaster prevention and mitigation procedure regarding opening/closing of tsunami gates. These procedures contain disaster prevention and mitigation preparation, which include mobile flooding mitigation equipment, such as drainage pumps, sump pumps, emergency generators, etc. The flooding related procedures are as follows:

Item	Name	procedure
1	Typhoon prevention and response procedure	104.22
2	ChienHwa Stream mudslide monitoring procedure	104.37
3	Procedure for operation during typhoon alert period	513
4	Procedure for operation during tsunami alerts	514
5	External flooding emergency response procedure	515
6	Internal flooding response procedure	515.2

Kuosheng NPP

Underground sump tanks and drainage pumps are installed around main buildings. When there is abnormal inflow of water, signals will appear on OC99 panel in the control room, and the operators will notify shift workers to solve the situation following the procedure 577 “Emergency operating procedure for heavy rain or flooding.” Besides, all buildings and emergency equipment areas have floor sumps and drainage pumps, and the operators can monitor water level from control rooms or waste control rooms any time when there is abnormal inflow of water. After the Fukushima accident, the plant reviewed drainage operating procedures for flooding outside and inside of buildings. In the end, the plant has established handling procedure for flooding in buildings, emergency operating procedure for on-site flooding, typhoon-period operating procedure and other guideline regarding accident prevention and mitigation. Relevant procedures are as follows:

Item	Name	procedure
1	Emergency operating procedure for heavy rain or flooding	577
2	Emergency drainage operating procedure for buildings	577.1
3	Tsunami emergency response procedure	577.2

Maanshan NPP

Sumps and water level detection instruments are installed in the lower areas inside the important buildings and ESF equipment rooms, and water level warning panels are installed in the control rooms. When there are high water level warnings, operators follow the

corresponding procedure to assign workers to conduct walkdown to find out the cause and take corrective measures to solve the problems. In addition, if operators discover abnormal intake or other abnormal situations at these sumps, procedure 583 “Emergency flooding procedure” will be followed to solve these abnormal situations.

Lungmen NPP

The plant has established procedure for flooding in buildings, emergency operating procedure for onsite flooding, typhoon-period operating procedure and other guidelines regarding accident prevention and mitigation. Relevant procedures are as follows:

Item	Name	procedure
1	Water accumulation/ flooding prevention and response during typhoons or very heavy rain	187.01
2	Flooding response	528.03.01
3	Flooding response	528.03.02
4	Inspection for abnormal water entry and leaking at sumps of buildings	233

After the Fukushima accident, the plant reviewed and revised the drainage relating procedures to increase its capability to respond to flooding. A new procedure 528.03.03 “Emergency drainage operation during power outage and abnormal water entry in buildings” has been added. The plant also plans about adopting mobile generators to provide temporary power source to sump pumps or mobile gasoline-driven drainage pumps during external flooding and a station blackout.

3.1.3 Plants compliance with its current licensing basis (CLB)

3.1.3.1 General organization of the licensee to ensure compliance with design basis

Chinshan NPP

1. Every year between June and September, the plant conducts routine and post-natural disaster walkdown of all on-site drainage trenches complying with procedure 104.22 “Typhoons disaster prevention and response procedure” and 795.12 “On-site structure monitoring and walkdown inspection operating procedure.” The plant has completed walkdown inspection of all on-site drainage trenches on March 15, 2011. Moreover, the plant has annual maintenance contracts to have these trenches cleaned.
2. The plant follows procedure 792.1 “Test operating procedure for closing and opening flood gates” to ensure the reliability of flood gates during tsunami and to provide detailed steps for the test operation of closing and opening flood gates.
3. Inspection of penetrations needs to follow two procedures: one is procedure 791.1 “Penetrator periodical inspection procedure” with inspection period of 18 months; the other is procedure 791.2 “Inspection procedure for the seal completeness of the perforated pipes and reserved holes at outer walls of buildings” with inspection period of 18 months.
4. The plant follows procedure 104.37 to monitor mudslides situation induced by ChienHwa Stream and Xiaoken Stream.

Kuosheng NPP

In response to natural disasters, such as tsunamis, storms, mudslides, etc., the operator should follow the operating procedures mentioned in Section 3.1.2.3. In addition, when natural

disasters are expected to arrive, the plant has set up the following disaster prevention and mitigation procedures for both normal operation period and special period:

1. Procedure 576 “Operation after typhoon warnings is issued.”
2. Procedure 576.1 “Typhoon emergency response procedure for Kuosheng Power Plant.”
3. Procedure 577.3 “Monitoring, warning, disaster prevention and mitigation procedure for active faults near the plant, precipitation, mudslide, and dip slopes.”

Maanshan NPP

1. Periodically inspect, maintain, and test safety related systems and structures under the guidance of procedure 600 and 700 series to ensure licensing basis.
2. In regard to protection against external flooding for buildings area, the plant enhances the water tightness of penetrations on exterior walls of buildings and maintains the normal functions of necessary openings of building, such as doors/windows.
3. To protect the building area against external flooding, the plant has drainage pipes/trenches in and around the building area.
4. To enhance the protection for the plant from internal flooding, there are sealing drainage holes on building floors, watertight doors (shift periodically conduct walkdown) at ESF pump rooms, and seal of penetrations on walls. In addition, buildings are equipped with sumps, sump pumps, and related pipe valves to conduct the drainage of inside of the buildings.
5. After flooding events or tsunami, the plant abides by the following procedures to conduct inspections and tests:

- (1) Procedure 582.2 “Tsunami emergency response procedure.”
- (2) When there are internal flooding warnings, procedure 583 “Emergency flooding procedure” should be followed. During the process, if there is a need to trip the reactor and/or when the safety injection automatically starts, comply with EOP 570.00. If the plant loses all AC power sources, abide by procedure 570.20.
- (3) Adhere to procedure 700-A-001 “On-site and offsite structure inspection procedure” to inspect structures, including the status of trenches and the structures of drainage pipes, and to examine the retaining structures around the plant to prevent occurrence of mudslides. This procedure requires periodical inspections of structures, including that of the drainage systems. The inspection should be done every year in June (before the flooding season), before and after typhoons, and after earthquakes with magnitude 4 and above.

Lungmen NPP

In response to natural disasters, such as tsunami, storms, mudslides, etc., the operator should follow the operating procedures mentioned in Section 3.1.2.3. In addition, the plant has set up the following disaster prevention and mitigation procedures for both normal operation period and special period when natural disasters are expected to affect the plant:

Item	Name	procedure
1	Operation during typhoons	187
2	Reactor operation during typhoon warning period	528.02.01
3	Operation during tsunami warning period	528.04

3.1.3.2 Use of mobile equipment and supplies

[Chinshan NPP](#)

According to current licensing basis, on-site flooding is not allowed when design basis tsunami happens, and the structure, systems, and components (SSC, including reactors and spent fuel pools) required to shutdown reactor would not be damaged and are capable of bring units to safe shutdown status.

After the lesson learned from Fukushima accident, Chinshan Power Plant has considered all category of equipment needed to respond to combined natural disasters and has procured one large 4.16kV/1500kW mobile container power vehicles, 12 medium size of 480V/500kW and 480V/200kW diesel generators, several portable gasoline/diesel generators, air compressors, internal combustion engine drainage pumps, and other mitigation equipment or spare parts. All the equipment is placed at safe elevation to protect the equipment from the influence of typhoons, floods, or tsunami and is placed at locations convenient for retrieving and use. Procedures are also added or revised concerning the preparation and management of the equipment.

Under emergency condition, Kuosheng Power Plant and Lungmen Power Plant will support and supply mobile mitigating equipment when needed.

[Kuosheng NPP](#)

The plant already has mobile equipment such as cranes, pumps, generators, and sand bags. After the Fukushima Accident, the plant has conducted a comprehensive review based on the direction of the Atomic Energy Council and has further expanded its mobile equipment similar to Chinshan NPP for mitigating any potential accidents.

Under emergency condition, Chinshan Power Plant and Lungmen Power Plant could share mobile mitigating equipment when needed.

[Maanshan NPP](#)

The plant has been equipped with similar mobile equipment such as mobile diesel generators, diesel/gasoline engine drainage pumps, etc. Guided by procedure 192 “Maintenance and management procedure for disaster mitigation equipment,” the equipment will be inspected, tested and maintained every week or every month.

[Lungmen NPP](#)

The designed drainage capability of the plant is adequate. However, mobile equipment for disaster mitigation has been procured following the procedure 186.01 “Important guidelines for disaster prevention and mitigation.” After the Fukushima Accident, the plant has further planned and expanded its mobile equipment for mitigating the effects of accidents.

3.1.3.3 Deviations from CLB and remedial actions in progress

[Chinshan NPP](#)

Even though the recently measured building ground elevation at Chinshan Power Plant is 80 cm lower than the original designed elevation (12 m), it is still higher than the maximum tsunami run-up height (10.7 m) and the plant still has enough flooding prevention and drainage capability.

[Kuosheng NPP](#)

After the Fukushima Accident, the power plant has reviewed all building structure. The only deviation is that the elevation of the floor on which the emergency circulating water pump motor is mounted at 6.72 meters. Therefore, if tsunami run-up height is over 6.72 meters, seawater may enter emergency circulating water pump chambers through emergency circulating water intake trenches and lead to the damage of panel casings of the emergency circulating water pumps chambers. To ease this concern, the power plant has completed an improvement program, which is to install water-proof walls for emergency circulating water pump (ECW) chambers, to add watertight doors right outside of the fire-proof doors at two current entrances/exits of the ECW equipment areas, and to set up 6 removable water-proof stainless steel walls between drainage pumps and traveling screen. Once the top of the water-proof walls reaches ceiling and all related penetrations are fully sealed, the main equipment as well as its surrounding area become a water-proof region. All these efforts in the program are to prevent seawater from entering ECW pump rooms, make the elevation of the whole tsunami prevention to be 12 meters, and maintain the operation of ECW pumps.

[Maanshan NPP](#)

The plant presently does not have any deviation situation. If any of them occurs, the plant will conduct safety evaluation and take corrective measures using related procedures.

[Lungmen NPP](#)

According to the “Lungmen NPP Tsunami Prevention Capability Review Report”, the plant is considered to have enough capability to sustain the design basis tsunami. However, some minor deviations are outlined as follows:

- Small leakage has been found on the penetration holes on the underground exterior walls of control building. Corrective action has been taken.
- The plant needs to confirm that the sealing material for openings of the RBSW pump houses can sustain the water pressure caused by tsunamis.
- When tsunami run-up height reaches at elevation of 8.6 meters, the exterior walls of RBSW pump houses will sustain additional water pressure (approximately 3.3 meters high) as well as impact force. The integrity of the RBSW pump house structure needs to be strengthened according to the speed of tsunamis.

3.1.3.4 Specific compliance check already initiated by the licensee

[Chinshan NPP](#)

Based on the lessons learned, Chinshan Power Plant has conducted related reviews and has made improvements as below:

Item	Name	Program
1	To respond to sudden seizure of tsunami, install automatic closing and opening functions of flood gates	DCR-C0-3307
2	Implement fixed bar at the opening of ESW intake structure to prevent large debris brought by tsunami to enter the trench	DCR-C0-308
3	Install floating valves at the opening for the ESW wash pumps on the second floor underground, which can help release accumulated water on the floor and protect against tsunami	DCR-C0-3283

4	Install flood barrier facilities at the entrances/ exits of buildings for reactors, 5th EDG, and ESW pump rooms	MMR-C0-0407
5	Install supporting walls for the seal of perforated pipes at the valve pits of ESW pump rooms on the first and second floors underground, as well as penetration of pipes of ESW pump and wash pumps	MMR-C0-0416

Furthermore, TPC has finished an investigation on the oceanic and terrestrial geographic landscapes near the power plant and reviewed the design basis tsunami (as stated in FSAR) to guarantee the safety of facilities. Based on the investigation result, the plant updates the elevation information in the Final Safety Analysis Report of Chinshan Power Plant.

Kuosheng NPP

1. Based on the PMP measured at Keelung weather stations of Central Weather Bureau over past 30 years, the plant estimates that the hourly maximum precipitation and PMP are 123 mm/h and 208 mm/h respectively and decides that the design basis of the plant is appropriate. However, extreme weather may bring precipitation that is beyond the design basis, so the power plant will install 63 flood barrier plates at the openings of important equipment buildings, making the elevation of the original flooding prevention structure to be 1 meter higher. As a result, the ability to fight against extreme weather is enhanced.
2. In view of the Fukushima Accident, to prevent loss of ultimate heat sink caused by earthquake-induced tsunami, the plant will continue the following improvement programs to ensure, in case of accidents, there are enough cooling water sources to feed water into the cores or to cool the units for a long term:

Item	Name	Program
1	Make raw water pipes above-ground	DCR-K0-3886
2	Increase the flexibility of particular sections of raw water pipes	DCR-K0-4057
3	Install standby feed water pipes for the RHR system	DCR-K1-4074/K 2-4075
4	Install shut-off valves and quick connectors at ECW trenches	DCR-K1-4043/K 2-4044
5	Install flood barrier gates for A/B trenches	MMR-K0-257
6	Install water pipes from Linhai Bridge to the plant gate	MMR-K0-259

Maanshan NPP

The improvement programs which the plant has established and are undertaking are listed in the following table.

Item	Name	Program
1	Install watertight doors to work with PA and improve lighting in the NSCW building	DCR-M0-4275
2	Install watertight doors to work with ventilation improvement in the NSCW building	DCR-M0-4276
3	Install watertight doors to work with fire-fighting improvement in the NSCW building	DCR-M0-4277

4	Install watertight doors and water-proof walls in all pump rooms of the NSCW building	DCR-M0-4285
5	The steel screen on drainage holes at the security fences on the north side of the protection area of the plant is modified to be able to be opened from outside	MMR- M0-0672
6	Install debris-proof covers at NSCW	MMR-M0-0683
7	Install simple flood barrier panels at waste treatment building /exterior openings of the new waste warehouse	MMR-M0-0732
8	Install simple flood barrier panels at fuel building /exterior openings of auxiliary building	MMR-M1-0733/ MMR-M2-0734
9	Install simple flood barrier panels plates at the exterior openings of the EGD/EDG-5 building	MMR-M1-0735/ MMR-M2-0736
10	Install simple flood barrier panels at control building /at exterior openings leading to control building.	MMR-M1-0737/ MMR-M2-0738
11	Install simple flood barrier panels at the NSCW building /exterior openings at the CST valve room.	MMR-M1-0739/ MMR-M2-0740

Lungmen NPP

1. According to the evaluation result of a simulation of probable maximum tsunami, the elevation of main buildings is not affected by tsunami. Nevertheless, to increase defense in depth to prevent external flooding resulting from storms as a result of extreme climate from entering buildings, the plant has conducted enhancement measures as follows:
 - (1) Adding water-tight doors to prevent flooding from flowing into rooms at elevation of 4,800mm in reactor building.
 - (2) Install flood barrier plates of 1 meter high at the following places:
 - the doors on ground floors directly connecting to the outside of buildings (reactor building, control building, diesel fuel tanks, auxiliary fuel building, fire-fighting pump houses, and RBSW pump houses);
 - the tunnel where the radwaste building enters auxiliary fuel building;
 - the tunnel where the radwaste building enters reactor/control building;
 - the passage where access control building at elevation of 12.3.m enters reactor buildings.
2. As planned in program RAP-LM-01-12-001, the plant will add a gas turbine generator of total capacity of 120MW inside of a seismic isolated building at the switchyard at elevation of 29.8 meters, so they can provide power to two reactors during station blackout. Besides, in order to increase the reliability of transmitting power to reactor safety systems from gas turbine generators during station blackout even in a beyond SSE condition, the plant plans to add 4.16kV independent transmission lines from each gas turbine generator at the switchyard to 4.16kV safety bus.
3. The plant has also concluded that the drainage capability inside buildings (including reactor building, control building and auxiliary fuel building) is enough. However, in addition to the existing sump pumps, each building has mobile drainage pumps for temporary drainage to speed up the recovery of the functions of the equipment on the ground floor of each building.

3.2 Evaluation of Safety margins

3.2.1 Envisaged additional protective measures based on the warning lead time

Chinshan NPP

1. In order to fight for more advance tsunami warning time, TPC has established a network connecting the earthquake and tsunami warning system of Central Weather Bureau and that of other power plants in Taiwan. Warning and maintenance mechanism has also been implemented.
2. Normally flood gates should stay at the fully closed position to protect against tsunami, so there is no need to consider tsunami warning lead time. During tsunami lead time, the plant should follow procedure 515 “On-site flooding emergency operating procedure” and increase manpower when necessary. Follow the plan to pile sandbags at ground floor entrances/exits of all important building to prevent tsunami from affecting or entering all buildings.
3. In case of heavy rain or typhoons, there is time between the issue of warnings and the occurrence of flooding. During this time period, Chinshan Power Plant should continue monitoring the outlet water level at ChienHwa Stream. When the water level reaches 1.0 m, open the flood gates closer to the ocean. When the water level reaches 2.0 m, open the flood gates closer to the plant to prevent on-site flooding.
4. If Central Weather Bureau forecasts that the precipitation figure is 500 mm/day, warnings for mudslide-prone streams will be issued. Then, the operator will follow procedures 104.37 and 106.9.4 to check whether there are abnormal situations, such as ground surface change, ground slope change, and mudslide, and to evaluate possible negative factors that influence the safe operation of the plant.
5. Install and enhance flood barrier facilities at entrances/exits of important buildings.

Kuosheng NPP

1. Tsunami warning time and additional protection measures
In order to fight for more advance tsunami warning time, TPC has established a network connecting the earthquake and tsunami warning system of Central Weather Bureau and that of other power plants in Taiwan. Warning and maintenance mechanism has also been implemented.
2. The way of warning and monitoring of heavy rain or flooding as well as the appropriate response are stated in the procedures cited in Section 3.1.2.3 and 3.1.3.1.

Maanshan NPP

When the plant discovers signs of tsunami or receives tsunami warnings from Central Weather Bureau, it complies with procedure 582.2 “Tsunami emergency response procedure” and considers the amount of warning lead time to prepare in advance. The description is as below:

1. Signs of tsunami after review:
The shift manager notifies pump room workers to inspect all doors designed to protect pumps against tsunami, watertight doors, manhole covers (EL 6'-6), and fine grid covers at the NSCW pump room. All these facilities need to stay closed and locked tightly.
2. On receipt of tsunami warnings from Central Weather Bureau:

When Central Weather Bureau issues tsunami warnings and forecasts that tsunami may affect the plant, the plant uses procedure 1401 “Event category judgment procedure” to judge whether the plant should enter the abnormal warning event category HU1(natural disasters have damaged the protection area of the plant.) If Central Weather Bureau has already forecasted that tsunami is beyond design basis, the plant also needs to follow procedure 1451 “Ultimate response guideline” together with procedure 1401 simultaneously. On receiving the notification, the Assistant Superintendent for Operation should order all technology related Divisions, supply Divisions, and the civil service Division managers to establish the tsunami emergency response team.

Lungmen NPP

1. Tsunami warning lead time and additional protection measures

In order to have enough tsunami lead time, TPC is planning on establishing a network connecting the earthquake and tsunami warning system of the Central Weather Bureau. Besides, the plant has included all protection measures for prevention, response, and enhancement in the procedure 528.04 “Operation during tsunami warning period”. When tsunamis affect the plant area, the plant will comply with the TPC Emergency Response Plan, the 1400 series procedure, based on the level of influence.

2. Warning systems regarding very heavy rain or flooding are implemented and will be operated following the procedures described in Sec.3.1.2.3.

3.2.2 Weak points and cliff edge effects

Chinshan NPP

Using the analysis methodology of nuclear plants in Japan as reference, TPC adopts event tree to find cliff edges and safety margin. According to the result of the tsunami case in “Stress Test Evaluation and Event Tree Analysis for Chinshan Power Plant” analysis, there is only one successful situation of reactor cold shutdown. The sequence is: tsunami causes LOUH (loss of sea water ultimate heat sink), reactor trip succeeds, high-pressure water makeup for the core succeeds, reactor depressurizing succeeds, diesel generators in buildings succeed, BCSS water injection succeeds.

Because there is only a success route, it is the cliff edge of tsunami. Its safety margin needs to adopt the smallest one, namely 0.6 m; its cliff edge also needs to be the smallest figure, namely 12.1 m.

Kuosheng NPP

According to the “Stress Test and Evaluation Event Tree Analysis for Kuosheng Power Plant”, there is only one successful situation of reactor cold shutdown regarding the tsunami case. The sequence is: the reactor trip succeeds after the tsunami causes LOUH, long-term high-pressure water makeup for the reactor fails but long-term alternative water makeup for the reactor succeeds, containment ventilation succeeds.

Because there is only a success route, it is the cliff edge of tsunami. Its safety margin needs to adopt the smallest one, namely 0.3 m; its cliff edge also needs to be the smallest figure, namely 12.3 m.

Maanshan NPP

According to the analysis result of the PRA event tree, the conclusion of the Maanshan Power Plant tsunami evaluation is that there is only one successful situation of reactor cold shutdown,

which is: tsunami causes loss of ultimate heat → reactors trip → remove heat with turbine-driven auxiliary feedwater pumps controlled by DC → due to loss of heat-removing capability, TDAFWP, MDAFWP, CCWN could not operate for a long term → SG standby makeup (diesel engine fire-fighting pumps) succeeds → cooling succeeds.

Because there is only a success route, it is the cliff edge of tsunami. Its safety margin needs to adopt the smallest one, namely 5.8 m; its cliff edge also needs to be the smallest figure, namely 15.0 m.

Lungmen NPP

TPC uses the event tree method to look for Cliff Edge and safety margin. “Lungmen NPP Seismic Case Study” considers the situation that earthquake-triggered tsunami seizes the shore near the plant and causes the plant to lose ultimate heat sink. The analysis result shows that the successful path of reactor core shutdown cooling is: after the tsunami causes loss of ultimate heat sink, RCIC system starts its short-term water feeding function, which gives operators the time needed to manually start SRV and set up ACIWA system. Thereafter, ACIWA system provides long-term water feeding to reactors and COPS offers containments long-term heat removal, so reactors can reach cold shutdown mode.

Because there is only one successful path of reactor core shutdown cooling, it is the cliff edge of the seismic case. The safety margin of each issue should take the minimum value, namely 0.3 meters, which is acquired through deducting 12 meters from 12.3 meters. The cliff-edge as defined should also take the minimum vibratory intensity value, which is 12.3 meters.

3.2.3 Envisaged measures to increase robustness of the plant

After the Fukushima Accident, TPC immediately established a tsunami evaluation team for all the plants to conduct an investigation on the oceanic and terrestrial geographic landscape near the power plant. TPC also reviewed the design basis tsunami and the safety of plant facilities in the Final Safety Analysis Report (FSAR) for all the plants.

Chinshan NPP

The plant has completed the following enhancement measures:

1. Based on the results of the investigation and inspection, the elevation of Chinshan Power Plant is 11.2 m, so it is confirmed that important buildings and equipment would not be inundated by tsunami. They promised to build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.
2. Through walkdown and carefully inspection of flood gates, sea water trenches that may be possible run-up routes, water-proof function of buildings penetrations, on-site drainage capability and routes, water-proof function of battery chambers/switchgear rooms as well as diesel generator building, it is concluded that the related facilities installed to resist tsunami have enough capability.
3. Six flood gates are controlled by power and can be closed in 5 min in compliance with procedure.
4. The plant has increased the capability of the emergency seawater system to resist tsunami and has completed the evaluation of the capability of the emergency seawater system to fight against tsunami. It is assured that tsunami run-up water would not cause damage to structure and equipment and the plant has enough cooling function of the emergency seawater system after tsunami attack.
5. The plant has reviewed the protection designs to fight against typhoons, heavy rain, and

on-site flooding. The plant has also examined its drainage systems to ensure their capability to fight against flooding.

6. The plant has procured 8 gasoline/diesel-driven drainage pumps to prepare for the attack of beyond design basis flood and to enhance the maneuverable drainage capability of buildings.
7. The plant has modified procedure 104.37 “ChienHwa Stream mudslide monitoring procedure” and included ChienHwa Stream and Xiaoken Stream as targets of mudslide monitoring.
8. Based on the analysis result of the tsunami event tree, Chinshan Power Plant has planned enhancement measures, which are to review the watertight function of the entrances/exits of all important buildings (containing ESW pump rooms) and to work out the design improvement program MMR-C0-0407 for installing flood barrier facilities in order to enhance flood resistance capability of important buildings.

Kuosheng NPP

The plant has completed the following improvement measures:

1. The plant has re-evaluated its analysis on probable tsunami run-up height, and confirmed that the tsunami run-up height chosen by FSAR is still adequate. They promised to build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.
2. After discovering the vulnerability of the ECW pump chambers, the plant immediately enhanced capability of the watertight doors of ECW pump chambers in order to increase their protection against tsunami. After the completion, the height of the tsunami run-up protection wall at ECW pump chambers is the same as the ground level of main buildings, namely 12 meters.
3. The plant has finished reviewing on-site flooding and on-site drainage function and again examined the historic record of the daily maximum precipitation over the past 30 years to confirm that the drainage trenches can withstand extreme precipitation resulting from extreme weather and there is no concern of flooding.
4. Referring to the environment, geography as well as the historic records of daily maximum precipitation of the site, the plant reviewed its prevention capability against mudslides. Furthermore, the plant has added new procedure to periodically monitor the land development activity near the power plant. The plant has also included the mechanism dealing with mudslide warning, prevention, and mitigation in its procedure using the precipitation information by Central Weather Bureau and the mudslide warning information by Soil and Water Conservation Bureau (SWCB), Council of Agriculture.
5. The plant has drawn maps of both inundation-prone areas inside and outside of buildings in order to plan for drainage methods in advance. These maps of flooding prevention are used to further improve the drainage capability of buildings. The plant has also completed lists of all drainage routes and their capability for both inside and outside of buildings.
6. The plant has reviewed past experiences of flooding caused by typhoons and heavy rain at switchyard battery chambers and the bottom floor of the turbine building. It is confirmed that the operating procedure has required in detail the reliability of related penetrations sealing work. The plant has also finished inspection on the design and integrity of water-tight doors in buildings, barriers, and penetration sealing to ensure everything is satisfactory.

7. To prevent on-site flooding from entering buildings, the plant has planned to install flood protection walls or rubber packing at entrance/exit doors or roller shutter doors of all main equipment buildings.
8. When there is no power supply, the plant will utilize engine-driven pumps to drain waters at flooded areas in buildings. The plant has finished the related standard operating procedure and procured 6 engine-driven, mobile and submersible pumps to increase its drainage capability.

Maanshan NPP

The plant has completed the following improvement measures:

1. The ground elevation of the main building area is 15 m above sea level. The entrance and exit on the roof of the NSCW pump room near the sea is at an elevation of 12.6 m. Both are higher than the potential maximum tsunami run-up height near the plant. Therefore, when earthquake-induced tsunami happens, there is still no concern that the seawater submerges the plant. They promised to build the tsunami wall to cover the uncertainty of the tsunami run-up predictions. However, in order to enhance protection capability, presently the plant finished installing grid covers at the service water intake pool to prevent large debris from entering the intake pool through its top during tsunami. Moreover, the plant completed watertight doors and flood barrier plates in the motor area of the NSCW pump rooms to protect and isolate these NSCW pumps by dividing them based on units and series, such that the plant would not lose NSCW pumps simultaneously. This improvement has changed the original design basis tsunami elevation from the motor elevation of the NSCW pumps, 9.12 m, to the elevation of bottom edge of the ventilation openings on the roof of the NSCW pump room, 12.9 m.
2. Using the historic information and empirical formulae, the plant estimated both the probable maximum precipitation with return periods of 100 years and 10,000 years, the results are 169 mm/h and 303 mm/h respectively. The volume flow rates caused by both PMPs are still smaller than the total drainage capability of the east and west sides of drainage systems, which is 20 cms (equivalent to 325 mm/h of precipitation intensity). In addition, the plant already has emergency drainage holes under the south side of fences in the building area, which give the plant additional 20 cms of drainage capability. Nevertheless, to enhance the capability to fight against flooding, the plant will still install 1 meter high flood barrier plates at the openings of important buildings.
3. To prevent external flooding from entering buildings, the plant has established a simple improvement program to evaluate the feasibility of installing flood protection plates at doors of safety related buildings, so the plant can install these plates in advance after receiving warnings of typhoon and extremely heavy rain from Central Weather Bureau or when the plant judges that external flooding may enter buildings. The plant has also submitted an improvement program to increase water-tightness of critical fire-proof doors or explosion-proof doors at safety related buildings to stop external flooding from entering critical areas/rooms in order to prevent important equipment and facilities from failure. In the future after this improvement program is finished, the plant would not lose important power sources (including DC power source) on bottom floor of important buildings due to flooding. The cliff edge can be increased from the original 15.0 m to the elevation of SG standby makeup, 15.3 m. Meanwhile, after this improvement program is finished, the elevation of the 5th emergency diesel generator will be increased from the original 16 m to the elevation of the ventilation openings of the building, 23 m.
4. In addition to its original 20 drainage pumps, the plant has procured 30 diesel engine drainage pumps to enhance its drainage capability.

5. The plant reviewed SG standby makeup water, and decided to use enhanced fire trucks delivery to be the alternative makeup measures if diesel driven auxiliary feedwater pumps and diesel fire-fighting pumps fail. Thus, the plant has procured a fire truck with water tank to enhance the mobile water supply capability. Because the existing fire trucks of the plant are located in the fire brigade building (EL 24 m), this also enhance the plant's capability to transport fire-fighting water to the SG feedwater system.

Lungmen NPP

The plant has completed the following improvement measures:

1. A new procedure has been completed for the plant protection against very heavy rain or typhoons. In addition, the plant has added maps for flooding prevention for both inside and outside of buildings to further improve the drainage capability of buildings.
2. The plant has re-evaluated the design of water-tight doors and barriers in buildings, to ensure all water-proof mechanism can function normally after the completion of penetration sealing.
3. When there is a concern of flooding, the plant has plans to install flood barrier plates or fill rubber packing at entrance/exit doors or roller shutter doors of all main equipment buildings.
4. The plant has procured 6 engine-driven mobile drainage pumps and 12 electric drainage pumps, which can work with gasoline/diesel generators. In addition, the plant will add 2 maneuverable engine-driven drain sump pumps and 20 electric drainage pumps. The related operating and maintenance procedure has been completed.

3.3 Assessment and conclusions of the regulatory body

The approach adopted by the licensee to reevaluate the flooding risk of the three plants is in conformance with the methodology provided by the licensee and approved by the regulatory body AEC (Atomic Energy Council). AEC basically confirms the information and assessments provided by the licensee, especially the information regarding the licensing basis. In general, the assessments of safety margins are acceptable and the resulting action plan for improvements is adequate.

However, the regulatory body identified additional requires and recommendations to further improve the robustness of the units and the sites against the risk of flooding:

1. Referring to the tsunami analysis result by the state-of-the-art approaches and the new guidelines for tsunami evaluation from major nuclear industrial countries, the licensee should further review the appropriateness of the design basis tsunami and take the associated improvements to its nuclear power plants.
2. The licensee should review the appropriateness of the DBF in FSAR considering the rapid climate changes in the recent years. Associated improvements should be taken to increase the robustness of the plants against flooding. These should be reviewed and approved by the regulatory body through the process of periodic safety assessment every ten years.
3. Regarding the ground level of the buildings of Chinshan Power Plant, the re-measured elevation is already 1 m lower than the original design value (12 m), which might not have enough margins even though it is still larger than the design basis tsunami run-up height (10.7 m). Licensee's action plan of improvements concerning this issue should be envisaged as soon as possible.
4. TPC should follow the first stage recommendations of USNRC NTTF report, especially the Recommendations 2.1 and 2.3 concerning the flooding and/or tsunami.

5. Referring to the experiences of other nuclear countries, it is recommended that TPC should conduct the following improvements to its nuclear power plant:
 - (1) a detailed scenario simulation of seismic and tsunami hazard;
 - (2) building sea walls, reinforced concrete flood barrier plates or watertight facilities to provide better protections against tsunami;
 - (3) Upgrading the watertight capability of doors of buildings containing important safety related equipment, fire-fighting doors as well as pipeline penetrations seals.

4. Extreme natural events

4.1 Extreme weather conditions (storms, heavy rainfalls)

Rainy season in Taiwan is between May and June, and typhoons frequently attack the island between July and October. Statistics data from Central Weather Bureau indicate that typhoon is an important factor of extreme rainfall in Taiwan.

TPC has considered “storms” as the design basis events for its NPPs (Chinshan, Kuosheng, Maanshan, and Lungmen). After Fukushima accident, TPC has conducted thorough examinations of all the NPPs in Taiwan. It is concluded that all protection equipment of the plants meets the requirement of the design basis. Meanwhile, extreme weather conditions such as typhoons, heavy rain, and mudslides can affect the sites of the NPPs in Taiwan. The most serious natural event is the combination of the three weather conditions. In response to the potential impact of the extreme weather, TPC has also considered the combined natural events of “typhoons, heavy rainfalls and mudslides,” and other beyond design basis (BDB) events.

4.1.1 Events and combination of events – reasons for a selection (or not) as a design basis event

Chinshan NPP

Located in Shimen area in New Taipei City, northern Taiwan, Chinshan Power Plant faces East Sea in its north. The plant can be divided into two parts: ChienHwa area in the west of the plant; and Xiaoken area in the east. In between the two parts there are mountain hills stretching from north to south, and ChienHwa Tunnel connects the two parts of the plant. In the east of Xiaoken area is Xiaoken Stream, which flows from south to north through Xiaoken area. As for ChienHwa area, ChienHwa Stream flows through it in its west.

Chinshan Power Plant has two units. Important equipment and buildings, such as the combined structure building, turbine building, the building where the 5th diesel generator is situated, gas turbine building, power switchyard, emergency seawater pump room, etc., are all located in ChienHwa area. Both reactors are in the combined structure building while steam turbine generators sit in the turbine building. The plant elevation is 11.2 m and above. Power Block is 500 meters from the coast. ChienHwa area is in the valley of the downstream of ChienHwa Stream. ChienHwa Stream is 8 km in length and its drainage area is around 9.5 km². While the plant was being built, the section of the downstream of ChienHwa Stream that flew through the plant was turned into man-made drainage trenches after evaluation (hereinafter referred as ChienHwa Stream man-made trenches) to serve as the main drainage trenches of the plant.

The description of the design of the protection capability for Chinshan Power Plant is as follows:

1. Drainage design for outside of buildings

(1) Drainage system

There are 5 drainage pipes in the west of the plant (the Power Block area), whose total drainage capability is 4.4 cms and whose ending sections connect with ChienHwa Stream man-made drainage trenches; there is also one drainage pipe in the north of the plant, whose drainage capability is 1.2 cms. Thus the total drainage capability of this Power Block area is 5.6 cms (5.6 metric tons/sec). According to the statement in FSAR 2.4.3.1, the design basis maximum precipitation intensity for the plant is 297 mm/h, which is still smaller than the actual total drainage capability of this Power

Block area.

(2) Drainage capability

- i. At the time that the power plant was designed, there was not enough historic record to determine the PMP (Probable Maximum Precipitation) of the site. Thus, historic precipitation records of Taipei, Danshui, Keelung, Anbu, and Zuzi Lake were taken into consideration. It was concluded that the maximum precipitation density of the site is 297 mm/h with 10,000-year return period.
- ii. The plant has been operated more than 30 years. During this period, the maximum precipitation observed by the Central Weather Bureau was 136.5 mm/h at Anbu weather station. It shows that the drainage capability of the Chinshan Power Plant is adequate and still has a big margin.
- iii. Storms or mountain floods often come along with typhoons in Taiwan. The most serious storm that has attacked Chinshan Power Plant is the one that happened when Typhoon Xiangsane slammed Taiwan between Oct. 30 and Nov. 1 in 2000. The maximum precipitation intensity at that time was 116.0 mm/h, which is much lower than the design basis PMP of the plant. ChienHwa Stream drainage trenches were not overflowed and there was no internal or external flooding at ChienHwa area of the plant.

2. Drainage design for inside of buildings

The protection designs of the equipment in turbine building, combined building, reactor building and waste treatment building are as follows:

- (1) Safety related components have redundancy and are appropriately separated.
- (2) Water-seal rooms are designed to protect safety related equipment. There are switches and circuits on the watertight doors, which allow alarms to go off to notify the control room when the doors are inappropriately opened.
- (3) Watertight design exists in rooms that have safety related equipment inside, passages for workers, piping, and other penetrated holes on walls.
- (4) In regards to sealing function of walls, doors, (control, electricity, gas, and etc.) plates, or other compartments, they are all designed based on design basis accidents (DBA).
- (5) In combined building and turbine building, there is a flooding alarm system, connected to the control room.
- (6) The drainage system for inside of buildings does not directly connect with the drainage system for outside of buildings, which deals with drainage of precipitation. This prevents external flooding from overflowing the drainage system from outside entering buildings.
- (7) Penetrations for pipes in the structure between turbine building and combined building are sealed and leak-tight.
- (8) There are 6 inches of curbs for the doors of the rooms where flooding level is low.
- (9) The sumps in the corner room on the bottom floor of reactor building are exclusively for this region and are not connected with other areas. This prevents external flooding from entering the building and ensures the reliability of important equipment (ECCS).

3. Sustainability of the plant against mudslides:

- (1) According to the information from Soil and Water Conservation Bureau (SWCB), the

mudslide potential of ChienHwa Stream is medium and Xiaoken Stream is not prone to mudslide. However, ChienHwa Stream does not have any mudslide historic records, and the closest distance between buildings and the ChienHwa Stream is 50 meters.

- (2) The only land development activity near the stream is the construction of “Interim Storage Facility for Spent Fuel at Chinshan Power Plant.” A strict monitoring program has been started since the construction of the project. This environmental monitoring program requires satellite images taken every 6 months to observe abnormal changes in the nearby area of the stream. No noticeable collapse has been observed in the basin of the upstream of ChienHwa Stream.
- (3) The plant has completed a mudslide evaluation project “Xiaoken Stream and ChienHwa Stream mudslides Risk Evaluation” in 2002. The result shows that the mudslide potential of Xiaoken Stream and ChienHwa Stream can be classified as low potential, low risk, or medium-low risk levels. And even if mudslides occur at their upstream, the mudslide deposition start points of ChienHwa Stream and Xiaoken Stream are still 4.2 km and 3.5 km away from the plant.

4. Capability to protect the plant from dip-slope sliding

According to the investigation results from Central Geological Survey, strata at the plant base are alluvion and volcanic breccia, which do not have the characteristics that form a dip-slope. Through site survey, it is learned that vegetation and large trees prosper on the hills on both sides of the plant base, and land development activity is very rare. Though the hills had incidents of regional land sliding due to consecutive heavy rain, these incidents had no direct influence on the buildings. Thus, it is concluded that there should be no dip-slope sliding concern within the plant.

5. Sustainability of buildings against strong winds

According to the typhoon intensity classification system of Central Weather Bureau in Taiwan, sever typhoons have winds that reach Beaufort Force 16 and wind speed is higher than 51 m/s.

(1) Building structures

The design wind speed and the maximum instantaneous wind speed at the elevation of 30 feet above the ground of both seismic category I and 2 structures are 134 mph (60 m/s) and 148 mph (66 m/s) respectively. Design wind speed and design wind pressure force at Chinshan Power Plant are shown below:

Height (feet)	Design wind speed (mph)	Design wind pressure (psf)
0~50	148	75
50~150	168	95

(2) Switchyard structures

The original design wind speed of the structures of the transmission towers was 40 m/s (Force 12) in western Taiwan. Besides, there was 30% of margin to resist gust at 52 m/s, which is Force 16. After Typhoon Thelma, the most destructive natural event in Taiwan since WWII, TPC enhanced the capability of the structure of the transmission towers against winds. The new design wind speed is 44.9 m/s (Force 14) and gust speed can reach 61.9 m/s (Force 17). Additionally, according to the design guideline for Power Switchyard, the design wind speed for Class A equipment and structures is between 70 m/s to 100 m/s.

(3) Design wind speed of the Off-gas stack

The design wind pressure force at the elevation of 98.5 m is 95 psf.

Kuosheng NPP

This plant is located on a platform 12 m above sea level and is 500 m away from the shore. It has a drainage system in main building area. It also has two open drainage trenches on both east and west side of the main building area. There is no river across the site. The nearest streams are Yuantan Stream, 1.5 km west of the site, and Malian Stream, 4.5 km east of the site. Both streams are separated away from the plant by mountain hills, so they will not cause onsite flooding.

1. Drainage capability of the plant

(1) Drainage system

The drainage system of the plant is divided into three major parts—the main building area, west of the site, and east of the site:

- i. The first drainage system is in main building area (Power Block). It collects surface flow from rainfall in main building area as well as drained water from emergency cooling water system. Then, water from both places is removed through the drainage system in main building area (a.k.a. yard drainage system). The drainage system in main building area is made up with onsite side trenches, pumps, manholes, and pipes.
- ii. The drainage system in the west of site area collects surface flow from rainfall at warehouse area, power switchyard, and hills in the west of main building area, and drains out through trench A (Creek A).
- iii. The drainage system in the east of site area collects surface flow from rainfall at the hills in the east of main building area, and drains out through trench B (Creek B).

All these 3 drainage systems remove drained water into the sea.

(2) Drainage capability

The trench A and B are both open man-made trenches with slope rate of 0.2% to 0.5%. The maximum drainage capabilities of both trenches are 138 cms at the river mouth of trench A and 114 cms for trench B. Besides, the security booth at the gate of the plant is 100 m (elevation 3.4 m) from the shore. According to FSAR 2.4.5.2, even if the swell in the sea is 1.2 m (including high tide water level) during typhoons, it would not affect the drainage capability of the plant.

According to the historic rainfall record measured in Keelung Weather Station by Central Weather Bureau in the past 30 years, the estimated PMP near the site is 123 mm/h. After statistic calculation, the resulting maximum precipitation is 209 mm/h (considering 10,000-year return period), which is lower than the PMP used in FSAR, 241 mm/h. Thus the drainage capability of the site is adequate to handle the extreme heavy rainfall induced by climate change.

2. Sustainability of the plant against mudslides

According to the information from SWCB, the potential of mudslide-prone streams in this area are all medium. Main buildings in the plant are not within the range of influence of these mudslide-prone streams. Only the #2 waste warehouse and two waste storage trenches are within the influence range of Masu Stream. However, Masu Stream has never had any historic record of mudslide incidents. According to the warning system of SWCB, if Central Weather Bureau forecast that the extremely heavy rainfall would reach the level of 500 mm/day, alerts for mudslide-prone streams are issued. Kuosheng Power Plant estimates that when mudslides happen at Masu Stream, the affected area should not

be large and it could possibly block only one small section of drainage trench B, which is between #2 waste warehouses and its waste storage trench.

3. Capability to protect the plant from dip-slope sliding

According to the investigation results from Central Geological Survey, dip-slope landscape locates at 400 meters southeast of the main buildings. The dip-slope area is well maintained and landslide potential is small.

4. Sustainability of buildings against strong winds

(1) Building structures:

According to FSAR 3.3 and Table 3.3-1~3 of the plant, all structures must be able to resist minimum design wind speed of 120 mph (53.6 m/s) (Beaufort Force 16) at the elevation of 30 feet above the ground. Meanwhile, seismic category I structures must be capable of resisting wind pressure of 63 lb/ft² (or 307 kg/m²) causing by typhoons (the minimum design wind speed is 157 mph or 70.2 m/s, which is in the range of Beaufort Force 17) and resisting the impact of the projectiles caused by typhoons. Wind pressure force of a seismic category I structure is 109 lb/ft² (or 532.1 kg/m²) due to maximum design wind speed, 206 mph (92.1 m/s). The height of these structures is between 175 and 200 feet. Note that the Beaufort Force 17 is the maximum scale of wind force classification by Central Weather Bureau.

(2) Switchyard structures:

The design wind speed is 44.9 m/s (Beaufort Force 14) and gust speed can reach 61.9 m/s (Beaufort Force 17).

[Maanshan NPP](#)

To protect the plant from the most severe event (the combination of typhoons, heavy rain, and mudslides), we have reviewed the following:

1. Protection against onsite flooding

(1) Drainage pipe design: Onsite flood draining utilizes gravity. The design for ground level flood drainage system includes:

- a. In the east of the site, drainage capability of pipes and trenches is 11 cms (m³/s).
- b. In the west of the site, drainage capability of pipes and trenches is 9 cms.

The total drainage capability is 20 cms. This drainage system covers the area of onsite building areas, parking lot in the north site, and warehouse areas. Based on the design maximum rainfall of 120 mm/h as stated in FSAR, the drainage capability needed is 7.2 cms, which is far smaller than the designed draining capability. Besides, there is a natural drainage gate at south side of the site, providing direct current to the sea where circulating water intake area is located.

(2) There are highlands in the north, east, and west sides of the site. This landscape surrounds the site such that the rainfalls outside of the site do not enter the site.

(3) Design considerations for the surrounding area of the site:

- a. In order to prevent accumulated rainfall from flowing into the buildings, all the doors on the outer walls of all buildings and openings on the ground are at least 6 inches above ground. The elevation of site buildings is 14.85 meters above sea level.
- b. Synthetic rubber water-proof tape is installed at contraction seams and structure seams of foundation and underground walls. The foundation and the outer walls under the ground of all onsite buildings are water-proof.
- c. The design of site surrounding area includes a ground drainage system which is capable to drain the probable maximum precipitation (PMP). The integrity of all

approachable water-proof doors, barriers and penetration sealing has been verified and examined.

- (4) According to FSAR 2.3.2.3, the design basis of the site can sustain sudden heavy rainfall of 7.2 cms at a peak intensity of 120 mm/h (100-yearly storm) and sudden heavy rainfall of 13.7 cms at a peak intensity of 228 mm/h (10,000-yearly storm). Both heavy rainfall data do not exceed the draining capability of the plant, which is 20 cms (maximum rainfall intensity of 325 mm/h).

2.Sustainability of the plant against mudslides

- (1) Official information from SWCB shows there is no debris-flow-prone stream in Hengchun region.
- (2) The site conducted a slope investigation after a freeway dip-slope collapsed a year ago at northern Taiwan. The investigation results confirmed that there is no dip-slope near the site.
- (3) The landscape in south of the site is next to the ocean and lower than the site, while the landscape in the other three directions of the site is higher and there are protecting stone walls in these directions. The slopes of these walls are stable and there is no concern of collapse.

3.Sustainability of outdoor equipment against strong winds

- (1) 345kV circuit can sustain wind velocity of up to 61.9 m/s (Beaufort Force 17: 56.1~61.2 m/s).
- (2) 161kV circuit can sustain wind velocity of up to 45 m/s (Beaufort Force 14: 41.5~46.1 m/s)
- (3) Towers can sustain wind velocity of up to 70.7 m/s (larger than Beaufort Force 17).
- (4) The wind resistant strength of seismic category I structure is 70 m/s (which is larger than Beaufort Force 17).

[Lungmen NPP](#)

Extreme weather conditions that may threaten Lungmen NPP include typhoons, heavy rain, mudslides, etc. The most severe event is the combination of typhoons, heavy rain, and mudslides. To protect the plant from this kind of combined disaster events, we have reviewed the following:

1. Drainage design for outside of buildings

(1) Drainage system

This drainage system comprises three main parts:

- i. Drainage and rainfall-induced surface flow in the main building area (power block) are removed via the yard drainage system in the main building area, which is designed to deal with **100-yearly maximum precipitation** in the main building area. Yard drainage system is made up with side ditches around buildings, collecting pools, pumps, manholes, pipes, and guide tubes.
- ii. Drainage and rainfall-induced surface flow in the following areas are removed through drainage trench III – the outside of the south fence of unit 1, the bordering area between unit 1 and unit 2, the switchyard area, the south and southwest of the main building area and the hill region to the west of the plant.
- iii. Trench II takes care of drainage in the east of the switchyard and rainfall-induced surface flow from the hill in the west of the main building area.

All the above three drainage systems have their own independent pipes to drain water into the sea.

(2) Drainage capability

- i. Trenches II and III are open channels, whose drainage capability is 81.57cms and 137.2cms respectively. Because the elevation of the ground floor of buildings are 12.3 meters above the mean sea level, and the depth of the maximum temporary water accumulation is estimated to be 12.1 meters, trenches II and III have enough drainage capability (with 0.2m margin) considering the probable maximum precipitation condition.
- ii. The FSAR for Lungmen NPP has the information on PMP measured at Keelung Weather Station from 1961 to 2006. Though the PMP figures in the recent years displays a slightly increasing trend, the maximum PMP figure in the last 40 years (happened on Sept. 23, 1980) is 107mm/h, which is still far lower than the PMP figure, 310mm/h, adopted for the design basis flood.

2. Drainage design for inside of buildings:

The design of protection against flooding for safety related SSCs consists of two parts: one is the design to fight against internal flooding caused by water from outside of buildings, and the other is to fight against internal flooding resulting from leakage from damaged equipment in buildings.

(1) Internal flooding caused by water from outside of buildings is prevented mainly through the following design:

- i. Thickness of the exterior walls that are lower than the elevation of the DBF is more than 0.6 meters.
- ii. Structure conjunctions of each building that are lower than the elevation of the DBF have water stops.
- iii. Penetration holes/doors that are lower than the elevation of the DBF are watertight.
- iv. Exterior walls that are lower than the DBF water level are treated with water-proof coating.
- v. Roofs of buildings are designed with a drainage system and weir walls to prevent massive water accumulation/ flooding on roofs.

Considering the possible rupture of storage tanks, all entrances/exits of plant buildings are 30cm higher than ground floor. With this design, water originating from rupture of onsite storage tanks would be drained before it could enter any buildings to cause damage to equipment inside. Managerial procedure is also implemented for flooding protection (Procedure 528.03.01 "Flooding response").

(2) Preventive measures are established to fight against internal flooding caused by leakage from damaged equipment in buildings. Reactor building, control building, and reactor building service water pump house are all equipped with watertight doors or semi-watertight doors. Other buildings such as the radwaste building, the auxiliary fuel building, access control buildings, and turbine building are with similar design. Some of the penetration holes below EL 12,300mm in each building are temporarily sealed during the construction, but the inspection on permanent sealing will be completed during post-construction testing.

3. Sustainability of the plant against mudslides:

Lungmen NPP is within the watershed of Shiding Stream and Shuangxi Stream. According to the information from Soil and Water Conservation Bureau (SWCB), these two streams

are not prone to mudslide. Furthermore, based on the current natural condition at the site, the chance of Shiding Stream and Shuangxi Stream having mudslides is very low.

Local road Route 2 is right outside of the east part of the plant. This route is a fully developed 110-acre flat land at EL.9~12 meters. The areas on the hill in the west of the plant that are under construction are: the raw water reservoir area, the temporary sand and rock stockpile southwest of the switchyard, the switchyard, the low-radioactive waste storage warehouse area, the temporary sand and rock stockpile north of the low-radioactive waste storage warehouse area, roads to take to go do maintenance work at the raw water reservoir, the temporary sand and rock stockpile at the south bank of the upstream area of Shiding Stream, and etc. The areas on the hill in the south of the plant that are planned to start land development include sea sand stockpile south of the warehouse area and in the south of the plant. All areas on hills that have been developed and are being developed comply with Water and Soil Conservation Technology Specification and with Water and Soil Conservation Guidebook to design all facilities to achieve water and soil conservation. Also, the design needs to be inspected and approved by SWCB. At the stockpiles in the plant that have more rocks in its rockfill, the filling and building of the rockfill is in a staircase style, which is that a platform of 2 meters in width is created for every 5 meters of height is built, in order to stabilize hills on the sides. Before rockfill is filled and built, RC pipes need to be buried at the bottom of the valley in order to drain the surface flow from the upstream watershed and to drain water permeating into under the ground from rockfill. Additionally, drainage systems are installed in both the bordering areas and on hills of the plant; vegetation is also grown at spots where the drainage systems are exposed without being covered to prevent the systems from being directly eroded by rain water and to lower the chance of mudslides.

4 main drainage trenches (I~IV) and 7 sub-trenches have been installed along flat lands at the foot of the west side hill in the plant. The design of the drainage capability is based on the once every 100-year maximum precipitation intensity; the design of main drainage trench II (containing II-1~II-3 sub-trenches) and main drainage trench III (containing III-1 sub-trench) uses PMP as a basis. These drainage trenches are to drain storm-induced flooding and the mud as well as sand the flooding carries in the plant and on the west side hill, in order to ensure the safety of reactors and equipment. Lungmen NPP encompasses a land area of 480 acres. The geographic landscape on the east side is flat and next to the Pacific Ocean, and the slope ratio of the hills on the west and south sides is small, with the highest slope of about 170meters. Areas on the hills that are not developed are covered with prosperous vegetation and have no signs of collapse. Areas on the hills that have been developed have drainage facilities, retaining facilities on side slopes, and greenery. After being through many years of typhoons, storms, and earthquakes, these areas only have some regional collapse, but there is no severe disaster caused by mud or rocks. The geographic landscape of Lungmen NPP is quite flat. Upstream watersheds of all little streams in the valley are small and have no signs of collapse of mud or rocks. In addition, slopes in the valley where little streams flow through descend slowly and there is no piling of collapsed substances; vegetation on both sides of the valley is intact. Furthermore, areas that have been developed have been protected and maintained for water and soil conservation purpose, so there should be no concern of mudslides in this area of the plant.

4. Capability to protect the plant from dip-slope sliding

There is no concern of dip-slope sliding at the plant.

5. Sustainability of buildings against strong winds

(1) Building structure:

The design wind speed as well as the maximum instantaneous wind speed at the elevation of 9 meters above the ground of seismic category 1 buildings (reactor buildings, control buildings, the switchgear building, the auxiliary fuel building, and the

off gas stack) are 121 mph (54m/s) and 157mph (70m/s) respectively. The design wind speed of other non-seismic category 1 buildings (turbine buildings, the radwaste building, the water plant, the fire-fighting pump house, and the switchyard) is 121mph (54m/s). (Note: According to the typhoon intensity classification system of Central Weather Bureau in Taiwan, sever typhoons have winds that reach Beaufort Force 16 and wind speed is higher than 51m/s.)

(2) Switchyard structure:

The original design wind speed of the structure of the transmission towers of TPC was 50m/s in eastern Taiwan (Beaufort Force 15) and, 40m/s in western Taiwan (Force 12). Besides, there was 30% margin to resist against gust wind at 52m/s, which is Force 16. After Typhoon Thelma, the most destructive natural event in Taiwan since WWII, TPC enhanced the capability of the structure of the transmission towers against winds. The new design wind speed is 44.9m/s (Force 14) and gust speed can reach 61.9m/s (Force 17). Additionally, according to the design guideline for Power Switchyard, the design wind speed for Class A equipment and structures is between 70m/s to 100m/s.

(3) The design wind speed for off gas stack:

The design wind pressure at EL. 60 meters is shown as follows:

Elevation(meters)	Design/max. wind speed(m/s)	Design /max. wind pressure(kg/meter ²)
60	54/70	282.06/473.97

4.1.2 Weak points and cliff edge effects

[Chinshan NPP](#)

According to the result of “Stress Tests of Combined Natural Events of Typhoons, Heavy Rainfall and Mudslides for Chinshan Power Plant”, weak points and cliff edge effects of the plant in extreme situations are evaluated and described as follows:

- 1.If unexpected mudslides happen and cause flooding to reroute and eventually flood the Power Block area, units may be affected.
- 2.When a beyond design basis storm seizes the plant with no occurrence of mudslides, and if the BDB precipitation could not be drained by the drainage trenches and the surface flow floods the Power Block area, units may be in danger.
- 3.If the BDB precipitation causes the flooding of combined building and reactor building, the floor levels with elevation below 39.8 feet are the flooding weak point.
- 4.The main flooding weak point is flooding on the bottom floor (elevation -0.83 feet) of reactor building. This is because all corner rooms on this floor level have RCIC and safety related emergency reactor cooling systems, including high pressure coolant injection system (HPCI), low pressure coolant injection system (LPCI), core spray system (CS). If all of these systems are flooded, it would cause all high and low pressure emergency injection systems unavailable. Reactor will lose its water makeup function that the emergency safety systems serve and can only count on the containment spray water pump (BCSS PUMP).
- 5.BCSS is not a safety related system. It connects fire-fighting water systems and containment spray pipes and is a cooling water source for reactor and containment. When the back pressure of this backup water pump is smaller than 110 psig, it can deliver over 250 GPM of water to reactor. But, if fire-fighting water source of BCSS PUMP is lower than 153 GPM, it may lead to serious result.

6. Flooding on the ground floor (elevation 39.83 feet) of the combined building is one of the cliff edge effects, because there is a safety related electricity switch box room containing 4.16kV essential buses #3 and #4. If the room is flooded, it would impair A/B series safety related AC power equipment and lead to station blackout and loss of ultimate heat sink. Consequently, only DC battery system is available and it can sustain for 8 hours.
7. If emergency seawater system (ESW) inlets are clogged by a large amount of debris, this would also cause grid clogged and affect the intake of the pumps, which will lead to loss of ultimate heat sink.

Kuosheng NPP

According to the result of “Stress Tests of Combined Natural Events of Typhoons, Heavy Rainfall and Mudslides for Kuosheng Nuclear Power Plant”, weak points and cliff edge effects of the plant in extreme situations are evaluated and described as follows:

1. The elevation of the plant is 12 meters and it is 500 meters away from the shore. The main area of the plant is lower than both of its west and east sides. Its north part is relative low and the fences turn it into a bowl-shaped lowland. In a heavy rainfall scenario, with the help of the drainage trenches B/A (the drainage capability is 241 mm/h), mudslides would not happen. However, if large mudslides (BDB) occur, it may cause flooding in the main building area and the units may be affected.
2. If a beyond design basis storm occurs and the precipitations exceed the capability of the drainage trenches, surface flow may enter the main building area of the plant and the units will be affected.

Maanshan NPP

1. If natural disaster with BDB precipitation causes flooding of buildings, the weak point should be 80 feet above the floor of control building.
2. Flood vulnerability and cliff-edge effect can lead to flooding at the bottom (elevation 80 feet) of control building, where there is safety related electrical equipment, including A/B essential bus, A/B/C/D safety train battery chamber, chargers, etc. If equipment were flooded, it could cause the loss of all AC/DC power, which will result in serious consequence.
3. Flooding in auxiliary building at elevation 74 feet could lead to the unavailability of the safety-related pumps (located in rooms with watertight doors).
4. If the inlets of nuclear service cooling water (NSCW) are blocked by debris, the screens will be clogged and pumps would lose its function and result in loss of ultimate heat sink.

Lungmen NPP

1. If unexpected mudslides happen and cause flooding to reroute and eventually flood the Power Block area, units may be affected.
2. When a beyond design basis storm seizes the plant with no occurrence of mudslides, and if the BDB precipitation could not be drained by the drainage trenches and the surface flow floods the power block area, units may be affected.
3. If beyond design basis flood happens or, in other words, the elevation of the flood water level is higher than EL 12.0 meters, internal flooding would happen because all exterior doors on the ground floor of the plant buildings are not watertight. The weak point is the floors in reactor buildings that are at elevation 4,800mm. Safety related electric

switchgear located in this area, including 4.16kV emergency buses A4, B4, and C4, could be in danger. If these are all flooded, there would be no safety related AC electric equipment available, which would lead to station blackout and loss of ultimate heat sink.

4. The main weak point is flooding on the bottom floor, -8,200 mm of the reactor buildings because this floor has safety related emergency reactor core cooling system such as HPCF, LPFC, and RCIC.
5. If the inlets of the seawater pump house in the reactor buildings are stuck by massive debris, causing further clogging at the mesh and affecting the water intake of the pumps, reactors would lose ultimate heat sink.

4.1.3 Measures which can be envisaged to increase robustness of the plant

Chinshan NPP

1. Response measures to extreme weather:
 - (1) When Central Weather Bureau issues “Alerts for typhoons at sea and land area” and/or the plant judges that the typhoons may threaten the power plant, the plant should follow procedure 104.22 “Typhoon prevention and response procedure” and procedure 513 “Procedure for operation during typhoon alert period.”
 - (2) Follow procedure 104.37 “ChienHwa Stream mudslide monitoring procedure” to conduct walkdown inspection.
 - (3) When there is internal or external flooding, procedure 515.2 “Internal flooding response procedure” or procedure 515 “External flooding emergency response procedure” should be followed.
 - (4) When BDB accidents happen and units lose onsite and offsite AC power sources or reactor makeup water, the plant must take decisive actions and be prepared to abandon the reactors and then implement procedure 1451 “Unit ultimate response guidelines.”
2. Enhancement measures:
 - (1) Due to a tsunami improvement program of the plant, all openings on the underground trenches of ESW intake pumps are installed with grids to resist tsunami. The first openings on the top are installed with fixed screens to prevent large trash from entering underground trenches, so the intake function of ESW drainage pumps would not be affected.
 - (2) Every year between June and September, the plant conducts routine and post-natural disaster walkdown inspection of all onsite drainage trenches following procedure 104.22 “Typhoons disaster prevention and response procedure” and 795.12 “Onsite structure monitoring and walkdown inspection operating procedure” in order to make sure the trenches can drain without any problems and their structures are sturdy. Moreover, the plant has annual contracts to have these trenches cleaned.
 - (3) Abiding by procedure 113.5, in addition to the existing spare general mitigation equipment, the plant has considered all categories of equipment needed to respond to combined natural disasters and procured 1 large 4.16kV/1500kW mobile container power vehicles, 12 medium size of 480V/500kW, 480V/200kW diesel generators, several convenient gasoline/diesel generators, air compressors, internal combustion engine drainage pumps, and other mitigation equipment or equipment spares.
 - (4) The bottom floor of the combined structure building is inundation-prone and if sump pumps could not drain fast enough in time, the two pumps of the Seeped Tank can be used as drainage pumps for accumulated water on the ground and remove the water

through circulating seawater trenches. Additionally, the plant has procured 8 large gasoline engine drainage pumps to enhance the drainage capability of plant buildings.

- (5) Simple improvement programs MMR-C0-0407 have been established, which requires installment of flood barrier facilities at entrances/exits of important buildings/facilities to enhance flood protection capability of buildings.
- (6) The plant has procured 8 fixed diesel generators and 4 mobile diesel generators, which can provide spare power sources to emergency makeup pumps, ventilation equipment, monitoring instruments, emergency lighting/communication equipment and etc.
- (7) The plant has procured one 4.16kV mobile diesel generators, which will be used to provide spare power sources to long term cooling related equipment.
- (8) Through the power loading management listed in procedure 535 “Station blackout procedure” and the mechanism of switching 125VDC SWBD #6 to DC SWBD #2, DC power source can sustain for at least 24 hours to maintain the operation of RCIC.

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The plant evaluates its drainage system under the threats of extreme climate and combined natural events that are beyond design basis. It is found that possible entering locations of external flooding are the gate of security booth, the gate on southeast of the plant, and all exterior entrances/exits of buildings.

1. Response measures to extreme weather:

- (1) If mudslides that are beyond expectation happen, the plant should follow procedure 576.1 “Typhoon emergency response procedure for Kuosheng Power Plant” to maintain the drainage trenches A/B unclogged and minimize damage.
- (2) Follow the newly established procedure 577.3 “Monitoring, warning, disaster prevention and mitigation procedure for active faults near the plant, precipitation, mudslide, and dip slopes.” The plant periodically evaluates natural disasters resulting from changes of climate and geography near the site and conducts walkdown inspection at the site before the typhoon season every year.
- (3) Review or revise related procedure 576 “Procedure for operation during typhoon warnings” and procedure 577 “Heavy rainfall or flooding emergency response procedure.” Add procedure 577.3 “Monitoring, warning, and disaster prevention and mitigation procedure for fault, precipitation, mudslides, and dip-slopes near the plant” to prevent mudslides from affecting the drainage capability of the plant.

2. Additional enhancement measures:

- (1) In order to prevent the flooding caused by surface flow or rerouting of drainage trenches on east/west sides of the plant from entering the main building area, install flood barrier panels at the gate of the security booth and southeast gate of the plant to block main building area and east/west areas of the plant.
- (2) Install 1-meter high flood barrier panels at entrances/exits of main buildings to prevent external flooding from entering main buildings.
- (3) Mitigation equipment (such as drainage pumps) is placed at high locations free from the threat of earthquake and flood, and is easy for workers to access.

Maanshan NPP

1. Response measures to extreme weather:

- (1) When Central Weather Bureau issues typhoon alert at the area where the plant located, procedure 154 “Typhoon-period operating procedure” will be followed.
 - (2) After tsunami alert for the site is issued, the plant will follow procedure 582.2 (tsunami handling procedure”.
 - (3) Once buildings on the site are flooded, the plant follows procedure 583 “emergent flooding event procedure”.
 - (4) When BDB events happen and units lose all AC/DC power or water supply of reactors/steam generators, the plant must get prepared to take actions to abandon reactors according to procedure 1451 “Unit ultimate response guideline”.
2. Enhancement measures:
- (1) A grating cover has been installed on top of the intake pool of NSCW pump house. The purpose of the installment is to prevent large garbage and debris from entering the intake pool. Besides, the pump motor rooms have been enhanced with watertight isolation to prevent the loss of seawater pump at the strike of tsunami.
 - (2) Perform structure inspection according to procedure 700-A-001. The scope of inspection includes trenches, integrity of pipe line, and the vicinity of retaining structures.
 - (3) Following procedures 582, 582.1, 582.2 to conduct equipment inspection and handling after the event of earthquake/tsunami.
 - (4) According to procedure 192, plant must keep emergency equipment available at all times. Emergency equipment includes 12 gas-powered water pumps, 8 electrical sink pumps and emergency power (1 diesel generator, 3 multifunctional devices, and 18 gasoline generators) for drainage pumps.
 - (5) In case that control building or auxiliary building were flooded and sump pumps could not drain out the water in time, additional temporary pumps will be added to increase the discharge capability.
 - (6) In control building, there are 10 inch thresholds at the entrances of rooms of A/B essential bus and A/B/C/D charger to prevent these rooms from flooding. The plant is in the process of reviewing how to enhance waterproof capability of these rooms.
 - (7) The plant has procured 30 diesel-powered water pumps to increase its mobile drainage capability.
 - (8) The plant has procured 10 480VAC mobile diesel generators, which can provide emergency backup power to feedwater pumps, air-conditioning equipment, monitoring instruments and emergency lighting/communication equipment.
 - (9) The plant has procured two 4.16 kV mobile diesel-powered generators to provide backup power to long-term cooling equipment.

Lungmen NPP

1. Response measures to extreme weather:

- (1) When Central Weather Bureau issues sea and in-land warnings of typhoons at the area, the plant will comply with procedure 187 “Operation during typhoons.”
- (2) If Central Weather Bureau forecasts that the radius of typhoons may cover the site, the plant should abide by procedure 528.02.01 “Reactor operation during typhoon warning period.”
- (3) During the occurrence of typhoons of moderate level or above as well as very heavy

rain, the plant should establish the Typhoon Emergency Team and should abide by procedure 187.01 “Water accumulation/flooding prevention and response during typhoons or very heavy rain.”

- (4) When internal or external flooding occurs, the plant should follow procedure 528.03.01 “Flooding response,” or procedure 528.03.02 “Flooding response,” or procedure 528.03.03 “Emergency drainage operation during power outage and abnormal water entry in buildings.”
- (5) If beyond design basis events happen and reactors lose all onsite and offsite AC power source or no water supply of reactors, the plant must get prepared to take actions to provide cooling to the reactor (regardless the quality and the associated adverse effects of the coolant) according to procedure 1451 “plant unit ultimate response guideline procedure.”

2. Enhancement measures:

- (1) To respond to tsunami improvement programs, the plant adds flood barrier plates at RB, CB, DG fuel tanks, AFB, fire-fighting pump houses, the RBSW pump house, the place where RBACB at elevation of 12,300 mm enters RB, and the place where the waste corridor at elevation of 12,300 mm enters RB/CB and AFB.
- (2) Before the typhoon season, the plant should comply with procedure 187 “Operation during typhoons” to conduct walkdown inspection on all drainage trenches in the plant as well as the drainage trenches of Shiding Stream. Also the plant should abide by procedure 769 “Walkdown inspection on the fire-proof and sealing of cable and ventilation duct penetration areas” to perform the inspection once every 18 months.

4.2 Assessment and conclusions of the regulatory body

The approach adopted by the licensee to reevaluate the risks associated with extreme weather conditions complies with the methodology provided by the licensee and approved by the regulatory body AEC (Atomic Energy Council). AEC basically confirmed the information and assessments provided by the licensee, especially the information regarding the licensing basis. Generally speaking, the potential consequences of extreme weather conditions (typhoon, storm, heavy rain, etc.) are covered by the major event – flooding, which is also reassessed in chapter 3 as part of the stress tests program. Most of the considered hazards were taken into account in the design basis of the facilities, and are hence not likely to affect the safety functions of the units.

However, based on the assessment of the licensee’s reports and the subsequent technical meetings and onsite inspections, the regulatory body identified additional requires and recommendations in order to further improve the robustness of the facilities when faced with extreme weather conditions:

1. Given the fact that typhoons of high intensities were observed in the past years in Taiwan, the protection of the buildings containing safety related equipment against projectile should be confirmed in case of a beyond design typhoon with wind speed exceeding 70.2 m/s (Beaufort Force 17). (According to the typhoon intensity classification system of Central Weather Bureau in Taiwan, several typhoons have winds that reach Beaufort Force 16.)
2. Climate changes have caused severe rainfall via the form of typhoons and/or tropical storms in recent years. The licensee should review the appropriateness of the design basis PMP (probable maximum precipitation). Associated improvements of the drainage systems should be envisaged to increase the robustness of the plants against heavy rain. These should be reviewed and approved by the regulatory body through the process of periodic safety assessment every ten years.

3. The watertight capability of fire-fighting doors and pipeline penetrations seals should be further investigated and clarified.
4. A systematic evaluation of combinations of extreme nature events should be performed.
5. TPC should follow the tier 1 recommendations of USNRC NTTF report, especially Section 2.3 concerning the external natural disasters.
6. Referring to the experiences of other nuclear countries, it is recommended that TPC should conduct the following evaluations or improvements to its nuclear power plants:
 - (1) a quantitative risk assessment concerning the potential volcanic hazard;
 - (2) Installation of the second ultimate heat sink.

5. Loss of electrical power and loss of ultimate heat sink

In order to provide a self-standing national report for the subsequent peer review process, first the relevant information supplied by the licensee in its stress tests reports is summarized. At the end of this chapter, a final section provides the conclusions and the assessment of the regulatory body (AEC).

5.1. Nuclear power reactors

5.1.1. Loss of offsite power (LOOP)

On-site power systems are classified into safety-related and non-safety-related. The safety-related power systems provide power to reactor protection and emergency cooling systems to ensure reactor safe shutdown. The safety-related power systems should meet seismic category 1 and electrical class 1 requirements. Non-safety related power systems provide various auxiliary loads needed for unit operation. When unit is in normal operation, service power can be provided from its turbine generator through auxiliary transformer.

Chinshan NPP

The power distribution systems are as follows (refer to Figure 5-1):

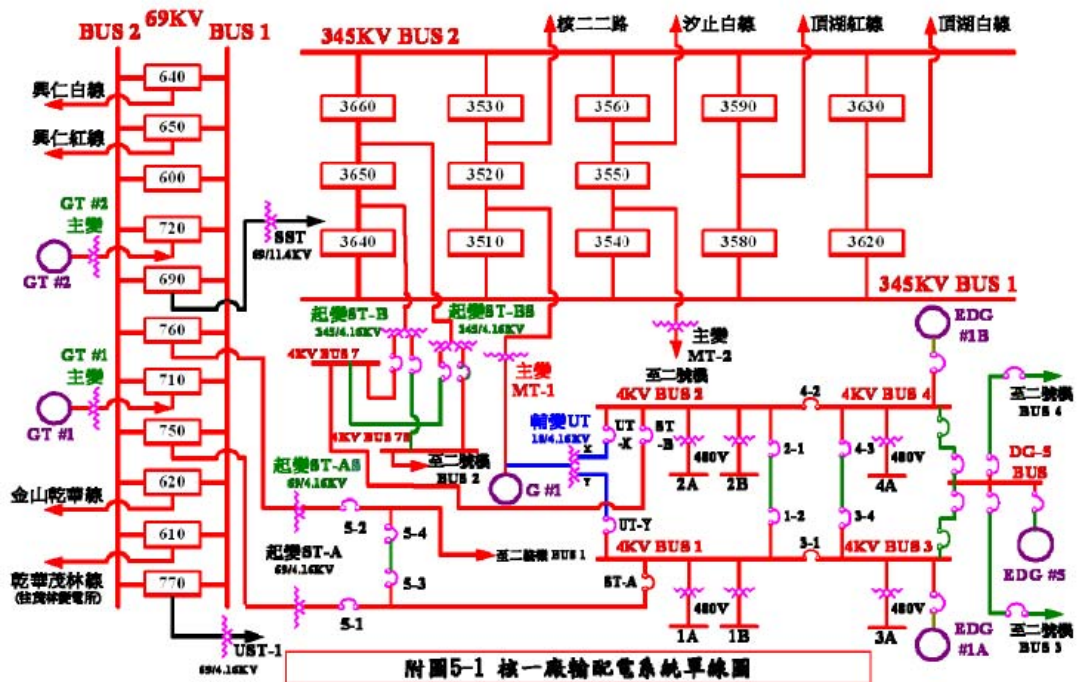


Figure 5-1 Power distribution system

1. In the event of a unit auxiliary transformer trip, the station auxiliaries are transferred automatically to the startup/standby transformers.
2. There are four 345kV offsite power sources. (Two lines from Ting-Hu extra high voltage (EHV) substation, one from Hsichih EHV substation and the other from Kuosheng Nuclear Power Plant). These lines are double-circuit and each circuit can transmit 2000 MVA. Structural failure of any one line would not result in the failure of the other. There are four 69kV offsite power sources. Two lines from Hsing-Jen secondary substation and

the other two from Chin-Shan secondary substation. Consequently, the 69kV start-up transformer will always be available even if one of the lines or breaker is tripped. Two onsite gas turbines can also supply power source to 69kV switchyard.

3. Each safety related power distribution bus is normally powered from the main generator, and is able to be transferred to 345kV or 69kV network system or emergency diesel generator (EDG). The transfer function is initiated automatically and accomplished within a few cycles when the under voltage is detected.
4. The source of non-safety-related power system (4.16kV Bus #1 /Bus #2) sources can be selected from auxiliary transformer or startup transformer. In cases of reactor scram, the power source will be switched to 345kV or 69kV startup transformer automatically.

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The design of plant power supply and distribution system is described as follows:

1. The power for the ESF buses of both units can be supplied from either the 345kV or 69kV offsite power systems in addition to the diesel generator sets.
2. Electrical power from the transmission network to the switchyard is provided by two physically independent transmission systems (345kV and 69kV). Four 345kV transmission lines from Hsichih(2 lines), Chinshan nuclear power plant and Hsiehho and two 69kV transmission lines from Chin Shan/Chung Fu and Wu Lun/Chien Hua are connected to the plant.
3. Safety-related power system comes from off-site 345kV start-up transformer or off-site 69kV start-up transformers. Via these transformers, the 345kV/69kV off-site power is stepped down to 4.16kV and fed to essential buses. Each of these essential buses is also connected to an independent emergency diesel generator to provide power to emergency cooling systems in case of loss of off-site power.

Maanshan NPP

1. Maanshan plant has two offsite power systems, one of them is 345kV system and the other is 161kV system. The 345kV system has two buses and is connected to electric grid by four transmission lines. Three lines are connected to Dapeng EHV substation; and one line is connected to Meelee EHV substation. The 161kV system has a single bus (161kV Bus) and two loops. One is associated to Fengkang substation; the other circuit is connected to Kenting substation then return to Fengkang substation.
2. Maanshan plant has two 345kV start-up transformer and two 161kV start-up transformers to provide the power required in start-up and shutdown for both units.

Lungmen NPP

The design features of Lungmen Station power distribution system is shown on Figure 5-1:

1. Safety related 4.16kV/480V bus

Each unit has three 4.16kV Buses (A4/B4/C4) and downstream 480 V PC /MCC. Each 4.16kV Bus is connected to one Emergency Diesel Generator (EDG). Lungmen Station also has one 4.16kV Bus (S4) which is equipped with one common EDG(SEDG or 7th EDG).

2. Normal Power Supply

The 345kV off-site power is provided from Shenmei Red/White and Longtan Red/White four transmission lines. The 161kV off-site power is provided from Nangang -Pinglin and Aodee two transmission lines.

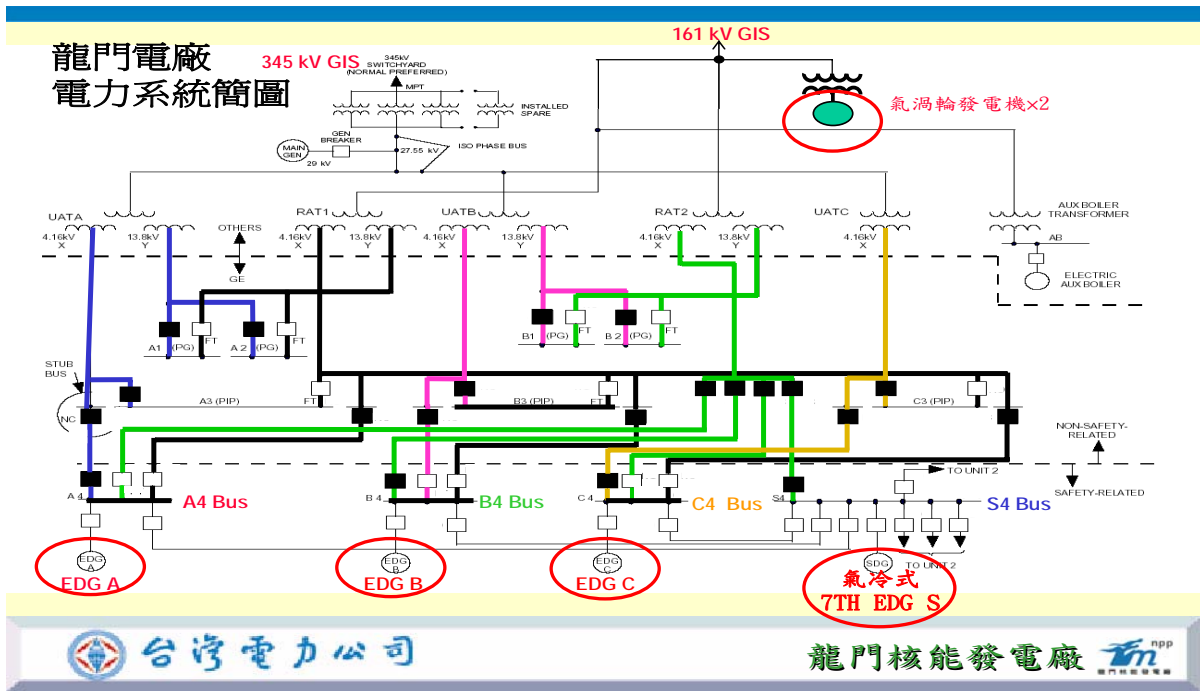


Figure 5-2 Lungmen Station Electrical Power Distribution Line Diagram

5.1.1.1. Design provisions of on-site back-up power sources

The diesel generator sets supply back-up power to those electrical loads which are needed to ensure safe reactor shutdown and cooling during the design basis events (DBE). In the event of loss of normal sources of power to the onsite power system, each diesel generator set will be started and put in service automatically. In case of loss of off-site power and loss of EDGs, the swing diesel generator and two gas turbine generators can be used as diverse emergency power sources.

Chinshan NPP

1. Each unit has 2 independent 3600kW safety-related EDGs and they can backup each other. These EDGs, which are Seismic Category I design, are located at elevation of 11.2 meters in combined building. EDG system is divided into two segregated and separated divisions - DIV I and II. The EDG supply power to the 4.16kV essential bus. If off-site power is lost, the EDG will be started and put in service automatically and its rated speed and voltage will be reached within 10 seconds. Each of these two divisions has enough capacity for safe shutdown.
2. In case of reactor trip, the 4.16kV bus power source will be switched to essential buses automatically within 10 cycles.

Kuosheng NPP

The design of plant power supply and distribution system is described as follows:

1. The EDG system is divided into three divisions - Div. I, II, and III. The EDGs are Seismic Category I design and located at elevation of 12 meters above sea level. The 4.16kV essential bus of each division is powered by corresponding EDG. The rated speed and voltage of the EDG will be reached within 10 seconds. The type and capacity of EDG in Division I and II are identical. Either EDG has enough capacity for safe shutdown and they can backup each other. Div. III EDG and essential bus only provide power to High Pressure Core Spray (HPCS) system.

2. Safety related 480V Load Center (LC) and Motor Control Center (MCC) are powered by essential bus via step-down transformer. The normal power supply for the Hydrogen Ignition System (HIS) is provided by safety related 480V LC, with one specific standby diesel generator as backup.

Maanshan NPP

Each unit has 2 safety related buses and each bus is equipped with one 4.16kV, 7000 kW emergency diesel generator. Each EDG is connected to the safety-related 4.16 kV load group. In case of loss of voltage (LOV), EDG will automatically start and load in sequence to supply power to the ESF components to shut down the reactor safely. The EDGs are Seismic Category I design. The EDG building is located at an elevation of 15 meters above sea level, higher than the design basis tsunami height (12.5 m). The building exterior gate is explosion-proof, but not water-tight.

Lungmen NPP

Lungmen Station has three seismic category I EDGs (EDG-A/B/C) located on 3 corners of Reactor Building at elevation 12.3meters. If any one of EDG A/B/C fails, the 7th EDG can take over its' design function. This 7th EDG is also seismic category I designed and located in Auxiliary Fuel Building at elevation 12.3 meters.

5.1.1.2. Autonomy of the on-site power sources

Chinshan NPP

Emergency diesel generator A and B (EDG A /B):

1. Fuel: Each diesel generator set has an independent fuel supply system. Each day tank has a minimum capacity to run its diesel generator set under full load for one hour. This tank has outdoor emergency fuel cap to make up fuel. The fuel oil transfer pumps are used to replenish the day tanks through independent lines from a 850×10^3 -gallon common fuel oil storage tank, which is filled with more than 450×10^3 gallons normally. This amount can provide 4 EDGs to run continuously for 17 days. The fuel for auxiliary boilers and gas turbines can be used to support EDG operation. The capacity of gas turbine fuel storage tank is 35×10^3 kiloliters and normally is filled with 12×10^3 kiloliters.
2. Cooling: The engine in each DG set is cooled directly by a forced circulation cooling water system. Then, the heat is removed by Combined Structure Cooling System (CSCW) to sea water, which is the ultimate heat sink.
3. Auxiliary system:
 - (1) Starting and controlling power of EDGs are supplied by 125VDC from 125V SWBD #1 or 125V SWBD #2, which can back up each other.
 - (2) Each EDG has one independent air starting system. This system has two motor driven air compressors to transport the compressed air to four air tanks. The EDG starting air reservoir has enough air for 6 consecutive startups.

Kuosheng NPP

Each emergency diesel generator is equipped with one fuel storage tank. The capacity of fuel storage tank is roughly 210 kiloliters each for Div. I/II EDG or the 5th EDG. The capacity of fuel storage tank in Div. III EDG is roughly 114 kiloliters. Without external support, the capacity of fuel is sufficient for each EDG to run continuously for 7 days. It takes about 20 minutes to startup the 5th diesel generator and to provide power to essential bus.

If necessary, existing station mobile tanks can be used to transport diesel from auxiliary boiler fuel storage tank and gas turbine fuel storage tank to EDG fuel storage tank. The capacity of gas turbine fuel storage tank is 12,336 kiloliters which is enough for two gas turbine generators to run continuously 72 days at full load. A transportation exercise was performed in 2011 and the feasibility of using mobile tank for fuel make-up was confirmed.

Maanshan NPP

1. EDG fuel storage and transfer system

The fuel storage and transfer system of EDG are Seismic Category I design. Each EDG is equipped with one fuel daily tank, one fuel storage tank and two fuel transfer pumps. The capacities of fuel daily tank and fuel storage tank are 1,950 gallons and 94,000 gallons respectively. This can support EDG continuous running at rated load for 4 hours and 7 days respectively. The minimum amount of fuel in fuel daily tank and fuel storage tank required by technical specification are 533 gallons and 81,420 gallons respectively.

Besides this, the fuel for auxiliary boilers and gas turbines can be used to support EDG operation. The capacities of auxiliary boiler fuel storage tank and gas turbine fuel storage tank are 1,155 kiloliters and 35,000 kiloliters respectively. This can support one EDG continuous running at rated load for 14 days and 140 days (assuming gas turbine fuel storage tank normally filled with 11,000 kiloliters of fuel) respectively.

2. The cooling water of EDGs is provided by Nuclear Service Cooling Water system.
3. EDGs startup air system: Except air compressors, the EDG is Seismic Category I design. Each EDG is equipped with two independent startup air systems. The EDG starting air reservoir has enough air for 5 times of startup.

Lungmen NPP

Emergency Diesel Generator (EDG A/B/C)

1. Fuel : Each EDG is equipped with one day tank with capacity 12 kiloliter and one storage tank with capacity 450 kiloliter. They can provide 1 EDG to run continuously for 5 hours and 7days, respectively. Fuel storage tank has gas cap to make up fuel from tank truck.
2. Cooling : Water-cooled.
3. Supporting System :
 - (1) DC controlling power of each EDG is provided from associated safety division DC system.
 - (2) Starting air system provides compressed air to start EDG and off-site power is not needed during starting. The EDG starting air storage tank can provide starting air for 5 times consecutively without running air compressor.
 - (3) Cooling water is provided from safety related Reactor Building Cooling Water (RBCW) system. Heat absorbed by RBCW is removed by the Reactor Building Service Water (RBSW) System.

5.1.2. Loss of off-site power and on-site back-up power (EDG)

In case of loss of offsite power and onsite back-up power, the station has a swing emergency diesel generator and two gas turbine-generators for SBO. These generators are air-cooled. The design provisions of these systems will be described as follows:

5.1.2.1. Design provisions

During SBO, reactor water level can be maintained by running RCIC(TDAFW for PWR). The operation of RCIC relies on 125V DC power. The battery set can provide DC power for 8 hours without considering the availability of the swing EDG and gas turbines.

Chinshan NPP

1. The plant has one additional 4000kW air-cooled safety-related swing EDG (5th EDG) located at elevation of 11.2 meters serving as the backup of the four EDGs of both units. It can perform the same function as the specific EDG being substituted. The 5th EDG, in full load operation, can provide all the AC power required by ECCSs. The start and control power of the 5th EDG are 125VDC, which is provided by independent battery set. The capacity of fuel daily tank is 1300 gallons, which can provide fuel for 4 hours continuous running. There is also one fuel storage tank with 52000 gallons capacity normally, which can provide fuel for 8 days continuous running. Fuel storage tank has exterior fuel cap to make up fuel. The 5th EDG can be started manually in control room to substitute any EDG of either unit.
2. Two air-cooled gas turbine generators with black-start capability located at elevation of 22.4 meters each has capacity of 69,600kVA. These two gas turbines can provide AC power if LOOP or SBO occurs. It takes about 10 minutes from start to engage into the distribution system; and takes about another 7.5 minutes to full load (50MW). Normally, the power needed to start gas turbine is provided from 69kV bus which is stepped down to 4.16kV. The gas turbine black-start power is provided from the two 1100kW 4.16kV appurtenant diesel generators, which are started by the 24 VDC battery sets. The control power of gas turbine generator is supplied by an independent DC battery set. The gas turbine set has one 35,000 kiloliters storage tank. Diesel fuel is transported to the 3 daily tanks, each with capacity of 600 kiloliters (158 x10³ gallons). The diesel fuel is normally maintained more than 12,000 kiloliters, which is enough for one gas turbine continuous running for 30 days. Each daily tank has exterior fuel cap to make up fuel.

Kuosheng NPP

1. The 5th diesel generator:

The plant has one additional 3,910 kW air-cooled diesel generator (5th EDG) located at elevation of 12 meters. It is the backup for the Div. I or II EDGs of both units. When the Div. I or Div. II EDG of any unit losses its essential power supply function, the 5th diesel generator can be manually put in operation in Control Room to substitute the malfunctioned EDG. Any essential bus of two divisions can provide enough power supply to maintain the unit in safe shutdown condition.

2. Gas Turbine Generators:

The plant is equipped with two air-cooled gas turbine generators with black-start capability located at elevation of 22 meters and capacity of 50 MW. Each gas turbine generator can provide enough power needed for the load of non-safety related buses and essential buses in both units to maintain the units in safe shutdown condition. It takes about 20 minutes to startup the gas turbine generator and to engage to the 69kV system.

Maanshan NPP

The plant has third power source. Through 11.4kV distribution line, power can be supplied to safety-related buses.

1. The 5th EDG

The 5th EDG is air-cooled. The rated load is 7,159 kW. The excitation power is independent of the onsite auxiliary AC power. The fuel storage tank of the 5th EDG can be accessed from the top of the tank. The 5th EDG fuel storage tank with a capacity of 118,730 gallons can support EDG continuous running at rated load for 7 days.

The operation of 5th EDG can be extended to 14 days by transferring fuel from the 1,155 kiloliters auxiliary boiler fuel storage tank to the fuel storage tank of 5th EDG. Fuel makeup to the fuel storage tank of 5th EDG can be taken from 35,000 kiloliters gas turbine fuel storage tank by fuel tanker. The gas turbine-generator fuel storage tank is normally filled with 11,000 kiloliters of fuel. It can provide one EDG continuous running for 140 days at full load. If the fuel in gas turbine fuel tank is used up, offsite supplement is needed. All the tanks that can provide fuel to EDG and gas turbine have been identified and listed.

The startup air system is composed of two independent compressed air subsystems. Any compressed air subsystem can start up the 5th EDG. The 5th EDG starting air reservoir has enough air for 5 times of startup. The 5th EDG can be started manually in control room to substitute any EDG of either unit.

The 5th EDG is Seismic Category I design. It is located at an elevation of 15 meters above sea level, higher than design tsunami height of 12.5 meters. The gate of the 5th EDG building is explosion-proof but not water-tight.

2. Gas turbine generator

The rated capacity of each gas turbine generator with black-start capability is 51.48MW (base output). The gas turbine-generator has one fuel storage tank with a capacity of 35,000 kiloliters and 2 daily tanks with a capacity of 600 kiloliters. The fuel storage tank is normally filled with 11,000 kiloliters diesel. It can provide 2 gas turbine-generator sets continuously running at full load for 14 days. If the fuel is less than 10,000 kiloliters, it has to be replenished.

Gas turbine-generator set is not Seismic Category I design. It is located at an elevation of 35 meters above sea level, higher than design tsunami height of 12.5 meters. There is also no concern of flooding due to heavy rains.

Each gas turbine-generator set is equipped with one 1,100kW black-start diesel generator. If offsite power is available, the offsite power provides the power for control. If offsite power is unavailable, black-start generator diesel engine provides the power for control at startup stage.

3. The third power supply (refer to Figure 5-2)

The third power supply is stepped down from 11.4kV system and the power from gas turbine can be served as the back-up power of safety-related 4.16kV buses.

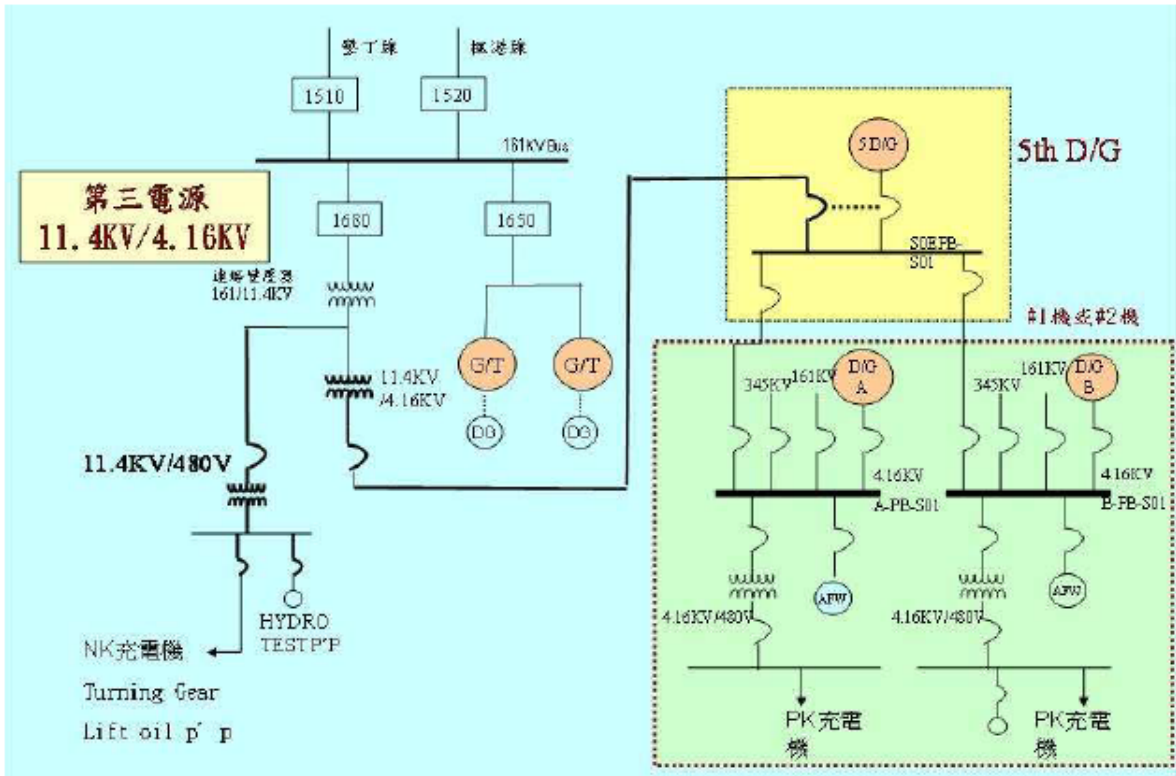


Figure 5-3 The third power supply at Maanshan

Lungmen NPP

1. The 7th EDG is air-cooled with capacity 7800kW. The function and fuel storage capacity of 7th EDG are the same as the pre-selected EDG being substituted. The 7th EDG, in full load operation, can provide all the AC power required by ECCSs. The 7th EDG, located at auxiliary fuel building, is separated from other EDGs. The start and control power are 125VDC, which is provided by independent battery set.
2. The station has plan to install two air-cooled gas turbine generators located at seismic isolated building with capacity 12MW~50MW. In case of loss of all off site power, the gas turbine can provide AC power to safety and non-safety 4.16kV bus (13.8kV to 4.16kV).

5.1.2.2. Battery capacity and duration

Chinshan NPP

The capacity of the 5th EDG 125VDC battery set is 410AH. This capacity can provide DC power to the essential loads for 8 hours. The capacity of each gas turbine 125V DC battery set is 400AH. It is also enough for 8 hours continuous operation.

Kuosheng NPP

Because any of gas turbine generators or the fifth DG can provide the power supply to the station essential buses which can provide power to each essential and non-essential DC charger power supply, the batteries are therefore continuously recharged. As long as the Gas Turbine Generator or the fifth DG is operational, the long term DC power is assured.

Maanshan NPP

The battery capacity of the 5th EDG is 125VDC/220AH. It can provide emergency power for 2 hours. The battery set of black-start DG of gas turbine generator consists of 6 batteries with a capacity of 200AH each which provides the 24VDC required by black-start DG startup. Once gas turbine generator or 5th EDG is started, AC power can be provided to charge the battery which is used to startup the EDG.

Lungmen NPP

The capacity of DIV. 0 125V DC Battery for 7th EDG is 1800AH. Based on FSAR, this capacity can provide DC power at least for 3.5 hours.

5.1.2.3. Envisaged measures to increase robustness of the plant

Chinshan NPP

1. Enhanced measures for building waterproofing: All EDGs, the fuel storage tanks, 4.16kV switchgears and MCCs are located above ground level, except the low voltage MCCs in Corner Room, which are located below ground level. As a design modification, flood barrier panels will be installed at doors and openings of the buildings of unit 1, unit 2, 5th EDG and ESW pump room to ensure the integrity of EDG and 4.16kV switchgear room.
2. The plant has recently installed an additional air-cooled spent fuel pool cooling system (SFPACS). This system is regarded as an alternative RHR system and can help the station to resolve the cliff edge effect. Currently, SFPACS has not been connected to RHR.

3. Procedure for Power Source Restoring Actions:

The procedure 535 has been modified to have the power source rescuing actions:

- emergency power supply from the EDG of another unit

The procedure 1451 has the following power source rescuing actions

- Power supply from 480V movable diesel generator
- Units 1 and 2 power supply from gas turbine 4.16kV black-start diesel generators
- Power supply from 4.16kV mobile diesel generator

4. Enhanced measures to provide emergency 4.16kV/480V AC power in case of SBO.

- (1) In case of emergency, it only requires one RHR, one ECWP, and one E-chiller to maintain reactor long term cooling. The total horsepower of these three facilities is 1,275 kW. The 5th DG with the capacity of 3,910kW is sufficient to provide 4.16kV emergency power to both units simultaneously with load shedding.
- (2) The two 4.16kV black-start diesel generators of gas turbines set has been modified to provide power to 4.16kV safety-related essential buses.
- (3) The plant will add eight 480V 500kW mobile diesel generators. The mobile diesel generators will be connected to battery charger to provide DC power to 125VDC bus, vital UPS, and 480V loads.
- (4) TPC will purchase six 4.16kV 1500kW mobile diesel generators. One of which will be allotted to the CS station. One will be placed onsite. The other one will be placed at Lungmen station temporarily. A connection is foreseen to be able to provide power to 4.16kV safety-related essential buses from the mobile diesel generators.
- (5) The power transformer of TSC building lighting system (including backup TSC, Unit 2 meeting room) will be moved from outdoor 1st floor to an elevated position and quick connections to mobile diesel generators will be added.

5. RCIC Emergency DC power

In SBO, the DC power required by the RCIC can be maintained for 24 hours with load shedding. A modified SBO procedure has been established accordingly. In addition, any of the AC measures described above can ensure the availability and durability of DC power supply required by RCIC and ADS.

6. Mobile Injection Equipment

The plant has proposed to procure 8 moveable large capacity fire engines. The residual heat can be removed by vaporization of the primary coolant and injection of water from these fire engines. Capacity: 38.2kW 2000 lpm@6kg/cm², 1500 lpm@10kg/cm².

Kuosheng NPP

1. Enhanced measures for EDG Building waterproofing: Flood barrier panels will be installed at personnel hatch and equipment hatch of the EDG building.

2. Enhanced measures for Emergency Circulating Water pump Room waterproofing:

The waterproof wall of ECW pump room was added to reach to the top of ceiling and all penetrations are sealed. After the improvement, the height of tsunami surge protection will be the same as that of ground level (12 feet). It can protect the ECW and the EDGs (Div. I, II, III) from the sea water invasion.

3. Power supply enhancement: In case of loss of both off-site and on-site AC powers, the following provisions can provide emergent 4.16kV/480V AC power:

(1) The Design Change Requests for both units were issued to allow the two 4.16kV /1,100kW black-start diesel generators of the gas turbines set to provide power to the essential buses. This has been completed.

(2) It is planned to provide 4.16kV emergency power directly to the essential switchgear buses to enhance the robustness of the system when non-segregated phase bus fails.

(a). The plant already revised the procedure 1451 to provide an operation guideline of which one set of EDGs can supply power to the essential buses(at limit load) in both units.

(b). The plant already revised the procedure 1451 in order that the fifth air-cooled Diesel Generator can simultaneously support both units and not impacted by non-segregated phase bus (NPB) malfunction.

(c). Two design changes were made so that the power supply from black-start diesel generator or 1500kW mobile power engine can be provided directly to essential bus in case of emergency without being impacted by NPB malfunction. In case of medium voltage switchgear malfunction, power will be provided to the safety related equipment by the jump connections of the cables in the same switchgear room. This jump connection can be completed within 8 hours.

(3) The two 480V/200kW DGs will be lined up from TSC/OSC to LC.

(4) Four sets of 480V 200kW mobile diesel generators are added to provide power to LC. This can provide power supply to 125V DC charger and essential 480V loads such as UPS, HIS etc. The construction has been completed [for unit 1 and 2 in 2012](#).

(5) TPC already procures 6 sets of 4.16kV 1500kW mobile DG power engines.

As long as any one of above-mentioned 4.16kV power sources is put in service, essential buses can provide the required long term power. If all the 4.16kV diesel generators are unavailable, TSC/OSC diesel generators or mobile 480V diesel generators still can supply

power to 480V essential buses which can provide the required long term power.

4. Enhancement of the emergency operation capability of RCIC & SRV:

(1) Enhancement of DC power supply:

- (a) Any one of above-mentioned measures can ensure that the required DC power for RCIC & SRV is available.
- (b) Five sets of small scale 120V mobile generators and power suppliers are additionally procured to provide DC power to RCIC & SRV and other essential instrument control power in case of emergency.
- (c) Procedure has been revised to provide the guideline on how to provide power to RCIC & SRV using jump.

(2) RCIC will be manually restarted at site if its DC power supply is lost. The associated operation has been demonstrated to be feasible and has been incorporated into procedure 1451.

(3) Two sets of mobile diesel driven air compressors and two sets of high pressure boosters are procured to provide the required compressed air for SRV emergency operation. Besides, a design change was undertaken to install emergency nitrogen fill piping and its adapter outside the building in order to provide the required compressed air for SRV emergency use.

5. Enhancement of reactor water makeup capability: The plant can make up water to reactor by gravity from the fire raw water system on the hill. In addition to that, the plant already review and plan to procure five sets of large scale fire pumps and one set of fire tanker equipped with pressure pump to enhance the station's mobile injection capability. The reactor water makeup can be done through each kind of the above-mentioned alternate water sources programmed in the procedure 1451.

Maanshan NPP

1. For flood prevention, the plant has proposed a design change request to evaluate the feasibility of installing flood barrier panel at the gates of the buildings enclosing safety-related systems. When Central Weather Bureau issues warning of typhoon plus heavy rain, or it is judged that the site has the possibility to be flooded, flood barrier panel will be installed to prevent water intrusion. The station has also proposed a design change request to improve the water-tight capability for the fire protection door or explosion protection door of buildings with safety-related systems. The doors after modification will be a barrier to prevent flood intrusion into key area or rooms.
2. TPC's "Nuclear Power Plant Seismic Evaluation Taskforce" has completed the seismic evaluation of gas turbine-generator and raw water reservoir. The station will implement the enhancement measures based on task force evaluation results.
3. For the crane in EDG building, gas turbine and the 5th EDG building, a safe crane parking point and a crane locking device have been proposed. The parking point is designated that there is no safety related component under the crane. Crashing of crane during earthquakes will not damage any safety related component. Locking device ensures that crane will not have a horizontal movement during earthquake, and will keep crane fixed at the safe parking point.
4. The capacity of battery sets can ensure continuous DC power supply for 8 hours. The related load shedding steps have been included into procedure 570.2. The station will purchase 480V mobile DGs. With quick connecting interface, the 480V mobile DG can charge battery sets and maintain the battery set with long-term supply capability.

5. The feasibility for the 5th air-cooled diesel generator to provide emergency AC power to both units simultaneously has been validated. The terminal points for quick connection have been set up. The related instructions have been included in plant procedure 1451.
6. The EDGs of each unit can support each other via the bus S-0E-PB-S01. The test has been completed and operating steps have been incorporated into plant procedure 1451.
7. TPC will procure six 4.16kV /1500kW mobile diesel generators, of which two will be placed in Maanshan station. The connection between the new mobile diesel generator and the existing equipment will be set up.
8. Ten 370kVA/480V mobile diesel generators have been procured to provide AC power to:
 - (1) battery charger to maintain 125VDC bus power
 - (2) vital water pumps to supply water to critical equipment/facilities
 - (3) important 480V loads such as: telephone exchange/TSC/control room in order to maintain the necessary communication, command, habitable systems

A DCR has been set up to install 480V mobile diesel generators power supply interface to facilitate rapid connection with mobile emergency 480 V power source.
9. The plant has already prepared 24 small mobile generators. They can provide power to submerge pumps, exhaust fans, and radiation monitors to ensure the proper function of those rescuing equipment or instruments.
10. If onsite water is not enough, water can be made up to CST, RWST, SFP, and RCS by fire engine. The plant is procuring one chemical foam fire engine with capacity of 7 tons; one water tanker fire engine with capacity of 12 tons. Offsite water sources can be taken from No.2 and No. 3 deep wells, Longluan deep pool, Modan reservoir, and sea water.
11. The plant has procured 3 mobile air compressors to provide working air.

Lungmen NPP

1. To ensure the integrity of EDG and 4.16kV switchgear room, enhanced measures have been implemented, for example, flood barrier panel installation and door seal rubber modification.
2. Enhanced measures to provide emergency 4.16kV/480V AC power in case of SBO.
 - (1) The two gas turbine generators will be added to provide power to 4.16kV A4/B4/C4/S4 BUS (in Construction).
 - (2) Starting diesel generators of gas turbine generators will provide power to 4.16kV Bus (in installation).
 - (3) Adding two 4.16kV/1500KW mobile generators to provide power to 4.16kV Bus and any train of RHR 、RBSW 、RBCW.
 - (4) Use 11.4kV/1250KW security system EDG to provide power to 4.16kV Bus and downstream 480VAC.
 - (5) In emergency, 7th EDG simultaneously provides power to both units.
 - (6) Unit 1 EDGs and Unit 2 EDGs can support each other in case of emergency.
 - (7) Adding five 480V 100kW mobile diesel generators to provide power to 480VAC PC/MCC (both Q and NON-Q). Thus, AC power is available to battery charger and DC power is available to DIV. I 125VDC bus and DIV. I CVCF.
3. Running RCIC can consume steam in reactor and can inject water into reactor. The speed

governor of RCIC turbine requires DC power. Based on the existing design, DC power can be supplied for 8 hours. During SBO, the duration of DC power supply to RCIC and SRV/ADS can be extended to 24 hours with load shedding. In addition, any of the AC enhancement measures described above can ensure the availability and durability of DC power supply required by RCIC and ADS.

4. If ECCS (including RCIC) is expected to be unavailable due to SBO, a controlled depressurization of the reactor must be performed while ECCS is still available. Once the ECCS is also unavailable, an emergency depressurization of the reactor must be performed immediately by opening SRVs. As reactor pressure drops below 0.6MPa, RHR ACIWA MODE can be used to inject raw water into reactor directly. Water can also be made up by gravity from raw water reservoir(24000 ton x2), located at elevation 116 meter, through fire piping to ACIWA piping, and finally to reactor.
5. The related emergency operation steps have been incorporated into Ultimate Response Guideline (URG) 1451.

5.1.3. Loss of off-site power, ordinary back-up power, and other diverse back-up power

This paragraph considers the loss of all sources of electric power, external or internal, first - level and second level.

5.1.3.1. Design provisions

In case of station black out along with loss of the 5th EDG and gas turbine generators, DC power will be the only available power. The reactor water level and pressure can be maintained at least for 8 hours by RCIC. Redundant battery chargers are provided for each independent battery system. As long as battery charger is available, battery sets are available and vital DC and AC (via UPS) power will also be available.

[Chinshan NPP](#)

The distribution of DC power and instrument power are described as follows:

1. Safety related DC loads and equipment control power

The DC power of this category consists of three 125V switch boards. One switch board provides DC power to ECCS-A train, while two other switch boards provide DC power to ECCS-B train. This design ensures that the reactor protection system and ESSENTIAL system will preserve their intended functions if any 125V DC subsystem is unavailable.

2. 120VAC instrument power source

Each unit is equipped with two UPS output power source and the rated capacity of battery is 8 hours. The non-UPS instrument power will be lost in case of SBO.

3. RCIC and HPCI DC power

Reactor water make-up relies on the operation of RCIC or HPCI during SBO. The operation of RCIC or HPCI only requires DC power and steam. The DC power of RCIC and HPCI are provided from two independent 125V DC switch boards respectively.

[Kuosheng NPP](#)

The design basis for the required DC power supplied to RCIC is 8 hours. If unnecessary loads are isolated, the battery capacity can provide DC to RCIC for 24 hours continuously running. The battery can also provide the required control power to actuate SRV.

1. Safety related DC power supply: It consists of five 125V DC power supply systems,

which belong to Div. I, II and III load groups. The design feature is to ensure that any system failure does not impact RPS and ESF to perform their intended functions.

2. Three safety-related 120V AC instrument power distribution panels have been provided for power supplies to ESF instruments. Each distribution panel is supplied from its own 480/120-volt step-down transformer. The 120V AC UPS are provided by three battery sets respectively. Each battery charger is supplied from a separate 480-volt ESF MCC.

Maanshan NPP

1. SBO event evolution

Loss of offsite power will cause reactor and turbine trip, the closure of MSIVs, the actuation of PORVs of SG, the decrease of SG water level, and the startup of the steam driven auxiliary feedwater pump. This pump will make up water into SG to maintain its water level and to consume some steam. Plant procedure 570.20 will be used to handle the SBO event. Based on NUMARC-87-00, it is assumed that each RCP has a 25gpm leakage during the first 8 hours of SBO. With this leak rate considered, the analysis in FSAR shows that the reactor core will not be uncovered during this period because the auxiliary feedwater system and PORV of SG can perform their design function.

2. Evaluation of the capacities and the design limits of mitigation systems

The capacities of the condensate storage tank, the compressed air system, the instrument and control system, the battery, the communication system and the lighting system have been evaluated. Each of them has shown to have enough capacity to perform its intended function within the first 8 hours of SBO.

Lungmen NPP

If loss of offsite power, EDG A/B/C, 7th EDG, and gas turbine generators, DC power will be the only available power. The operation of RCIC relies on 125VDC power. The design of CVCF and DC power is as follows :

1. CVCF System

Safety essential AC powers include 3 CLASS 1E CVCF subsystems. The normal input of these CVCFs is three phases 480V AC and standby 125VDC. The output of CVCF can provide uninterrupted 120V AC power with stable voltage and frequency.

The capacity of CVCF can last for at least 8 hours. The safety essential CVCF 480V power can be supplied from EDG A/B/C and SEDG.

2. DC System

- (1) The safety DC system includes 3 CLASS 1E 125VDC subsystems. It can provide reliable DC power to ensure safe reactor shutdown.
- (2) In normal operation, DC Bus is charged from Normal Charger. The Battery Charger is powered from 480V bus.

5.1.3.2. Battery capacity and duration

Chinshan NPP

RCIC 125V DC power is provided from 125V switch board-1; while HPCI 125V DC power is provided from 125V switch board-6. Both of these two switch boards can provide DC power for at least 8 hours.

Kuosheng NPP

1. KSNPP has issued a DCR to upgrade the capacity of battery set A, B, C & D from the original designed 8 hours power supply capacity to 24 hours power supply capacity.
2. Except for 24 hours power supply capacity, the operation time period of stations enduring SBO accident can reach 24 hours according to the further assessment performed by TPC in June 2010. The related load shedding operation is included in the procedure 500.15.

Maanshan NPP

The capacity and operation duration of battery train A, B, C, and D has been evaluated. It is shown that for the existing minimum loads at SBO, the designed battery rated capacity can continuously provide DC power for at least 8 hours.

Lungmen NPP

In case of SBO and loss of 7th EDG, reactor water level can be maintained by RCIC. The DC power is designed to support RCIC for at least 8 hours. The analysis of FSAR indicated that RCIC can run for at least 21 hours (It is approximately 24 hours with load shedding).

5.1.3.3. Autonomy of the site before fuel degradation

Chinshan NPP

The reactor water level and pressure can be maintained by RCIC for at least 8 hours. If reactor and spent fuel pool water level is maintained by raw water (Ultimate Response Guideline), the amount of water can be provided continuously for 9 days. If continuous actuation of ADS/SRV is considered, the air supply source gives autonomy of 11.2 hours. Therefore, the station can withstand the effects of SBO for at least 11.2 hours (RCIC+Raw water Injection). In the case of emergency, HPCI can be used to provide water and to depressurize the reactor vessel. However, because ultimate heat sink will be lost during SBO, the suppression pool water temperature will increase rapidly once HPCI is put into operation. Therefore HPCI should be used discreetly.

Kuosheng NPP

In case of station black out and loss of gas turbine and the 5th diesel generator, the reactor water level can be maintained by RCIC. The design DC power capacity of RCIC can last for 8 hours (The DC power capacity is enough for 24 hours if unnecessary loads are isolated).

Maanshan NPP

1. If SBO occurs, emergency operating procedure EOP 570.2 has to be followed immediately. To ensure that CLASS-1E battery sets are capable to provide the total DC demand in SBO, unneeded loads have to be isolated within 30 minutes after SBO.
2. In the case of loss of all DC power, turbine driven AFP and PORV of SG still can be manually operated to make up water into SG and to release steam from SG. These actions can control RCS temperature and pressure to ensure core cooling.
3. If turbine driven AFP is unavailable, one added diesel driven AFP after 2001 SBO event can make up water into SG.
4. The unit will take about 16 hours from hot standby to hot shutdown. This process will require approximate 1,041 tons of water. The available volume of CST is 2,680 tons which is adequate for 40 hours. The available volume of DST is 378.5 tons which is

adequate for 6 hours. If AFP intakes water from raw water reservoir (100,000 tons), it is adequate for 32 days for two units.

Lungmen NPP

- (1) By means of reactor depressurization and containment ventilation, more time is available to recover AC power.
- (2) RCIC pump can be run by manually open one steam inlet valve and one water discharge valve. These two valves are located outside the containment to provide free access.

5.1.3.4. Foreseen actions to prevent fuel degradation

Chinshan NPP

1. Station existing equipment, e.g., equipment of other unit

- (1) Establish 24 hours DC power capability in SBO

Based on the SBO loads listed in FSAR, the discharge capacity (amp-hour, AH) of each battery set was calculated. Among these battery sets, three 125V DC battery sets are insufficient for 24 hour needs. On the other hand, one battery set has 1867AH excess power. By load manipulation, the target to provide DC power continuously for 24 hours is accomplishable with 473AH margin.

RCIC can maintain reactor water level and pressure for at least 24 hours by isolating some DC loads and shifting loads. Currently the shifting among 125V DC Battery-1, -2, -6, and -7 in SBO has to rely on non-seismic class I electric circuit. A design change will be made to modify the wiring to let Battery-6 directly provide power to SWGR-1, -2, and -7.

- (2) In “535 Station black out” procedure, the emergency diesel generator of either unit can be used to supply power to the other unit via the 5th EDG distribution panel. This procedure also describes the steps for load control and power saving.
- (3) The plant has planned to prepare movable diesel generators, which will be connected to battery charger to prolong the battery capability of providing DC power.
- (4) The plant has several fire engines. These fire engines can take suction from raw water reservoir, ChienHwa stream, or sea water. The outlet of fire engine can be connected to Backup Containment Spray System (BCSS) to inject water into reactor or suppression pool to prevent fuel degradation.

2. Supports available from offsite if all onsite equipment are damaged

- (1) If all the mitigating systems are unavailable along with the loss of ultimate heat sink (loss of power supply), available offsite supports include fire equipment from site and Kuosheng Plant, and also from Shiman, Chinshan, and Shanzhi districts.
- (2) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four mobile diesel generators from Kuosheng station. In addition, mobile diesel generators supported from Lungmen plant are also available.
- (3) Chinshan Plant and NewTaipei city government has signed a protocol of fire fighting support. Depending on the characteristics of event, Fire Bureau will support manpower, vehicles, and equipment to site to mitigate emergency.

3. Power cable specially connected to the power plants in the vicinity:

Kuosheng nuclear power plant and Linko fossil power plant are the two plants in

vicinity. However, no special power cables are connected to these two plants.

4. The required operation time for above mentioned systems

- (1) It takes about 25 minutes for station fire engine taking suction from raw water pump room, through BCSS and RHR piping system, and injecting into reactor core.
- (2) Assuming the fire engines are standing by with water filled and the water injection paths are lined-up, the total required operation time will be the same as the driving time. It takes about 10 minutes for fire engines driving from Shiman district to station. It takes about 20 minutes for fire engines driving from Shanzhi or Chinshan district to station; and 30 minute for fire engines from Wanli district. It takes about 25 minutes for fire engines driving from Kuosheng nuclear power plant to station.
- (3) It takes 2 and 5 hours to move the Kuosheng and Lungmam mobile diesel engine to station, respectively.

5. Availability of qualified operators to perform above actions

The operation of systems and equipment are performed by shift staff. Other manpower required must be supported from offsite. The operations of fire engines are performed by fireman. The operators are well trained to meet the mission requirements.

6. Confirming the critical time before the onset of damage in this scenario

If DC power is unavailable, then:

- (1) The reactor pressure will be released by the safety function of ADS/SRV. If continuous actuation of ADS/SRV is considered, a design change will be implemented to extend the supply of working air to 48 hours. Based on above description, the station can withstand SBO for more than 48 hours (RCIC+ Raw water system) without offsite support, if system betterment is completed. Before the implementation of this design change, air supply hose and connectors are placed on the 1st floor of reactor building temporarily. In case of emergency, 40 bottles of standby HCU N2 can be connected to supply working gas to actuate ADS/SRV for 43.2 hours. In addition, throttling the bypass valve in the primary containment N2 purge system can provide SRV/ADS operating gas for longer period.
- (2) Reactor water level can be maintained by supplying raw waters (Ultimate Response Guideline). For combined events, the total required amount of reactor and spent fuel pool makeup water is 1600 gpm (363.4 ton/hour). The raw water storage capacity can provide makeup water for 220 hours (9.17 days). If taking water from brook, the duration of making-up water can be longer.
- (3) Approximate 40 hours after reactor depressurization and water injection, torus water level will increase to the elevation of vent pipe. As a consequence, torus can not be vented and drywell vent will be implemented instead.

[Kuosheng NPP](#)

1. Station existing equipment, e.g., equipment of other unit

RPV can be depressurized via SRV and the water in fire protection storage tank system can be used to prevent fuel degradation via gravity feed in case of station black out.

2. Supports available from offsite if all onsite equipment are damaged

- (1) Kuosheng has signed an agreement with New Taipei city government Fire Bureau for off-site support. If equipment is all damaged, the New Taipei city government Fire Bureau can provide fire engine, chemical foam truck, and/or aerial ladder fire truck for emergency response or reactor water makeup.
- (2) TPC already procured 6 sets of 4.16kV 1500kW mobile diesel generator power

engines which are scheduled delivery in April, 30, 2012. One set of them will be allocated for KSNPP and three sets will be allocated for CSNPP and Lungmen Project. If required, they are also available for KSNPP.

3. Power cable specially connected to the power plants in the vicinity:
Chinshan nuclear power plant and Shieho fossil power plant are the two plants in vicinity. However, no special power cables are connected to these two plants.
4. The required operation time for any of the above-mentioned system
Water is supplied by gravity from the fire raw water system on the hill. It takes about 40 minutes to open the blind plate.
5. Availability of qualified operators to perform the special line-up
The operators who are responsible for the operations of above mentioned actions are well trained and exercised. They can meet the mission requirements.
6. Confirmation of the cliff-edge effective occurrence time:
In the case that the DC power that is required for the operation of the RCIC & SRV is consumed and no countermeasure is adopted, the reactor pressure relief and water makeup function will be hampered. Meanwhile, low pressure injection system will not be able to inject water to reactor due to high reactor pressure so that the nuclear fuel in the reactor will be uncovered and degraded due to the lack of water makeup.

Maanshan NPP

If onsite water source is inadequate, water can be made up from fire engine to CST, RWST, SFP, and RCS. The plant has one 7 tons fire water tankers. The Pingtung County Fire Bureau has two 10 tons and two 12 tons water tanker; one 3 tons and four 3.5 tons water tanker; and also have four 1 ton small water tankers. Offsite water sources can also be taken from No.2 and No. 3 deep wells, Longluan deep pool, Modan reservoir, and sea water. The supply of supporting manpower from contractors is governed by the contract.

Confirming the critical time before the onset of damage in this scenario

The available volume of CST is 2,680 tons which is adequate for 40 hours. The available volume of DST is 378.5 tons which is adequate for 6 hours. The total is 46 hours. If AFP intakes water from raw water reservoir (100,000 tons), it is adequate for 32 days for two units.

Lungmen NPP

1. Station existing equipment, e.g., equipment of other unit

- (1) Establish DC power 24 hours capability in SBO

Based on the calculated battery set discharge capacity (amp-hour, AH) , it is shown that in case of SBO, the battery set can supply DC power to RCIC for at least 24 hours with load shedding.

- (2) The station has several fire engines. These fire engines can take suction from raw water reservoir, Chinren lakelet, Shiding rivulet, Shuangxi rivulet, or take sea water from discharge channel. The outlet of fire engine can be connected to RHR system ACIWA to inject water into reactor or suppression pool to prevent fuel degradation.
2. Supports available from offsite if all onsite equipment unavailable
Offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from

station, Gongliao, Shuangxi, and Ruifang District.

Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and eight 480V 500kW mobile diesel generators from Chinshan station.

Lungmen station and New Taipei city government has signed a protocol of firefighting support. Depends on the characteristic of event, Fire Bureau will support manpower, vehicles, and equipment to site to mitigate calamity.

3. Power cable specially connected to the power plants in the vicinity

Kuosheng nuclear power plant and Linko fossil power plant are the two plants in vicinity. However, no specific power cables are connected to these two plants.

4. The required prestage time for above mentioned systems

- (1) It takes about 30 minutes for station fire engine taking suction from raw water pump room, through RHR piping system, and injecting into reactor core.
- (2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.
- (3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.
- (4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

5. Availability of qualified operators to perform the above actions

The operation of systems and equipment are described in URG 1451. The support manpower from offsite is commanded by shift supervisor. The operation of fire engines and fire equipment are performed by fireman. The operators are well trained to meet the mission requirements.

6. Confirming the critical time on the verge of an event

If DC power is unavailable then :

- (1) If loss of DC power, the safety function of ADS/SRV can release reactor pressure. Normally, ACS nitrogen tank provides the working gas ; abnormally, the two groups of nitrogen cylinders (DIV. A and DIV. B) supply the working gas. The capacity of each division can maintain SRV/ADS continuously in open position for at least 7 days. Besides, each SRV/ADS has accumulator. Thus, each SRV/ADS can be actuated once under drywell design pressure and five times under drywell normal pressure.
- (2) Following “Ultimate Response Guideline”, reactor water level is maintained by supplying raw water. For combined events occurred in both units, the total required makeup water, including reactor and SFP, is 1947gpm (442.2ton/hour). The raw water storage of 3.84×10^4 ton can supply continuously for 86.84 hours (3.62 days) .
- (3) However, approximate 15.6 hours after reactor depressurization and water injection, suppression pool water level will increase to the elevation of vent port. As a consequence, wetwell can not be vented and drywell vent will be implemented instead.

5.1.3.5. Envisaged measures to increase robustness of the plant

Chinshan NPP

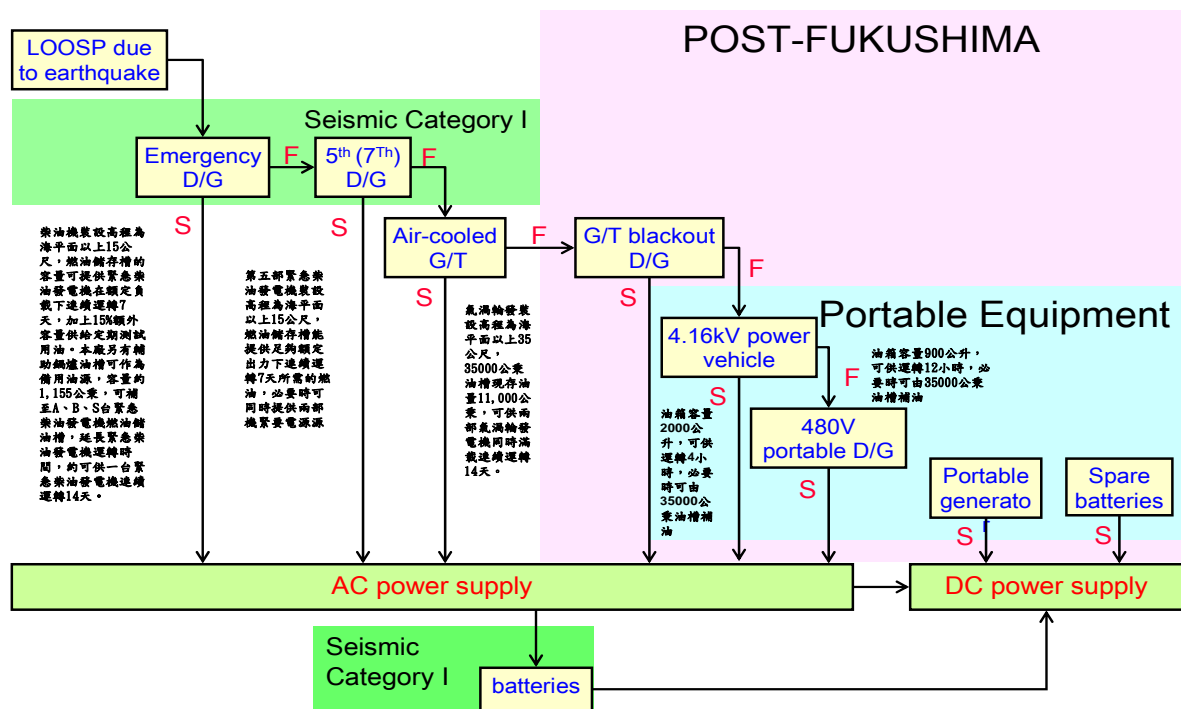
1. Operation of RCIC/HPCI without DC supply (manual startup)
RCIC will be manually restarted if its DC power supply is lost. The operating steps have been demonstrated to be feasible and have been incorporated into procedure.
2. Most of the measures described in Section 5.1.2.3 are also applicable.

Kuosheng NPP

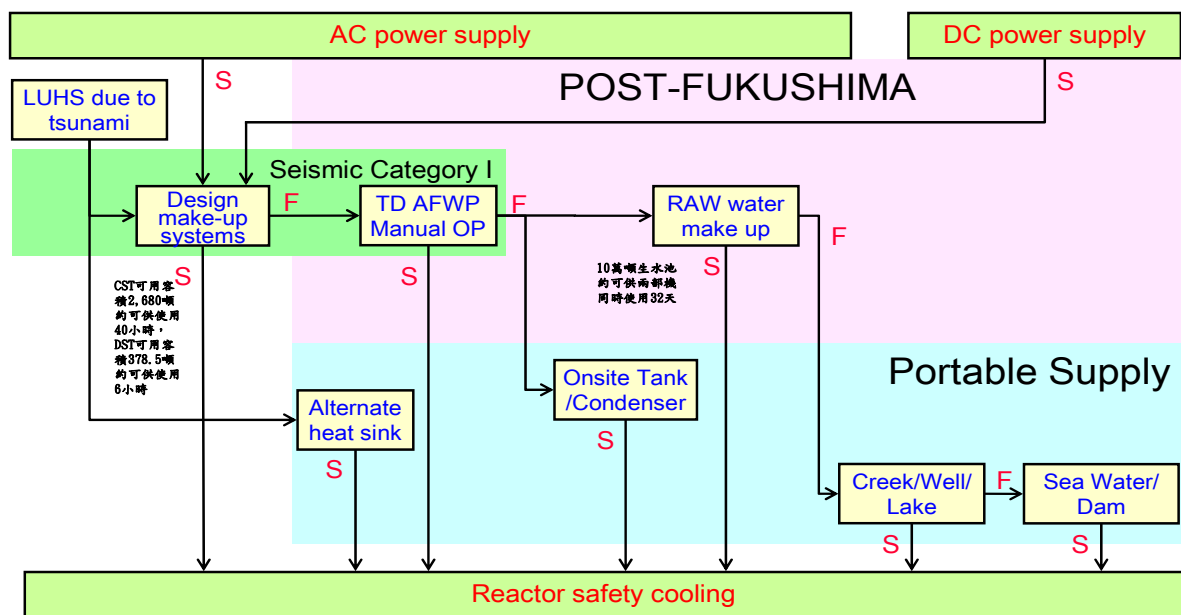
1. Enhancement of the emergency operation capability of RCIC & SRV:
 - (1) Enhancement of DC power supply:
 - (a) Five sets of small scale 120V mobile generators and power suppliers are additionally procured to provide DC power to RCIC & SRV and other essential instrument control power in case of emergency.
 - (c) Procedure has been revised to provide the guideline on how to provide power to RCIC & SRV using jump.
 - (2) RCIC will be manually restarted if its DC power supply is lost. The operating steps have been demonstrated to be feasible and have been incorporated into procedure.
 - (3) Two sets of mobile diesel driven air compressors and two sets of high pressure boosters are procured to provide the required compressed air for SRV emergency operation. Besides, a design change was undertaken to install emergency nitrogen fill piping and its adapter outside the building in order to provide the required compressed air for SRV emergency use.
2. Most of the measures described in Section 5.1.2.3 are also applicable.

Maanshan NPP

1. The capacity of battery sets can ensure continuous DC power supply for 8 hours. The related operating steps to isolate some non-essential loads have been included into plant procedure 570.2. The plant will purchase 480V mobile diesel generators. With quick connecting interface, the 480V mobile diesel generator can charge battery sets and maintain the battery set with long-term supply capability.
2. A review of the key parameters that have to be monitored in the main control room during SBO has been completed. Those key parameters include the water level and pressure of the major components (e.g., steam generator, reactor, pressurizer, and containment), reactor temperature, containment radiation level, spent fuel pool water level and temperature, ex-core nuclear instrument indications, AFW flow rate of steam generator, and water level indication of RWST/BAT/CST. By enhancing the emergency back-up AC power for SBO, the availability of the battery sets can be ensured and the instrument power supply can be strengthened.
3. Most of the measures described in Section 5.1.2.3 are also applicable.



在全黑狀況下，安全有關電池組具8小時的供電容量



Lungmen NPP

1. RCIC loss of DC power (manual start)

RCIC will be manually restarted if its DC power supply is lost. The operating steps have been demonstrated to be feasible and have been incorporated in procedure.

2. Power Source Enhancement Measures

Before battery exhausted, use 480 VAC mobile diesel generator or security DG to provide

power to 480V PC/MCC and then to CVCF and DC Battery charger. Most of the measures described in Section 5.1.2.3 (including the 4.16 kV/480V AC power enhancement measures) are also applicable.

3. If SRV loss of operating gas or electrical power due to beyond design basis event, the following methods can be used :

- a. If SRV loss of operating gas, lineup temporary air compressor to the nitrogen gas system (P54) located at the northeast and southeast corner of reactor building 7th floor. Thus, operating air can be supplied to those SRVs with ADS function. Based on existing design, there are 20 nitrogen cylinders, which can maintain SRV/ADS in open position for at least 7 days.
- b. If SRV loss of operating electrical power, start mobile diesel generator to provide AC power to CVCF, and then to SRV.
- c. Bring portable DC power source to provide power to SRV directly.

5.1.4 Loss of ultimate heat sink

5.1.4.1 Design provisional autonomy of the site before fuel degradation

Chinshan NPP

1. Normal ultimate heat sink

In normal operation, four Circulating Water (CW) pumps, each with capacity of 137,000 gpm, take suction from sea to provide cooling water as ultimate heat sink. The CW intake structure is Seismic Category II design. It is designed to have the strength of 75 lb/ft² to withstand wind, tsunami, highest or lowest tide. The intake structure is also designed with breakwater to protect canal from wave.

2. Ultimate heat sink

Each unit has 2 Emergency Service Water (ESW) pumps, which take suction from emergency intake. If the normal intake structure is damaged, the emergency intake structure can be used as an alternative suction port. ESW is located just beside ChienHwa stream. Its structure is Seismic Category I design. The cooling water is a mixture of sea water (East Sea) and ChienHwa stream water and serve as the ultimate heat sink. The ultimate heat sink has the capability to withstand the most severe natural disaster. ESW vertical pumps are separated from each other by concrete structural wall. The Seismic Class I piping of ESW system is laid out underground around the sides of ChienHwa stream. This piping is protected from multiple failures.

(1) ESW system capacity

Each unit has two ESW pumps and each has 100% capacity of 8,000 gpm with separated layout and can provide sufficient cooling water for safe reactor shutdown. The surface level of the ESW pump building is 11.2 meter. The motor and electrical distribution panels are located inside ESW building to protect against the design basis tsunami.

(2) Supporting system

a. Power source

Design provisions of the two EDGs and the 5th EDG are shown in Section 5.1.1.1.

b. Ventilation

There are four roof fans in emergency pump room. Normally, two of them are running to prevent from sultry and moist.

(3) ESW intake structure and tsunami protection evaluation

- a. The design basis tsunami is based on historic data of tsunami that happened at Keelung in 1867. The maximum tsunami surge of 7.5 meters was estimated at Keelung. Assuming the slope of coast is 1/5, the combined run up can reach 9 meter if the tsunami and the maximum wind wave occur concurrently. The height of tide will increase to 10.7 meter if the maximum recorded storm tidal level is also added.
- b. The plant has tsunami protection facilities (including tsunami protection gate). Tsunami protection gate is constructed at the discharge end of ChienHwa stream with a top elevation of 11.34 meters. It is designed to ensure the integrity of emergency intake structure. There is always sufficient opening at the bottom of the gate structure (1.57 meters) to allow discharge of circulating water plus a certain amount of creek water to the sea. A fast close motor driven system and associated mechanism have been newly installed to close the gate within 5 minutes after receiving tsunami alarm. In addition, the gate is now kept normally close which was normally open before Fukushima nuclear accident.

[Kuosheng NPP](#)

The circulating water system (CW) and emergency circulating water system (ECW) is the ultimate sink of Kuosheng nuclear power plant. CW is the ultimate sink when units are in normal operation and ECW is the ultimate sink when units are in emergency shutdown condition. Descriptions of these two systems are described below:

1. Circulating water system

The main function of CW system is to provide cooling water to remove heat from main condenser. It also serves as heat sink to remove the downstream heat loads (Normal Chiller and NCCCW, and TPCCW) of External Circulating Water System. If Emergency Circulating Water System is unavailable, the CW system can provide cooling water to RHR in all operation modes through External Circulating Water System and RHR booster pump. However, this system is not designed as safety-related and the electrical power is not provided by essential bus and the structure is designed as Seismic Category II.

2. Emergency circulating water system

The Emergency Circulating Water System (ECW) serves as ultimate heat sink to remove decay heat, for the purpose of reactor safe shutdown and to maintain reactor at cooled shutdown mode. ECW system provides the required cooling water to RHR heat exchanger, emergency diesel generator water jacket, emergency chiller and HPCS pump room, and Div. III switch room unit cooler.

ECW pump house is located at elevation of 12 meters above sea level. In this building, the ECW pump motor and switchboard are located at a height of 6.6 meters. On June 30, 2011, the plant had reconstructed the wall of ECW pump house to be watertight. This measure improves tsunami protection capability of ECW pump house to 12 meters, which is the same as that of the main building and is able to meet the requirement of current design bases. In addition, based on the "The effects of potential massive earthquake induced tsunami on nuclear power plants," published by National Science Council Tsunami Simulation Research Group on June 30, 2011, the potential tsunami height is lower than the design basis of KSNPP. [However, there are still significant uncertainties in tsunami run-up predictions due to the definition of tsunami sources.](#) The ECW pump house has to [consider the protection](#) of being inundated by tsunami.

ECW is a safety-related system. The design of this system, including supporting system, e.g. power supply and ventilation, are all designed as safety-related. The ECW structure is Seismic Category 1 design. The intake structure is designed to withstand tsunami load,

and designed to prevent flow path blockage. (ECW intake structure is designed with breakwater and a total of four lines of screens to trap waste and debris). Therefore, ECW system is highly reliable.

3. The design alternative ultimate heat sink

CW and ECW system are served as the ultimate heat sink to remove decay heat. If both systems are lost, the current design of alternative heat sink is to inject water to reactor and to actuate SRV to discharge steam generated in reactor into suppression pool. By this way, the decay heat can be removed from reactor to suppression pool. As a result of the heat accumulated in suppression pool and containment, the temperature and pressure of the containment increase, the containment shall be vented into environment (atmosphere) which constitutes a path of ultimate heat sink.

Maanshan NPP

1. The ultimate heat sink of Maanshan station is sea water. Nuclear Service Cooling Water (NSCW) system takes sea water from South Bay to cool the heat exchanger. Normally, reactor decay heat will be removed by injecting water into steam generator and releasing steam from steam generator. After RCS pressure is reduced to 30kg/cm^2 , heat can be removed by RHR system via Component Cooling Water (CCW) system along with NSCW.
2. NSCW pump and sea water intake screen device are located in Seismic Category I structure.

(1) The bottom of NSCW intake pool is EL.-28'; pump room is EL.-36.5'. The NSCW intake pool with the capacity of $350,382\text{ ft}^3$ can provide the required water of two units for 30 minutes. The water storage capacity of the NSCW is long enough to cover the drawdown time of tsunami and ebb.

(2) Supporting system: power, traveling screen, spare parts (including supporting system)
a. Traveling screen rotates in vertical direction, which is driven by chain. If necessary, it can be manually rotated. AC power is provided from two safety trains.

b. The station has regular maintenance program, spare parts, e.g., traveling screen sprocket, traveling screen chain, and screen mesh, are adequate for three outages.

(3) The Seismic Category I structures of the NSCW system consist of the NSCW intake tunnel, NSCW intake basin and NSCW pump house. The design basis for ground horizontal acceleration is $0.4g$. The possibility of pump suction blockage due to the collapse of intake tunnel during earthquake is low.

(4) Status of intake structure (latest inspection date and results) and inspection period

Intake structure was inspected every 5 years. Unit 1 and unit 2 were inspected in 2010 and 2009 respectively. Inspection results showed that some concrete pieces were flaked off and were repaired.

In case of loss of ultimate heat sink, unit can make up water by operating AFP. Reactor pressure and temperature can be decreased by injecting water into SG and steam release from SG (2nd side heat sink).

1. Steam generated in SG can be released into atmosphere through PORV (power operated relief valve) located on main steam line. Thus, atmosphere serves as heat sink to absorb decay heat in the reactor.
2. Water can be injected into SG by running motor driven or turbine driven AFP. The water is taken from CST, DST or raw water reservoir.

3.If NSCW system is unavailable but CCW system is available, CCW system water is adequate to cool CCP (During CCW circulation, system water will be cooled by environment). The continuous operation of CCP will provide water injection to RCS and to RCP shaft seal. Seal LOCA can be prevented, thereby avoiding core uncovers.

Lungmen NPP

1. Normal ultimate heat sink

During normal operation, Circulating Water Pump (CWP) removes the heat of the condenser to sea. After reactor shutdown, decay heat is removed by RHR through heat exchangers to RBCW and then to RBSW and finally to sea.

2. Ultimate heat sink

(1) The heat dissipated from systems is removed by Turbine Building Cooling Water (TBCW) System, RBCW System, and main condenser. Through heat exchangers, TBSW, RBSW, and CCW system respectively remove heat into sea (served as ultimate heat sink). RBSW is designed with safety function :

- a. In case of loss of cooling water, 2 trains of RBSW systems (50% each) will have enough capacity to remove the designed heat load.
- b. The capacity of RBSW sea water inlet UHS reservoir is enough for 3 trains 6 RBSW pumps of both units continuously running for 23.2~28.1 min. Because sea water will influx into inlet UHS reservoir within 18 minutes after tsunami drawdown, the sump water will increase. Therefore, there is no low water level concern.

(2) Each RBSW, RBCW, and RHR system has 3 identical divisions. Ultimate heat sink function can be maintained if any division can perform its design function. The supporting systems of these three systems are described as follows:

- a. The AC power of these 3 systems is provided from safety bus. Besides offsite power 345kV and 161kV, emergency diesel generator serves as the backup power.
- b. The RBSW pump room temperature can be maintained below 40°C by its safety related ventilation system.
- c. The heating and ventilation system of Safety-Related Equipment Area(SREA) is used to maintained RBCW pump room temperature below 40°C. ESF building is safety classed with ability to withstand the design pressure. Typhoon and missile shielding are installed outside the air intake and exhaust louver to prevent typhoon caused foreign objects.
- d. During Design Basis Events and after system isolated, safety-related equipment heating and ventilation system provides ventilation for SREA. Ventilation system circulates the air in RHR, HPCF, and RCIC pump room and is cooled by RBCW system.

5.1.4.2 Foreseen actions to prevent fuel degradation

Chinshan NPP

1. Station existing equipment, e.g., equipment of other unit

If loss of ultimate sink occurs, the following measures will be established:

(1) Ultimate Heat Sink Path

- a. If loss of ultimate sink occurs, after depressurizing reactor by actuating ADS/SRV, the low pressure raw water or sea water can be injected into reactor. The injected water will be vaporized by decay heat. Steam is discharged into torus through ADS/SRV and totally/partially condensed. The mixture of gas and steam is released to atmospheres (serving as heat sink) through containment venting system.
- b. The sea water serves as cooling water to remove the heat from Combined Structure Cooling Water (CSCW) System and Residual Heat Removal (RHR) System.
- c. Water-cooled EDGs (A/B) alternative power supply mode: If combined event occurs and ESW is unavailable, the heat generated in EDG can be alternatively removed by CSCW to SFP. The heat stored in SFP can be removed by SFPACS and dissipated into atmospheres through cooling tower. The cooling capabilities of SFPACS and SFPACS are calculated to be enough for removing the heat generated in EDGs. In this way, continuous operation of the EDG can be maintained without ESW.

(2) Reactor water makeup:

- a. Prolong/enhance RCIC water injection duration

Running RCIC can consume steam in reactor and inject water into reactor at the same time. The speed governor of RCIC turbine requires DC power. Based on the existing design, DC power can last for 8 hours. However, it can be extended to 24 hours if some unnecessary DC loads are isolated. In SBO, controlling the DC loads can prolong the period of DC power supply to RCIC and SRV/ADS.

- b. Reactor water injection enhanced measures in responding to RCIC unavailable

If ECCS is expected to be unavailable due to SBO, a controlled depressurization of the reactor must be performed while HPCI and RCIC are still available. Once the HPCI and RCIC are also unavailable, the reactor has to be depressurized immediately by opening SRVs. Reactor pressure must be depressurized below 6kg/cm^2 to allow water injection from low pressure water source, e.g. fire water (raw water), movable pump, or fire engine. RHR piping system can be used as the injection flow path. The plant has alternative injection flow path. By this path, the 3000 tons (x2) water in raw water reservoir, at elevation 78 meter, can be injected into reactor by gravity.

(3) Containment heat removal and venting:

If the loss of ultimate sink occurs, the reactor has to be depressurized. Heat generated in reactor will be transported to the primary containment. The temperature of torus water will be increased rapidly. If fuel is uncovered and overheated, hydrogen will be generated. It is likely that torus temperature and primary containment pressure will be higher than design limit. Therefore, the containment pressure has to be released to protect the integrity of containment.

2. Confirming the critical time before the onset of damage

Once the accident occurs, before suppression pool pressure reaches its limit, the Primary Containment Air Control System (PCACS) can release primary containment pressure by suppression pool venting. Torus water can absorb some radioactive material and decrease the amount of radioactive material release. During suppression pool venting, the gas is treated by Standby Gas Treatment System (SBGT) before it is released to atmospheres. Drywell venting will be performed if suppression pool venting can't achieve its goal. The plant has installed Direct Torus Venting System or hardened vent. As primary containment pressure increase to 50 psig, venting can be performed through harden vent pipe to limit the containment pressure below the design value and to maintain containment integrity.

In this scenario, forty hours after reactor depressurization and water injection, torus water

level will be increased to the elevation of vent port. The suppression pool venting and containment integrity would be affected if there is no intervention.

Kuosheng NPP

1. Station existing equipment, e.g., the equipment of other unit

In case of loss of ultimate heat sink but AC power still available, the support equipment from other unit are as follows:

- (1) Fire water is pumped into reactor via RHR-B.
 - (2) The unit can inject water into the reactor from the Condensate Storage Tank (CST) of other unit.
2. Equipment available from off-site supporting in case of loss of ultimate heat sink.
 - (1) Kuosheng NPP 345kV system has one dedicated power transmission cable directly connected to Chinshan NPP; and another dedicated power transmission cable directly connected to Shieho fossil power plant.
 - (2) TPC already procured six sets of 4.16kV/1500kW mobile diesel generators power truck. One of them is allocated to Kuosheng Station and three sets are allocated to Chinshan and Lungmen. These mobile generators can be used to support each other.
 3. The required operation time for any above-mentioned system.

It takes about 40 minutes to deliver water from fire water system to reactor.

4. Availability of qualified operators to perform the special line-up

The operators who are responsible for the operations of above mentioned actions are well trained and exercised. They can meet the mission requirements.

5. Confirmation of the cliff-edge effective occurrence time:

In case of loss of ultimate heat sink but AC power is still available (e.g., via the enhancement measures described in Section 5.1.3.5), the reactor water level can be maintained by the operation of RCIC or other ECCS system. Steam in the reactor is discharged into suppression pool by actuating SRV. In this way, the decay heat is removed from the reactor to the suppression pool. With various actions including continuous water makeup to suppress pool, and containment venting, the reactor residual heat can be continuously removed so that the cliff-edge effect of fuel degradation will not occur.

Maanshan NPP

1. If both motor driven and turbine driven AFP are unavailable, the plant has additional diesel driven AFP able to deliver water into SG.
2. When all types of AFP (installed after 2001 SBO event) are unavailable, diesel engine fire pump can be operated to deliver water into SG.
3. If the other unit is not damaged, supports from other unit include:
 - CST and DST can be connected to AFP to provide water source.
 - The diesel driven AFP of the other unit can be connected to deliver water into SG.
4. If both units are damaged, supports available from offsite:

Water makeup to CST, RWST, SFP, and RCS can be provided by fire engine. The station has one 7 tons fire water tanker. The Pingtung County Fire Bureau two 10 tons and two 12 tons water tankers; one 3 tons and four 3.5 tons water tankers; and also have four 1 ton small water tankers. Offsite water sources can be taken from No.2 and No. 3 deep wells, Longluan deep

pool, Modan reservoir, and sea water.

5. The required time for above mentioned operations:

- (1) Starting diesel driven AFP: two men for 1 hour for each unit.
- (2) Connected to fire system to deliver water into SG: two men for 30 minutes.
- (3) CST connection: one man for 15 minutes.
- (4) DST connection: one man for 15 minutes for each unit.
- (5) Fire engine intake water from Longluan deep pool: three men for 1 hour.

6. Availability of qualified operators to perform the above action:

- (1) For manpower required in normal operation and emergency repair, including plant staff, supporting personnel from offsite organization, and contractor staff, the plant has a training program. All those people has been trained with radiation protection and other related fields.
- (2) Every maintenance division of the emergency preparedness has a supporting manpower list, which is established based on mission assigned, professional specialty, etc. The man power list includes name, phone number, and address. People around Hengchun area can be the first priority of supporting manpower.

7. Confirming the critical time before the onset of damage in this scenario

The available volume of CST is 2,680 tons which is adequate for 40 hours. The available volume of DST is 378.5 tons which is adequate for 6 hours. The total is 46 hours. If AFP intakes water from raw water reservoir (100,000 tons), it is adequate for 32 days for two units.

Lungmen NPP

1. Station existing equipment, e.g., equipment of other unit

If loss of ultimate sink occurs, the following measures will be established:

(1) Reactor heat removal

- a. If RBSW loses function due to tsunami, the response measures include: First, reactor is depressurized by releasing steam into wetwell and wetwell is depressurized by venting from wetwell to atmosphere which serves as passive heat sink. At the same time, water is continuously made up through ACIWA into reactor from all possible water sources.
- b. Loss of RBSW but RBCW available, one of following methods can be selected :
 - (a) Provide cooling water to RHR/EDG heat exchanger by feed and bleed RBCW. The cooling water is provided from RBCW Surge Tank which can be made up by fire water or Makeup Water System.
 - (b) Pumping sea water to RBCW heat exchanger through temporary piping.

(2) Reactor water make up

Same as described in Section 5.1.2.3 item 3 and 4.

(3) Containment heat removal and venting :

If losing of ultimate heat sink, reactor has to be depressurized. Heat generated in reactor will be removed to the primary containment. Suppression pool water temperature will increase rapidly. If fuel is overheated, hydrogen will be generated. It is likely that suppression pool temperature and primary containment pressure will be higher than design limit. Therefore, the containment pressure has to be released to protect the integrity of containment.

Once event occurs, before suppression pool pressure increasing to pressure limit, Atmosphere

Control System (ACS) can perform venting function for suppression pool. Radioactive material release can be reduced if venting is filtered by pool water. After treatment by SGBT system, gas can be released to atmosphere and primary containment pressure can be reduced. If it does not work, venting can be performed from drywell. The station has Containment Overpressure Protection System (COPS), as wetwell pressure increases to 652 kpaG, rupture disk will break to release pressure. The primary containment integrity can be maintained by preventing pressure exceeding limit.

2. The foreseen actions to prevent fuel degradation in Section 5.1.3.4 Item 2,3,4,5,6(3) are also applicable to this section.

5.1.4.3 Envisaged measures to increase robustness of the plant

Chinshan NPP

1. Ultimate Heat Sink Enhancement

Based on existing design basis, one train Emergency Service Water (ESW) System is enough to ensure the removal of core decay heat and heat generated by safety related equipment. The plant has already established the ESW pump motor replacement procedure. Currently there is only one spare ESW motor, in order to ensure the availability of spared motor, it is planned to purchase another one. The spare ESW motors will be stored in the building with high elevation.

2. Increase heat removable path

The building of existing SFPACS is Seismic Category 1 design. The related equipment are safety grade class 1 (except cooling tower). The building is located at 100ft (30.48 meters) above sea level. This system will not be affected by tsunami and earthquake and is highly reliable. During outage, the decay heat of spent fuel is dissipated into atmosphere, acting as the ultimate heat sink, via cooling tower. After reactor shutdown for more than 12 hours, SFPACS has the capability to remove all decay heat from reactor. However, this system is not connected to RHR system yet and a DCR has been proposed. Once modification is completed, it can mitigate, or even terminate, the combined effect accidents such as those occurred in Fukushima Daiichi NPP.

SFPACS requires AC power. To ensure reliable power supply, movable 480VAC diesel generator is planned to be implemented as standby emergency AC power. In addition, it is planned to add a boost pump and related piping in RHR system. Once the planned design modification has been implemented, water can be transported from reactor and torus to SFPACS heat exchanger; then back to reactor, torus, or drywell. A design modification is performed for the primary and secondary side of SFPACS. Movable 480VAC diesel generator will be implemented to increase system reliability. The reactor and the torus water heat removal paths have been identified in the report provided by the licensee.

3. Reactor water make-up

Four different reactor water make-up paths have been identified in the licensee's report. A DCR has been proposed to install connecting pipes for the 100x10³ tons raw water reservoir so that raw water can be transported to site by gravity. TPC is performing "Seismic Evaluation and Enhancement for Raw Water Reservoir in Nuclear Power Plants". This evaluation also includes the seismic evaluation for raw water supply system.

4. As RCIC is running, steam is discharged into torus. Long term operation will increase the back pressure and finally may terminate the operation of RCIC. The station has proposed measures to enhance the venting capability of primary and secondary containment in case of loss of ultimate heat sink or SBO. A system, including boost fan, related valve and piping, is planned to bypass SGBT. A movable 480VAC diesel generator will be used in

this system. The modified system is beneficial to venting, hydrogen dilution and removal. In addition, the primary containment pressure will be decreased and RCIC operating duration will be extended.

5. Makeup water source structure integrity evaluation and enhancement:

Station has performed seismic evaluations to respond the possible damages by strong earthquake.

- (1) The plant is conducting a project to move fire raw water pipe from underground to above ground. This will improve the reliability and the maintainability of fire raw water pipe. Piping replacement efficiency will also be improved. This project will be completed before [the end of July, 2013](#).
- (2) A DCR has been proposed to improve the flexibility of some raw water pipes. Flexible pipes will be installed in specific place to absorb the displacement caused by earthquake. This will prevent pipes from damage by earthquake.

[Kuosheng NPP](#)

1. Enhancement of the heat removal capability of primary containment

- (1) By way of disconnecting interlock, containment can be vented through containment venting system or Standby Gas Treatment System (SGTS).
- (2) Suppression pool water is made-up by manually drawdown Upper Pool or from Condensate Water Storage Tank (CST) or from Auxiliary Condensate Water Storage Tank (ACST) or from Demineralizer Water Storage Tank (DST) or from Auxiliary Demineralizer Water Storage Tank (ADST) in order to increase the heat sink capacity of suppression pool.

2. Enhancement of ECW

- (1) Provide alternative cooling water to RHR

In case of loss of ECW, a procedure (Procedure 1451) has been established to use fire water storage tank as an alternation to provide cooling water to RHR heat exchanger to remove heat from suppression pool or to remove decay heat from reactor.

- (2) Emergency replacement of ECW pump motor:

Spare ECW pump motors have been purchased. The plant has established the operating procedure for emergency replacement of ECW pump motor and it has been demonstrated that one ECW pump for one unit can be restored to operable state within 4 hours. The plant has two spare ECW pump motors which are enough for the emergency replacement needed for both units.

- (3) Improvement of the ECW capability to withstand tsunami:

The waterproof wall of ECW pump room has been added to reach to the top of ceiling and all penetrations are sealed. After the improvement, the height of tsunami surge protection is the same as that of ground level (12 feet).

- (4) Emergent clean up of ECW intake sump: If ECW inlets are clogged by large amount of debris, this would also cause grid clogged and affect the intake of the pumps, which will lead to loss of ultimate heat sink. Kuosheng plant has 10 tons, 13.5 tons, 20 tons, and 30 tons crane, and also has two large trucks. The equipment can be used to clean up the debris and wastage in front of the "first fixed screener". During the same time, the plant can request Military Emergency Coordination Center to support excavator and other required machines and manpower to assist the station in cleaning up the

intake sump.

The related emergency operating actions have been incorporated into procedures to instruct operator to properly respond to the above-mentioned conditions.

Maanshan NPP

1. Steel grating was installed on the top of NSCW intake pool to prevent large litter and debris, carried over by tsunami, intrusion into intake pool. Thus, the possibility of NSCW pump failed by foreign material can be minimized.
2. Measures to prevent flooding, such as water-proof walls and water-tight doors, have been completed. The NSCW pump motors and related electrical components are separated from each other to prevent common cause failure of all motors because of flooding. The improved elevation of pump room to prevent tsunami intrusion is same as the elevation of pump room exhaust fan, both are 12.6 meters.
3. Large trashes (limbs, rubbish) at sea water intake are removed manually from grating.
4. If traveling screen is failed, trash is removed manually at sump and trash grating to ensure that NSCW pump has clean water source. (Plant has one 20 tons and one 60 tons crane, and one 15 tons truck to support garbage removal. SOP 1451 has defined the procedures for intake pool emergency trash removal).
6. Plant has 5 spared NSCW pump motors that can be used for emergency replacement. SOP 1451 has defined the process to perform the emergency replacement. This work can be completed in 7 hours. (2 hours for transportation and 5 hours for replacement)
7. The plant is purchasing one chemical foam fire engine with capacity of 7 tons; one water tank fire engine with capacity of 12 tons.

Lungmen NPP

1. Ultimate Heat Sink Enhancement

Based on the existing design basis, the operation of only one train RBSW system can ensure the removal of decay heat and other heat generated by safety related equipment. Station already has emergency sea cooling water recovery plan, and has prepared spare RBSW and RBCW motors for emergency replacement. Once these motor fail, immediate replacement can recover these systems as soon as possible.

2. Increase heat removable path

Same as described in Section 5.1.4.2 Item 1 (1).

3. Reactor water make-up

- (1) from CST through ECCS pipe using CSTF charging pump powered by mobile diesel generator, or by gravity
- (2) from test tank using SLC motor powered by mobile diesel generator
- (3) from sea through feedwater or fire water pipe using temporary pump.

4. Primary/Secondary containment venting

Station has purchased 480V mobile diesel generators and accessory components to enhance the primary and secondary containment venting ability during loss of ultimate heat sink and SBO. The venting function can be improved. The hydrogen accumulated in the primary containment can be diluted and released. The related measures are described as follows:

- (1) Primary containment venting path:

- a. Mobile diesel generator can provide AC power to SGTS fan and FCS heater.
 - b. All the containment isolation valves locate at CTMT outboard. It is accessible for operators to operate manually.
- (2) Secondary containment venting path: Two secondary containment venting paths have been identified.

5. Make up water source structure integrity evaluation and enhancement

To respond the possible damages by strong earthquake, the station has performed seismic evaluations to enhance structural integrity

- (1) Install new pipes for raw water supply. The new pipes are seismic category II-A design and are not buried underground. As the installation of new pipes has been completed, the existing pipe will not be moved out. However, the isolation valve will be closed to prevent water lost from the existing pipes.
- (2) The newly installed pipes will be connected to flexible pipes in certain locations to absorb possible displacement caused by earthquake and to minimize the possibility of being damaged by earthquake.

5.1.5 Loss of the ultimate heat sink combined with station black out

5.1.5.1 Design provisional autonomy of the site before fuel degradation

[Chinshan & Kuosheng NPPs](#)

The station blackout (loss of all AC power) leads into core degradation more rapidly than the loss of the primary ultimate heat sink. Therefore, the information given in Section 5.1.3 is representative also of the combination of the loss of the primary ultimate heat sink with station blackout.

[Maanshan NPP](#)

1. If SBO occurs, the station will lost ultimate heat sink at the same time. Section 5.1.3.3 describes design provisional autonomy of the plant. Diesel driven AFP is not an original design. It was a design modification after the SBO event occurred in March 18, 2001. During SBO, core heat is removed by SG secondary side with turbine driven AFP. SG performs the function to decrease primary side temperature and pressure.
2. If SBO occurs at full load operation, together with loss of secondary side heat sink. During this type event, reactor heat cannot be removed through SG, AC power cannot be recovered to operate CCP to maintain RCP seal water. Reactor core could be damaged within 2 hours.

[Lungmen NPP](#)

The information given in Section 5.1.3 is representative also of the combination of the loss of the primary ultimate heat sink with station blackout.

5.1.5.2 Foreseen external actions to prevent fuel degradation

[Chinshan & Kuosheng NPPs](#)

The information given in Section 5.1.3 is representative also of the combination of the loss of the primary ultimate heat sink with station blackout.

Maanshan NPP

1. In the scenario SBO together with loss of ultimate heat sink, a description of foreseen external actions to prevent fuel degradation can be found in Section 5.1.3.4 and 5.1.4.2. During this period, core heat is removed by secondary side heat sink. SG performs the function to decrease primary side temperature and pressure.
2. If SBO occurs, the issues of maintaining secondary side heat sink to remove primary side heat, including improved measures, are described as follows:
 - (1) Each unit has one diesel driven AFP. The diesel engine is 480HP, 1800 rpm, and 6 cylinders. The discharge pressure of this pump is 860 psig; the rated flow is 360 gpm. Water intakes from CST, DST or raw water tank. Diesel driven pump of Unit 1 and 2 are connected to each other. If steam generator pressure drops to 60 kg/cm², they can be started to inject water into SG.
 - (2) Connecting to fire water system, diesel engine fire pump can be used to make up water. The rated flow of the fire pump is 1,500 gpm. If the pressure of steam generator drops to 9kg/cm², this pump can be started to inject water into SG.
 - (3) Fire engines can be used to make up water. The flow rate and discharge pressure is approximate 250gpm and 6~10kg/cm², respectively. Once SG pressure drops to 6 kg/cm², fire engine can be started to inject water into SG. (Following plant procedure 1451 “Ultimate Response Guideline”)
 - (4) For the three SG water makeup methods mentioned above, operator can manually open SG PORV locally to release steam into atmosphere to reduce SG pressure.
3. If it is unable to reduce primary temperature and pressure by operating SG or RHR system, reactor pressure has to be released to inject water into reactor directly. The actions are described as follows:
 - (1) Reactor pressure is released to pressure relieving tank by operating PORV on pressurizer.
 - (2) Reactor pressure is released to pressure relieving tank by operating the vent valve on reactor head. (The 480V mobile diesel generator will be connected to safety train battery charger for providing DC power)
 - (3) Follow plant procedure 1451 “Ultimate Response Guideline”.
4. Supports from offsite if all onsite equipment are unavailable:

If sea water from intake tunnel is not available, the water sources which can be considered as backup heat sink are shown below.

Note (1) The original seismic design class of items 1~3 meet the requirement of Building Technical Rules issued by Ministry of the Interior.

- (2) Total capacity of No.2 and No.3 deep well is 2.56 ton/minute.
 - (3) Fire engine can drive to Modan reservoir (or another far away or higher elevation raw water source) to take raw water.
 - (4) Fire engine or temporary water pump can take sea water at pump house dock. The Pingtung County Fire Bureau has two 10 tons and two 12 tons water tankers; one 3 tons and four 3.5 tons water tankers; and also have four 1 ton small water tankers.
5. Confirming the critical time before the onset of damage in this scenario

The available volume of CST is 2,680 tons which is adequate for 40 hours. The available volume of DST is 378.5 tons which is adequate for 6 hours. Total time is 46 hours. If AFP

intakes water from raw water reservoir (100,000 tons), it is adequate for 32 days for two units.

The Nuclear Safety Department of TPC completed Ultimate Response analysis report in September 2011. This report use advanced accident analysis program RELAP5-3D to simulate the scenario and process in developing the measures defined in Ultimate Response Guideline. The minimum flow rate of sea water or raw water to be injected into SG or reactor at different scenario is calculated quantitatively. The core fuel temperature has to be ensured not higher than the temperature that fuel cladding begins to oxidize (1500°F). The analysis gives the following conclusions:

- (1) Assuming auxiliary feedwater system, both motor driven auxiliary feedwater pump (MDAFP) and turbine driven auxiliary feedwater pump (TDAFP), is operable prior to SBO (10 minutes period before event occurred), then the secondary side water level of SG can be maintained at nearly normal level. If TDAFP still can be operated normally within one hour after SBO event, pressure relieving at secondary side can be performed. After that, if TDAFP fails and emergency pressure reducing operation is required, secondary side can be maintained at a low pressure (12 kg/cm²) and high water level favorable state. Performing emergency pressure relief via PORV at this state, reactor cooling water at natural circulation mode can be maintained (about 4.36% of initial flow before SBO event). Fuel will be fully covered by core cooling water and fuel cladding temperature is well below the temperature of oxidation (1500°F).
- (2) As SG pressure drops to 60 psia, raw water or sea water is injected into SG. Analysis is performed for five different injection rate ranged from 500 gpm to 2,000 gpm. The longest and shortest time, at which SG narrow range water level begins to increase, is 24.3 hours (500 gpm) and 2.81 hours (2,000 gpm), respectively. The time for water level increasing to normal level (50%) is 38.2 hours (500 gpm) and the 3.2 hours (2000 gpm), respectively.
- (3) NSSS long-term equilibrium pressure is about 500 psi. The amount of RCS natural convection flow rate is about 4.3%. The amount of injected water at the time of accumulator pressure decreasing is about 24% of original value. The maximum fuel cladding temperature is 441°F.
- (4) Assuming RCP shaft seal leakage (Seal LOCA) occurs 0 hours after SBO, primary side will have 75 gpm loss of cooling water. Analysis result shows that due to continuously loss of core cooling, core will not be covered and fuel cladding temperature will increase. About 8 hours after SBO, core water level will drop to the top of fuel. About 10 hours after shaft seal leakage, fuel temperature begins to increase rapidly. Assuming ACC is isolated to make up water, fuel temperature will increase rapidly 9 hours after shaft seal leakage.

[Lungmen NPP](#)

The information given in Section 5.1.3 is representative also of the combination of the loss of the primary ultimate heat sink with station blackout.

5.1.5.3 Envisaged measures to increase robustness of the plant

[Chinshan & Kuosheng NPPs](#)

The information given in Section 5.1.3 is representative also of the combination of the loss of the primary ultimate heat sink with station blackout.

Maanshan NPP

1. RCS standby makeup water path:

Three different RCS standby makeup water paths have been identified in the report provided by the licensee.

2. Containment standby water injection:

Three different containment standby water injection water paths have been identified in the report provided by the licensee. Maanshan has one fire water tanker with capacity of 7 tons. The station is procuring one fire chemical foam fire engine with capacity of 7 tons; one fire water tanker with capacity of 12 tons ([Scheduled completion on December 31, 2012](#)). The Pingtung County Fire Bureau has two 10 tons and two 12 tons water tankers; one 3 tons and four 3.5 tons water tankers; and also have four 1 ton small water tankers.

3. RWST and CST standby makeup water path:

RWST and CST standby makeup water paths have been identified in the report provided by the licensee.

4. SG standby makeup water source

Three SG standby makeup water reservoirs with the capacity of 50,000 ton, 2,000 ton and 5,000 ton raw water reservoir have been identified in the report provided by the licensee.

5. SG pressure release: In case of no AC power and compressed air, SG PORV can be manually operated to release SG pressure.

6. RCS pressure release: Pressure is released from pressurizer (PZR) PORV or from reactor vent valve. The 480V mobile diesel generator provides AC power to PK battery charger. Then DC power can be maintained.

7. Containment pressure release:

The operation of above mentioned power supply (480V movable diesel generators supply AC power to MOV), air supply, and supporting systems, and also the decision making mechanisms, shall follow plant procedure 1451 "Ultimate Response Guideline". The plant personnel have been well trained for this procedure.

8. Examine the seismic capability and integrity of raw water reservoir and connected piping

(1) Based on the results of Seismic Evaluation Task Force, enhanced or improved measures will be considered.

(2) In order to improve raw water pipeline reliability, maintainability after event, and efficiency of piping replacement, underground raw water pipeline will be moved to above ground. (Scheduled to be completed on December 31, 2012)

(3) Together with underground raw water piping design modification, improve local flexibility of raw water main pipe. At specific locations, add elastic pipe to absorb pipe displacement induced by earthquake and to prevent pipe rupture. ([Scheduled completion date December 31, 2014](#))

(4) Together with underground raw water pipe design modification, evaluate the possibility to add a flow control valve between raw water reservoir A/B and main raw water pipe to prevent water loss in case of broken main raw water pipe.

(5) Raw water Ultimate Response measures shall follow plant procedure 1451 "Ultimate Response Guideline". (Isolate to prevent water loss and debris flow. Methods to repair are prepared. Plant personnel have been well trained and exercised.)

Lungmen NPP

The information given in Section 5.1.3 is representative also of the combination of the loss of the primary ultimate heat sink with station blackout.

5.2 Spent fuel pool

5.2.1 Loss of offsite power

5.2.1.1 Design provisions of on-site back-up power sources

Chinshan NPP

1. Spent Fuel Pool (SFP) makeup water system:

- (1) Condensate Storage Tank (CST) has capacity of 500×10^3 gallons. It is Seismic Category I design. CST system has two water supply pumps rated at 500gpm each. The motor is rated at 60HP. Power is supplied from 480V MCC 1A-2 or 2A-2 which is not classified as essential power source. The CST system is Seismic Category I design. In normal operation, CST is maintained with at least 250×10^3 gallons water.
- (2) Demineralized Water Storage Tank (DST) has capacity of 50×10^3 gallons. It is Seismic Category II design. DST system has two water supply pumps rated at 275gpm each. The motor is rated at 40HP. Power is supplied from 480V MCC 1A-2 or 2A-2 which is not classified as essential power source. In normal operation, DST is maintained with at least 10×10^3 gallons water.

2. SFPCS & SFPACS power supply

- (1) The power of Spent Fuel Pool Cooling System (SFPCS) is supplied from essential power source (480V MCC 3A-1 or 4A-1).
- (2) The power of Spent Fuel Pool Additional Cooling System (SFPACS) is supplied from essential power source (480V MCC 3A-7 or 4A-7). The backup power is not essential (480 V MCC 2A or 1A).
- (3) SFP water level/ temperature instrument power is supplied from control room 120V instrument power source (IDP-120V-1&2, supplied from essential 480V MCC 3A-1&4A-1).

The electrical power distribution system is described in section 5.1.1.1. If loss of offsite power, the power required by heat removal equipment in SFP and water level/temperature monitoring system can be provided by 4.16kV bus connected to EDGs, the 5th EDG, and/or gas turbine, but the emergency AC power will not supply to SFP water makeup system. However, in case of loss of offsite power, SFP water level and temperature will not immediately change to cause safety concern, so the operator will have enough time to take response actions.

Kuosheng NPP

The station power distribution system is divided into the safety-related and the non-safety-related power systems. Non-safety related power supply system provides the required power for the spent fuel cooling in the normal fuel pool in coordination with the safety related essential power system. The safety-related power system provides the required power for the related loads of spent fuel emergency cooling in each fuel pool in order to assure the safety of the spent fuel in the fuel pool. The related power supply and distribution system design description please refer to section 5.1.1.2.

The emergency diesel generator which provides the required power for the related loads of spent fuel emergency cooling and emergency water makeup is divided into two divisions. The

essential bus of each division is independently powered by corresponding EDG.

Maanshan NPP

Each unit has one spent fuel pool (SFP) located in fuel building. It is Seismic Category I reinforced concrete structures. The inner surface is lined with stainless steel. Seismic Category I stainless steel fuel rack located in SFP is used to store spent fuel. Based on current design basis, the spent fuel pool cooling and water makeup systems are described as follows:

1. Cooling system

Each unit has two trains of independent SFP cooling system. Each train has 100% capacity of cooling water pumps, heat exchangers and associated pipelines; all of these are Seismic Category I design. Power of SFP Cooling water pump is supplied by safety-related bus. In case of loss of off-site power, power can be provided by emergency diesel generator or gas turbine generator. Component Cooling Water (CCW) system provides cooling water to SFP heat exchanger, then, heat is transferred to Nuclear Service Cooling Water (NSCW) system from CCW. Finally heat is dissipated into ultimate heat sink (South Bay). The power of CCW and NSCW pump is also provided by safety-related bus. In normal operation, each train is designed to have the capability to remove the heat generated by following sources: the total fuel assembly off loaded 150 hours after reactor shutdown, 72 fuel assembly off loaded during previous cycle, and all the spent fuels historically off loaded. Any train of SFP cooling system can remove a total of 2,160 fuel assembly heat load and maintain pool temperature less than 140°F. The maximum designed capacity of SFP cooling system is to remove all the following heat loads: the total fuel assembly which off loaded 150 hours after reactor shutdown, 72 fuel assemblies which off loaded 36 days ago, and all the historically off loaded spent fuels. For the maximum loads, SFP cooling system can maintain pool temperature less than 150°F.

2. Makeup water system:

- (1) Normally, water is made up to SFP from Demineralizer Storage Tank (DST) at a rate of 215 gpm. The capacity of DST is 100×10^3 gallons. If boric acid is required, the make-up is from Refueling Water Storage Tank (RWST), through SFP purification system, to SFP. The boric concentration in RWST is 2400~2500 ppm. The capacity of RWST is 460×10^3 gallons and make-up rate is 100 gpm.
- (2) In case of emergency, the two independent, Seismic Category I designed CST transfer pumps with capacity of 210gpm each are used to make up water. Water is supplied from Seismic Category I Condensate Storage Tank (CST). The capacity of CST is 750×10^3 gallons. The power of CST transfer pump is provided by safety-related bus. In case of loss of off-site power, power can be provided by emergency diesel generator or gas turbine.

Spent Fuel Pool Cooling System has two independent trains. Each has 100% capacity and has full capability to perform cooling function. During normal operation, pool level will decrease due to pool water vaporization or valve/pipe leakage. If both trains of SFPCS are unavailable, pool water temperature will increase and vaporize thus pool water level decrease. In these cases, water make-up has to be performed by incorporating related system to prevent spent fuel from damage.

In case of loss of offsite power, EDG-A and EDG-B will provide emergency AC power through safety-related electrical bus to SFP cooling pump and emergency make-up pump. These cooling and make-up function can be started by operator at the time of necessary in order to prevent fuel degradation.

Lungmen NPP

1. Spent Fuel Pool (SFP) make up water system

(1) Reactor Building

- a. Fuel Pool Cooling and Cleanup (FPCU) System has two 100% capacity skimmer-surge tanks, two 100% circulating water pumps, two 100% filter-demineralizers (F/D), and two 50% heat exchangers. The spent fuel decay heat is removed by RBCW and RBSW system, both of them has two trains.
- b. Except filter-demineralizer /related piping and motor are seismic category II-A, all other components of FPCU system are seismic category I design.
- c. Makeup water into SFP has following ways:(a) from suppression pool or CST through Suppression Pool Cleanup System (SPCU); (b) from suppression pool through RHR A/B/C; (c) from fire water system, fire engine, or raw water reservoir through RHR-C piping system; (d) from CST through RHR A/B/C or FPCU surge tank, by Condensate Transferring System (CSTF).
- d. Pumping by SPCU pump (480VAC/75kW, powered from R12-LSWG-0100B1-5C, rated capacity 250 m³/h) from SFP makeup water pool or CST (4340 ton); or pumping by CSTF charging pump (480VAC/22.5kW, powered from R12-MCC-5020A1-5A, rated capacity 30 m³/h) from CST to fuel pool through SPCU/CSTF/RHR pipes and FPCU.

(2) Auxiliary Fuel Building

- a. Auxiliary Fuel Pool Cooling and Cleanup (AFPC) system is seismic category II-A design. This system has two 100% capacity skimmer-surge tank, two 100% circulating water pump, one 100% filter-demineralizer (F/D), and two 50% heat exchanger. Power is provided from non-safety bus.
- b. Based on existing design, AFP water makeup is provided by CSTF.

2. SFP Cooling and Purification System Power Supply

(1) Reactor Building SFP

- a. SFP Cooling and Cleanup System pump (FPCU pump) is powered from non-safety power center (480VAC/93.3kW, R12-LSWG-0200A2-5B or R12-LSWG-0300C3-5A) to provide fuel pool cooling water.
- b. SFP Cooling and Cleanup System , cooling water is provided from DIV I/II RBCW and power is provided from safety-related buses A4/B4 and downstream MCC.
- c. RHR Fuel Pool Cooling mode has 3 Divisions. During outage, SFP can be cooled by anyone of the them ◦
- d. The power of Spent Fuel Pool water level/ temperature monitors G41-LT-0012A/B/ G41-TE-0013 is provided from control room 120VAC instrument power and 120 V ICP.(These power come from non-safety CVCF power source R14-PPL-0220A3 and R13-PPL-0110A3/0110B3) ◦

(2) Auxiliary Spent Fuel Pool Cooling Capability

- a. The power of AFPC pump is provided from 0R12-LSWG-1200B2-4B / 2200B2-4B.
- b. The power of SFP water level/ temperature instrument 0G42-LT-0010A/B/ G41-TE-0013 is 120VAC power (1/2R13-PPL-0130C3 and 0R12-FUBX-1212B2).

3. The design features of Lungmen Station power distribution system is described in Section 5.1.1.1. Based on the description, station is designed with one emergency diesel generator connected to each essential 4.16kV bus. In case of loss of offsite power, EDG will be

started automatically and will reach rated speed and voltage within 20 seconds. Related breakers will be closed automatically to provide emergency power to essential buses. If anyone of DIV I/II/III EDGs successfully provides power to essential bus, reactor can be maintained in safe shutdown condition. Station has 7th EDG common to both units. This swing EDG serves as the backup of Div.I/II/III EDG of either unit. If any EDG of either unit is unavailable, the 7th EDG can take over the design function.

5.2.1.2 Autonomy of the on-site power sources

Chinshan & Kuosheng NPP

When off-site power is lost, EDG is designed to automatically tied-in operation to provide the power supply for each essential system, and EDG fuel oil storage tank has enough capacity to meet EDG operation need. Please refer to section 5.1.1.2.

Maanshan NPP

The power of SFP cooling and emergency make-up system is mainly provided by EDG-A and EDG-B. Therefore, the operable duration of the cooling and emergency make-up system depends on how long EDG-A and EDG-B can be operated.

The operation duration of EDG-A/B fuel system and startup air system is described in Section 5.1.1.2.

SFP water level and temperature instrument power is supplied from non-safety-related system. If offsite power is lost, power can be provided from non-safety-related battery set for 2 hours. During this period, operator can shift the power source to safety-related bus to maintain the monitor function of related instruments. If operator does not perform this action, after 2 hours, control room will lost the function of monitoring pool water level and temperature.

Lungmen NPP

In case of loss of offsite power, non-safety related bus will not be able to provide AC power. FPCU pump cannot operate normally and no cooling water will be provided to SFP. In this case, RHR FPC mode will be operated to perform fuel pool water makeup and cooling function. The fuel oil and cooling of the emergency diesel generator is described in Section 5.1.1.2. The auxiliary system is described as follows.

- (1) Starting and controlling power are supported from DIV 125VDC.
- (2) Each EDG has one independent air starting system, which has 2 motor driven air compressors. The compressed air is transported to air storage tank through air dryer. From storage tank, compressed air is sent to the diesel engine by two paths. Each path has two air starting motors. The air storage tank can provide starting air for 5 times consecutively without running air compressor .
- (3) Cooling water is provided from Div. I & II safety related Reactor Building Cooling Water (RBCW) system. Heat absorbed by RBCW is removed by the Reactor Building Service Water (RBSW) System, which serves as the ultimate heat sink.

5.2.1.3 Provisions to prolong the time of on-site power supply

Chinshan, Kuosheng & Maanshan NPP

The time of on-site power supply can be prolonged by making up fuel from auxiliary boiler fuel storage tank or gas turbine fuel storage tank. Detailed description is provided in Section 5.1.1.2.

Lungmen NPP

Each EDG (EDG A/B/C) has one fuel Day Tank. This tank has emergency gas cap to make up fuel from tank truck.

5.2.2 Loss of off-site power and on-site back-up power (EDG)

5.2.2.1 Design provisions

In case of loss of off-site power and on-site back-up power, all three NPPs (Chinshan, Kuosheng and Maanshan) are equipped with the 5th EDG and two gas turbines to provide essential AC power. Besides, Maanshan NPP has equipped with the 3rd power source to provide the AC power.

Chinshan & Kuosheng NPP

When the station losses off-site power and on-site backup power (EDGs), it still has another type backup power (the 5th diesel generator and gas turbine generators) to provide the required power supply to each essential facilities. Its design provisions can be referred to section 5.1.2.1.

Maanshan NPP

If loss of off-site power and on-site back-up power occurs, gas turbine generator, the 5th diesel generator, or the 3rd power source can provide AC power through safety-related bus to SFP cooling and emergency make-up water pumps. These pumps can be started by operator at the time of necessary to protect spent fuel from uncover.

The description of supporting power, e.g., gas turbine generator, the 5th diesel generator, and the third power source is described in Section 5.1.2.1.

Lungmen NPP

In case of loss of offsite power and onsite back-up power, the 7th EDG and gas turbine generators can provide the emergency back-up power. The 7th EDG and gas turbine generators are air-cooled with capacity 7800kW. It can be placed to substitute only one of the 6 EDGs at the same time, which need to be pre-selected. The 7th EDG and gas turbine generators, in full load operation, can provide all the AC power required by ECCSs and RBCW.

5.2.2.2 Battery capacity and duration

Chinshan, Kuosheng & Maanshan NPP

The capacity and duration of the battery of gas turbine generator and the 5th diesel generator are described in Section 5.1.2.2.

Lungmen NPP

The capacity of DIV. 0 125V DC Battery for 7th EDG is 1800AH. Based on FSAR Table 8.3-6 and FSAR 8.3-7 S4, this capacity can provide DC power at least for 3.5 hours to ensure the safety of nuclear systems.

5.2.3 Loss of off-site power, ordinary back-up power, and other diverse back-up power

5.2.3.1 Design provisions

Chinshan NPP

If loss of off-site power, the emergency standby power (EDG), and other types of standby power, the SFP will lose normal makeup and forced cooling function. The pool bulk temperature will increase to 100°C. However, there is enough time for operator to take actions to make up water into SFP.

Kuosheng NPP

The spent fuel pool cooling/make-up water pump is powered by AC source. Circulating and making-up cooling water capability will be lost once loss of off-site power, loss of stand-by power (EDG) and other alternative AC power. Therefore, keeping AC available is essential to maintain SFP cooling system operable.

Maanshan NPP

In the scenario of loss of offsite power, back-up power (EDG) and all other supporting power occurs, the unit will be in the status of long term SBO event. Under this scenario, SFP cooling and emergency make-up water system will be unavailable due to loss of power.

1. The design of SFP loss of cooling is described as follows:

Based on Maanshan SFP Re-racking Thermal Hydraulic Analysis Report, assume 157 fuel assembly offloaded 150 hours after reactor shutdown; previous offloaded 72 fuel assemblies have been cooled for 1 year, and SFP is fully occupied (totally 2160 fuel assemblies), the pool water temperature increasing rate will be 5.94°C/hr in case of loss of SFP cooling. It will take 6.7 hours for pool water to boiling. (Calculation is based on initial pool temperature 60°C. Normal pool temperature is 30°C) The time for pool water level drops to 10 feet above the top of spent fuel is about 40 hours.

2. Evaluation of SBO event:

Based on FSAR Section 15.9, assume no AC power is available in the first 8 hours after SBO. Under this assumption, station SBO scenario depends on the results of performing the measures defined in “EOP 570.20 Loss of all Essential AC Power Operation Procedure”.

Based on the above conservative assumption, AC power is available at 8 hours after SBO. Then, SFP cooling and water make-up function can be recovered. The estimated time that pool water level drops to 10 feet above the top of spent fuel assembly is about 40 hours. Therefore, based on the design basis, there is enough time for operator to take response actions to prevent spent fuel from degradation if SBO event occurs.

In this scenario, the pool water level and temperature instrument can still perform their functions for 2 hours (non-safety related battery will provide DC power). The spent fuel in pool can be prevented from degradation by following methods:

1. The newly procured 4.16kV 1500kW mobile diesel generator can (Section 5.2.3.5 Item 2) provide power to safety-related bus A/B-PB-S01. Power can be provided from A/B-PB-S01 bus to SFP cooling and emergency make-up water pumps. These pumps can be startup by operator if needed.
2. Pool water vaporization will remove decay heat from spent fuel. By the measures of enhancing pool water make-up capability (Section 5.2.3.5 Item 3 to Item 8), SFP water level can be recovered timely.

Lungmen NPP

If loss of offsite power, standby power (EDGs), and other types of standby power, SFP will lost forced cooling and normal water makeup function.

5.2.3.2 Battery capacity and duration

[Chinshan NPP](#)

The operation of this system does not rely on battery.

[Kuosheng NPP](#)

Circulating and making-up cooling water capability will be lost once loss of off-site power, loss of stand-by power (EDG) and other alternative AC power. The spent fuel will be cooled by the natural convection of pool water. The operation of SFP cooling system does not rely on battery.

[Maanshan NPP](#)

SFP cooling and water make-up system is not designed with DC battery. However, SFP water level and temperature instrument power can be supplied from non-safety-related battery set for 2 hours. After 2 hours, control room will lost the function to monitor pool water level and temperature.

[Lungmen NPP](#)

This system has no DC power.

5.2.3.3 Autonomy of the site before fuel degradation

[Chinshan NPP](#)

The safety and appropriateness of all core off load during refueling outage is evaluated in the condition of loss of spent fuel pool cooling. If both SFPCS and SFPACS are unavailable, the SFP water temperature increasing rate is 6.25°C/hr. If the initial pool bulk temperature is 57°C, pool water will boil at 6.9 hours later. If the initial temperature is 30°C, it takes about 11.2 hours to boil.

In the scenario of loss of offsite power, back-up power (EDG) and all other supporting power, the SFP will loss normal makeup and forced cooling function. However, the station still has emergency pool water makeup capability. The fire system in the 5th floor of Combination Structure building can supply water to SFP by using fire hose (The normal capacity is 3600 metric tons. It can be connected to two 3000 metric tons raw water storage tanks. The backup of these tanks is a 100x10³ metric tons raw water reservoir).

The SFP water can also be made up by using newly installed pipes and spray components. These pipes and components are seismic designed. The water makeup rate is at least 500gpm and the spray rate is 200gpm. If SFP water temperature continues to increase, Ultimate Response Guideline 1451 shall be followed to vent secondary containment and to remove heat into atmosphere.

[Kuosheng NPP](#)

The spent fuel pool water will be continuously warmed-up and evaporated when fuel pool cooling and make-up capability are lost. Once fuel pool water level drops to the level which results in fuel uncovered with water and cooling unable to maintain so that fuel degradation may occur. It is more important that each kind of cliff-edge time (the shortest time for the

station's action) at the moment shall be assessed.

The decay heat of the spent fuel is decreased following the increasing unit shutdown time. During the special fuel cycle, the decay heat of the spent fuel is the maximum at the moment after completion of core fuel transfer that all spent fuels (624 bundles) are pulled out to be stored in the spent fuel pool. Take unit 1 EOC-21 outage as an example, the cliff edge time of the spent fuel after loss its cooling can be evaluated based on analysis of the following three conditions:

1. The total decay heat is approximately 1.5MW in the pre-outage condition of the spent fuel pool:
 - The temperature rising time till boiling : 90.3 hr
 - Time of water level drop to the level (fuel tip 8 feet) which can't maintain adequate shielding against radiation: 438.9 hr.
 - Time of water level drop to the tip of fuel elements: 587.2 hr
 - Time to onset of fuel degradation: 602.2 hr.
2. During fuel transfer, it is assumed conservatively that the spent fuels are pulled out to be stored in the spent fuel pool at the third day. For this example, the total decay heat of 160 bundles of spent fuels is estimated approximately 3.0 MW.
 - The temperature rising time till boiling: 45.3 hr.
 - Time of water level drop to the level (fuel tip 8 feet) which can't maintain adequate shielding against radiation: 219.5 hr.
 - Time of water level drop to the tip of fuel elements: 293.6 hr.
 - Time to onset of fuel degradation: 308.6 hr.
3. All core spent fuels (624 bundles) are pulled out to be stored in the spent fuel pool at the 10th day after outage .The total decay heat of 160 bundles of spent fuels is estimated approximately 6.6 MW.
 - The temperature rising time till boiling: 20.4 hr
 - Time of water level drop to the level (fuel tip 8 feet) which can't maintain adequate shielding against radiation: 99.0 hr
 - Time of water level drop to the tip of fuel elements: 132.4 hr
 - Time to onset of fuel degradation l: 147.4 hr.

Note: According to CFD analysis report performed by Institute of Nuclear Energy Research, the time of fuel clad reaching degradation temperature (2200°F) (rapid oxidation to release hydrogen) is approximately 15 hours.

[Maanshan NPP](#)

1. In the scenario of loss of SFP cooling capability or loss of pool water, plant procedure 597.1 will be followed to recover SFP cooling capability or mitigate loss of pool water. If pool water level or cooling capability cannot be recovered, pool water temperature will increase and decreasing rate of pool water and the time to boiling shall be evaluated. Supporting methods shall be incorporated to make up water. The "feed and bleed" cooling mode shall be established to prolong the time to boiling.
2. Plant procedure 570.20 will be followed to recover power supplied to safety-related bus. The SFP water level will be monitored. If water level indication (EC-LI109) is less than 35%, notify TSC and try to make up water.

[Lungmen NPP](#)

Although forced cooling and normal water makeup ability is lost, emergency water

makeup is applicable. Firewater in reactor building 7th floor can be injected into spent pool by using the fire hose located on the side of SFP, or use newly installed permanent seismic grade specific pipe lines. The water makeup and spray capacity at least are 500 gpm and 200 gpm, respectively. The backup raw water reservoir has capacity of 48,000ton. If SFP water temperature still increases, following Procedure “1451Ultimate Response Guideline” to perform 2nd containment venting to discharge heat into atmosphere.

5.2.3.4 Foreseen actions to prevent fuel degradation

Chinshan NPP

Same as described in Section 5.1.3.4

Kuosheng NPP

1. Station existing equipment, e.g., the equipment of other unit
 - (1) The hose is pulled out from the fire hose boxes which utilize the fire raw water source on the hill to directly inject water to spent fuel pool by gravity makeup.
 - (2) The rollup door in fuel building is opened and mobile water pump is used to pump water from normal or backup water source and directly inject water to spent fuel pool.
 - (3) The rollup door in fuel building is opened and fire truck is driven into fuel building to inject water into spent fuel pool.
2. Equipment available from Off-site supporting in case of station facilities are all damaged.

As described in the section 5.1.3.4, emergency water makeup can be provided by Off-site support from (1) the Sixth Team of New Taipei city government Fire Bureau with fire engine, chemical foam truck, and/or an aerial ladder fire truck, CSNPP can provide power supply and (2) Chinshan and Lungmen can provide three sets 4.16 kV 1500kW mobile diesel generator power engines.

3. Power cable specially connected to the power plant (such as hydro, gas turbine plant) in the vicinity:

Kuosheng NPP 345kV system has one dedicated power transmission cable directly connected to Chinshan NPP; and another dedicated power transmission cable directly connected to Shieho fossil power plant.

4. The required operation time for above mentioned system.
 - (1) It will take 40 minutes to pull out the hose from the fire hose boxes and inject water to spent fuel pool directly.
 - (2) It takes 60 minutes to open fuel building gate and to use mobile water pump to pump water from normal or backup water source and directly inject water to spent fuel pool.
 - (3) It takes 60 minutes to open the rollup door in fuel building and to drive fire truck into fuel building to inject water into spent fuel pool.
5. Availability of qualified operators to perform the special line-up

The operators who are responsible for the operations of above mentioned actions are well trained and excised. They can meet the mission requirements.

6. Confirmation of the occurrence time of the major cliff-edge effect

Fuels will not start to degrade till 147.4 hours(6 days)after loss of spent fuel pool cooling and water makeup at the most serious condition as described in section 5.2.3.3 (All spent fuels of 624 bundles are pulled out to be stored in the spent fuel pool at the tenth day after

outage).

Maanshan NPP

1. If the other unit is not damaged, the available supporting equipment, operating time, and manpower to mitigate event is described as follows:

- (1) Make-up water source:

- a. The CST of both units can be connected to provide making-up water to SFP:
- b. The DST of both units can be connected to provide making-up water to SFP:

- (2) Boric acid:

- a. RWST can be connected to other unit through SFP Purification System to provide ECCS or SFP water source.
- b. SFP can also be connected to other unit through SFP Purification System to provide some water to ECCS or SFP.
- c. If there is water in fuel transfer channel, it can be connected to other unit through SFP Purification System to provide water source to ECCS or SFP.

The supporting from the other unit has been confirmed by site walkdown on April 25, 2011.

- (3) The required time and manpower for above operations:

- a. CST connection: 15 minutes and one man
- b. DST connection: 15 minutes and one man for each unit
- c. RWST connection:
 - Valve operation: 30 minutes and one man for each unit
 - Installation of removable DG: 1 hour and 4 men for each unit (divided into two groups)

Note: One group is responsible for the transportation and installation of mobile diesel generator. The other group is responsible for the transportation and installation of movable air compressor.

- Installation of removable air compressor: 1 hour and 2 men for each unit.

- d. Spent fuel connection:

- Operation of connecting valves: 30 minutes and one man for each unit.
- Installation of removable DG: 1 hour and 4 men for each unit (divided into 2 groups).

- e. fuel transfer channel:

- Operation of connecting valves: 30 minutes and one man for each unit.
- Installation of removable DG: 1 hour and 4 men for each unit (divided into 2 groups)

- f. Fire engine intakes water from Longluan deep pool: 1 hour and 3 men.

- (4) Availability of qualified operators to perform the above action:

- a. For the manpower required in normal operation and emergency repair, including station staff, supporting personnel from offsite organization, and contractor staff, station has completed a checklist. All those people has been trained with radiation

protection and other related fields.

- b. Every maintenance division has supporting manpower list, which is established based on mission assigned, professional specialty, etc. The manpower list includes name, phone number, and address. People around Hengchun area can be the first priority of supporting manpower.
2. If both units are damaged and onsite water source is inadequate, water can be made up from fire engine to CST, RWST, and SFP. Station has one 7 tons fire water tanker. The 4th battalion of Pingtung County Fire Bureau has four squads (Hengchun, Cherchen, Manchu, and Fangshan). They have two 10 tons and two 12 tons water tankers; one 3 tons and four 3.5 tons water tankers; and also have four 1 ton small water tankers. Offsite water sources can be taken from No.2 and No. 3 deep wells, Longluan deep pond, Modan reservoir, and sea water. The supporting manpower from contractors is the total supporting manpower of contractors signed with each division.
3. TPC integrates electrical power generation, transmission and distribution, and sale of electricity. If station has emergency and loss of offsite power, headquarters will immediately take action to recover 345kV or 161kV power system. Offsite power can be provided to station onsite safety-related systems.

Lungmen NPP

1. Station existing equipment, e.g., equipment of other unit
 - (1) Station procedure 1451 defines the emergency steps to use 7th EDG to provided AC power to both units. It also describes load estimation and load saving operations.
 - (2) The fire engines are same as described in Section 5.1.3.4 Item 1(2).
2. Supports available from offsite if all onsite equipment is unavailable
Same as described in Section 5.1.2.4 Item 2.
3. Power cable specifically connected to the power plants (such as hydro, gas turbine plant) in the vicinity
Same as described in Section 5.1.2.4 Item 3.
4. The required prestage time for above mentioned systems
Same as described in Section 5.1.2.4 Item 4. The critical time on the verge of an event is about 9.5hours. At this moment, the members of TSC, AMT, OSC, HPC, and EPIC should be in site already. The supporting should be ready.
5. Availability of qualified operators to perform above actions
Same as described in Section 5.1.2.4 Item 5.

5.2.3.5 Envisaged measures to increase robustness of the plant

Chinshan NPP

1. If SFP and reactor cavity is in connection during outage, Backup Containment Spray System (BCSS), fire engine, or moveable fire pump can be used to make up water to reactor or SFP through RHR piping system.
2. If SFP and reactor cavity is not in connection during non-outage period, BCSS, fire engine, or moveable fire pump can be used to make up water to SFP through RHR piping system. (The blind plate SSF-116-200 shall be disassembled).
3. The 5th floor of Combination Structure building has fire system. Fire water can be

supplied to SFP using fire hose (The normal capacity is 3600 metric tons. It can be connected to two 3000 metric tons raw water storage tank. The backup of these tanks is a 100×10^3 metric tons raw water reservoir).

4. Raw water is filled into DST through makeup demineralizer bypass pipe by gravity. Normally, DST is maintained with 10×10^3 minimum gallons water. DST pump can be powered from MCC which is sourced from 480V removable diesel generator. Since the cover plate of SFP buffering tank overflow port is not watertight, pool water may overflow to reactor cavity. Therefore, temporary hose shall be connected to Service Box to make up water during non-outage period.
5. If loss of all AC power, the new removable diesel generator can be connected to MCC to provide power to SFPACS to support fuel pool cooling.
6. The following two emergency response procedures to make up water in case of abnormal SFP cooling have been issued: procedure 503.6 “Spent Fuel Pool Cooling and Purification System Malfunction” and procedure 1451 “CS Station Ultimate Response Guideline”, and the operators have been trained and exercised.
7. Based on the recommendation of NEI 06-12, station has initiated a DCR to install new SFP makeup water pipes and spray equipment (seismic grade) to increase at least 500 gpm water makeup and 200 gpm water spray capability. The implementation of this DCR will enhance the alternative to make up pool water in case of SFP normal makeup is unavailable.
8. New moveable 480V diesel generator will be purchased to provide emergency power to spent fuel pool cooling. The seismic class of the new cooling system will be improved to increase the depth of defense.
9. Procedure 1024 is modified to stipulate the fuels in the SFP, including just offloaded fuels, re-used with higher decay heat fuels, existed with lower decay heat fuels, and new fuels, should be arranged in a chessboard-like pattern. In the pattern, the spent fuel with lower decay heat will be the “heat sink” of fuel with higher decay heat. Or the spent fuel with higher decay heat will be scattered to delay the time of fuel cladding beyond design limit.

[Kuosheng NPP](#)

Considering the power response capability as in the Fukushima accident compound disaster condition and if air-cooled power supply equipment (including gas turbine generator) are all failed, KSNPP proposes the following strengthening measures of defense in depth:

1. Power enhancement measures: The Power enhancement program as described in section 5.1.3.5 consists of the 5th diesel generator, two sets of Gas Turbine Generators, mobile type 4.16kV 1500kW diesel generator, TSC/OSC diesel generator power supply to 1B3/2B3 or four sets of mobile type 480V 200kW diesel generators.
2. To strengthen spent fuel pool water makeup capability:
 - (1) KSNPP already reviewed and planned to procure 5 sets of large scale fire pumps and a water tanker equipped with booster pump in order to strengthen mobile water injection capability.
 - (2) An additional 6 inch removable cover has been installed on the CST manhole cover in each unit so that water can be provided from CST by the engine-driven pump.
 - (3) Standby fire water injection pipes have been installed so that water can be added from outside of the fuel building to the spent fuel pool either directly or through the spray equipment, which haven't been completed yet. The mobile engine-driven water pump can be used to pump water from the CST of unit 1 or unit 2 to the spent fuel pools in need in both units.

Maanshan NPP

1. The new plant procedure 1451 “Ultimate Response Guideline” has detailed description regarding the responding to every beyond design basis accident. The emergency measures for SFP is also included. The procedure defined in this guideline is adequate to protect the spent fuel in the pool. Operators have been well trained for this procedure.
2. TPC will procure 4.16kV/1500kW mobile diesel generators (scheduled delivery in April, 2012) to serve as the supporting equipment to provide power to safety-related bus. DCR-M0-4325 has been set up to connect the new mobile diesel generator with the existing equipment. This DCR will enhance SFP long term cooling and water make-up capability.
3. The station has procured 480V mobile diesel generator to provide back-up power to CST transfer pump and Seismic Category I fire pump. The capability of long term SFP water make-up from CST can be improved. In addition, DCR-M1-4245/M2-4246 has been proposed to improve the interface of existing distribution system and 480V mobile diesel generator.
4. The station has procured 480V mobile diesel generator to provide back-up power to SFP purification pump. In addition, mobile air compressed has also been procured to support the supply of working air to AOV. The capability of long term SFP water make-up from RWST can be improved. In addition, DCR- M1-4245/M2-4246 has been proposed to improve the interface of existing distribution system and 480V mobile diesel generator.
5. The station has procured mobile diesel engine driven pump. Together with piping modification, this can be a supporting back-up water supply pump for CST transfer pump and can enhance the capability to make up water into SFP from CST. The DCR-M1-4304/M2-4305 has been proposed and design modification has being evaluated. (Scheduled completion date is December 31, 2012)
6. It is planned to use diesel engine fire pump to make up water from fire water tank to SFP, through the fire station in fuel building.
7. It is planned to make up water into SFP from fire engine or outdoor hydrant via fire hose. Besides, DCR-M1-4269/M2-4270 has been proposed to modify the layout of existing SFP piping system. Through this modified piping system, water can be directly makeup into SFP from fire engine or outdoor hydrant.
8. Consider that it is likely people cannot get in and out of fuel building, after event, due to high radiation or other environmental factors. DCR-M1-4273/M2-4274 (completed) has been proposed to modify the normal fire water make-up piping. Fire water can be directly make-up into SFP from fire engine or outdoor hydrant, through fire hose and exterior fire piping. Plant staff does not need to operate any valve nor need to go inside fuel building. This modification can enhance the capability of making-up water into SFP.
9. In the hypothetical event that SFP structure was damaged and no method is available to maintain pool water level, the spent fuel may be uncovered and degraded. A countermeasure has been proposed so that fire water can be directly sprayed into SFP from fire engine or outdoor hydrant, through fire hose and exterior fire piping. The temperature rise of the spent fuel can be mitigated by spray and the spent fuel degradation can be prevented.
10. The station has already prepared small mobile generators. They can support to provide power to exhaust fans, and radiation monitors to ensure the proper function of those rescuing equipment or instruments.
11. The key parameters that have to be monitored during SBO have been reviewed. Those key parameters include spent fuel pool water level and temperature indications. By

enhancing the emergency backup AC power supply for SBO, the instrument power supply can also be strengthened.

12. If there is shortage in onsite water source, water can be made up to CST, RWST, and SFP by fire engine. Station is procuring one chemical foam fire engine with capacity of 7 tons (delivered); one water tanker fire engine with capacity of 12 tons (scheduled for delivery before June 30, 2012). Offsite water sources can be taken from No.2 and No. 3 deep wells, Longluan deep pool, Modan reservoir, and sea water.
13. A review of operating parameters that have to be monitored in main control room is completed. These parameters include SFP water level and temperature. The 24VDC working voltage of transmitter can be provided from I&C division. The current of the specific control loop is measured. Then, engineering reading can be calculated and the value of water level and temperature can be obtained.
14. The monitoring capability of SFP water level and temperature will be enhanced (E-M1-100125/M2-100126). New water level and temperature instruments will be installed, and power will be supplied from UPS. If event occurs, key parameters of SFP can be monitored from control room for 8 hours.
15. Implement a crane locking device including parking point planning and horizontal locking device for the Cask Crane and Fuel Handle Crane in fuel building when it is not in service. The parking point is designated that there is no safety related component beneath. Crashing of crane during earthquakes will not damage any safety related component. Locking device ensures that crane will not have a horizontal movement during earthquake, and will keep crane fixed at the safe parking point.

Lungmen NPP

1. Mobility of Water Injection Equipment: Station plans to purchase 4 mobile firewater pumps (15HP) and air inflated water tanks (15 ton) to be the backup of firewater .
2. Fuel Exhausted: EDG A/B/C and Swing EDG: every EDG has independent fuel storage tank. Each tank has gas cap. Fuel can be made up from truck tank through gas cap.
3. Measures have been proposed to enhance the flooding prevention ability of RB, AFB, and EDG Building, etc., to ensure unit operation will not be affected by flooding. .
4. During outage, SFP and reactor cavity are interlinked. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP or reactor core through RHR system.
5. When unit is not in outage, SFP and reactor are isolated from each other. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP through RHR-C piping system.
6. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines. (Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.) The backup raw water reservoir has capacity 48,000ton.
7. Water can be made up by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.
8. If loss of electrical power, connect mobile diesel generator to power center(PC) to provide fuel pool cooling system power to perform cooling function.

9. Complete SFP emergency water makeup response procedures (Procedure 515.5 “ Fuel Pool Cooling and Cleanup System Failure” and 1451 “Lungmen Station Ultimate Response Guideline”) . These procedure include:(1) mobile diesel generator provides power to related systems to make up water;(2)firewater system makeup water;(3)raw water reservoir makeup water by gravity;(4) fire engine makeup water.
10. Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to make up and to spray firewater. This modification will have 500 gpm more makeup and 200 gpm more spray capacity. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.
11. Install above-ground piping system and upgrade piping seismic category of raw water reservoir.
12. Prepare fuel offload planning instruction. Define the checkerboard layout of fuels during outage and non-outage period. For example: the spent fuels with low decay heat serve as the “heat sink” of high decay heat fuels, or layout the high decay heat fuels dispersedly to delay the time of cladding degradation.

5.2.4 Loss of ultimate heat sink (access to water from the sea)

5.2.4.1 Design provisional autonomy of the site before fuel degradation

Chinshan NPP

The original ultimate heat sink is East Sea and ChienHwa stream. In case of loss of ultimate heat sink without loss of power, power can be provided to the SFP cooling system and the water makeup system to maintain the design functions. However, eventually the design functions will be lost because of no ultimate heat sink. Beside the East Sea and ChienHwa stream, the newly installed air-cooled SFPACS can also serve as an ultimate heat sink by dissipating heat into atmosphere via cooling tower. When 2 trains of SFPACS are in operation, SFPACS can remove the heat of the maximum heat load as described below: The pool water temperature can be maintained less than 65.5°C for the heat load generated by 3083 total fuel bundles, which include the full core off load for 150 hours after reactor shutdown, the previous cycle fuels offloaded 36 days ago, and the historic offloaded spent fuels. SFPACS includes two trains of heat exchangers and raw water/air-cooled cooling towers. The required power of this system is supplied from 480V essential power, while the standby power is supplied from 480V non-essential power. The heat removal capability is 16.2E+6 Btu/hr x 2. The piping is Seismic Category I design. The 2nd side is also Seismic Category I design, but cooling tower is Seismic Category II design.

If SFPACS is unavailable, heat can be removed from SFP only by making up water and by natural convection (natural vaporization).

Under this condition, SFP has the following ways to make up water:

1. If SFP and reactor cavity is in connection during outage, Backup Containment Spray System (BCSS), fire engine, or moveable fire pump can be used to make up water to reactor or SFP through RHR piping system.
2. If SFP and reactor cavity is not in connection during non-outage period, BCSS, fire engine, or moveable fire pump can be used to make up water to SFP through RHR piping system. (The blind plate SSF-116-200 shall be disassembled).
3. The 5th floor of Combined Structure building has fire system. Fire water can be supplied to SFP by using fire hose (The normal capacity is 3600 metric tons. It can be

connected to two 3000 metric tons raw water storage tank. The backup of these tanks is a 100×10^3 metric tons raw water reservoir).

4. Raw water is filled into DST through makeup demineralizer bypass pipe by gravity. Normally, DST is maintained with 10×10^3 gallons water at least. DST pump can be powered from MCC 1A-2 or 2A-2 which is sourced from 480V removable diesel generator. Since the cover plate of SFP buffering tank overflow port is not watertight, pool water may overflow to reactor cavity. Therefore, temporary hose shall be connected to Service Box to make up water during non-outage period.
5. Based on the recommendation of NEI 06-12, station has initiated DCR-C1-3292 /C2-3293 to install new SFP makeup water pipes and spray equipment (seismic grade) to increase at least 500gpm water makeup and 200gpm water spray capability. The implementation of this DCR will enhance the alternative to make up pool water in case of SFP normal makeup is unavailable.

At this time the SFP is cooled by natural convection (natural vaporization). The plant should follow Ultimate Response Guideline 1451 to vent secondary containment and to remove heat.

Kuosheng NPP

As described in section 5.2.1.1 “the design provisions of spent fuel pool water makeup and heat removal”, KSNPP heat sink system is designed to have circulating water system and emergency circulating water system. Circulating water system is for normal operation and emergency circulating water system is for emergency condition. The spent fuel pool water which is evaporated due to decay heat can be made up according to the following methods in case that spent fuel pool losses its ultimate heat sink and power supply is still available (or power supply according to the power strengthening measures as described in section 5.1.3.5):

1. The water level of fuel pool is regulated by means of CST transfer pump.
2. Water is made up to fuel pool by means of RHR Pump.
3. Water is made up to fuel pool by means of emergency make-up pump (1/2P-56A/B).

Maanshan NPP

In case of loss of ultimate heat sink without loss of power, SFP cooling pump and makeup pump still have power to operate. However, heat generated in SFP cannot be removed by NSCW. This situation is the same as loss of spent fuel pool cooling system, but normal water makeup is still available. In this scenario, plant procedure 597.1 will be followed to recover SFP cooling capability or to mitigate the loss of pool water. If water level or cooling capability of the SFP cannot be recovered, the water temperature increasing rate and the time to boiling shall be evaluated and the “feed and bleed” cooling mode shall be established to prolong the time to boiling.

Lungmen NPP

If loss of ultimate heat sink and AC power is available, fuel pool cooling system can perform water make up function; but cooling function will be affected. Since decay heat cannot dissipate into ultimate heat sink, evaporation will be the only way to remove decay heat.

The SFP has following ways to make up water:

1. During outage, SFP and reactor cavity are interlinked. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP or reactor core through RHR system.
2. When unit is not in outage, SFP and reactor are isolated from each other.

Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP through RHR-C piping system.

3. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines. (Firewater pump capacity is 3000 gpm. Two hydrants can discharge flow at 500 gpm.) The backup raw water reservoir has capacity 48,000ton.
4. Water can be made up by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.
5. Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to make up and to spray firewater. This modification will have 500 gpm more makeup and 200 gpm more spray capacity. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.

In this condition, SFP decay heat is removed by evaporation. Station will follow procedure 1451 “Ultimate Response Guideline” to vent secondary containment to remove heat.

5.2.4.2 Foreseen actions to prevent fuel degradation

Chinshan NPP

1. Station existing equipment, e.g., equipment of other unit

If air-cooled SFPACS is operable, it can be utilized to remove the decay heat generated in the SFP. If it is unavailable, SFP heat can be removed only by water makeup and natural convection (natural vaporization).

In procedure 535 “Station Black Out”, it is described that the emergency power of one unit can be provided from the EDGs of another normal unit through the distribution panel of the 5th EDG.

2. Supports available from offsite if all onsite equipment unavailable
Same as described in Section 5.1.3.4 Item 2.
3. The required time for above mentioned systems
Same as described in Section 5.1.3.4 Item 4.
4. Availability of qualified operators to perform the above actions
Same as described in Section 5.1.3.4 Item 5.
5. Confirming the critical time before the onset of damage in this scenario
Same as described in Section 5.2.3.3 Item 3

Kuosheng NPP

1. Except the above-mentioned normal power water makeup methods, gravity or mobile water makeup method as described in section 5.1.3.4 can be used to make up water to the spent fuel pool to make up the water which is evaporated due to decay heat in order to prevent from fuel degradation.
2. Under the most serious condition as analyzed in section 5.2.3.3 (all spent fuels of 624

bundles are pulled out to be stored in the spent fuel pool at the tenth day after outage), fuels will not start to degrade till 147.4 hours (6 days) after loss of spent fuel pool cooling and water makeup.

Maanshan NPP

1. If other unit is not damaged, the available supporting equipment, operating time, and manpower from other unit to mitigate the event are described in Section 5.2.3.4 Item 1.
2. If both units are damaged and onsite water source is inadequate, water can be made up from fire engine to CST, RWST, SFP, and RCS. Station has one 7 tons fire water tanker. The 4th battalion of Pingtung County Fire Bureau has four squads (Hengchun, Cherchen, Manchu, and Fangshan). They have two 10 tons and two 12 tons water tankers; one 3 tons and four 3.5 tons water tankers; and also have four 1 ton small water tankers. Offsite water sources can be taken from No. 2 and No. 3 deep wells, Longluan deep pool, Modan reservoir, and sea water. The supporting manpower from contractors is the total supporting manpower of contractors signed with each division.
3. Confirming the critical time before the onset of damage in this scenario

According to Maanshan SFP Re-racking Thermal Hydraulic Analysis Report, the maximum pool water temperature increasing rate will be 5.94°C/hr in case of loss of SFP cooling. It takes about 6.7 hours for pool water to boiling. As described in Section 5.2.3.1, the time that pool water level drops to 10 feet above the top of spent fuel is about 40 hours.

Lungmen NPP

1. Station existing equipment, e.g., equipment of other unit

In case of loss of ultimate heat sink, the SFP's decay heat can be removed only by water makeup and evaporation. Station will follow procedure 1451 "Ultimate Response Guideline" to provide AC power to both units from 7th EDG or use Unit 1 /2 EDG to support each other..

2. Supports available from offsite if all onsite equipment unavailable

Same as described in Section 5.1.3.4 Item 2.

3. The required prestage time for above mentioned systems

Same as described in Section 5.1.3.4 Item 4. The critical time on the verge of an event for Reactor Building and Auxiliary Fuel Building Fuel Pool are 9.5 and 151.6 hours, respectively. At this moment, the members of TSC, AMT, OSC, HPC, and EPIC should be in site already. The supporting should be ready.

4. Availability of qualified operators to perform above actions

Same as described in Section 5.1.3.4 Item 5.

5. Confirming the critical time on the verge of an event

Under the condition of SFP loss of cooling water and full core off loaded during outage, calculation shows the pool water temperature increasing rate is 5.4°C/hr. If the initial pool water temperature is 49°C, pool water will begin to boil after 9.5 hours. If the initial AFP water temperature is 49°C, AFP pool water will begin to boil after 151.6 hours.

5.2.4.3 Envisaged measures to increase robustness of the plant

Chinshan NPP

1. Ultimate heat sink enhancement:

- (1) Based on the existing design basis, the operation of only one train Emergency Service Water (ESW) System can ensure the removal of core decay heat and other heat generated by safety related equipment. CS station has already established the ESW pump motor replacement procedure. Currently the station has only one spare ESW motor, in order to ensure the availability of spared motor, it is planned to purchase another one.
- (2) The SFPACS cooling tower and related piping will be upgraded to Seismic Category I design.
- (3) The 5th EDG and ESW pump room of both units will install watertight equipment at doors and openings to prevent flooding.
- (4) The station is purchasing two 4.16kV 1500kW diesel generators. One will be placed on site, the other one will be placed at Lungman station temporarily. Kuosheng station has same type diesel generators, which can be an offsite support in case of emergency. All of these can improve the availability of emergency power supplied to ESW.

Kuosheng NPP

1. When emergency circulating water system is unavailable such that the ultimate heat sink of fuel pool is lost, KSNPP shall promptly restore emergency circulating water system to be operable in accordance with the envisaged measures to increase robustness of the plant as described in section 5.1.4.3 item 2 “Enhancement of ECW”.
2. If the heat sink of fuel pool still could not be restored and designed power supply is still in normal condition, water makeup can be proceed according as designed water makeup. If the heat sink of fuel pool still could not be restored and designed power supply is also lost, water makeup can be preceded in accordance with diversity mobile water makeup as described in section 5.2.3.4 and section 5.2.3.5. The spent fuel pool water which is evaporated can be continuously made-up such that it is assured that spent fuels in spent fuel pool are covered with water and the cliff edge effects of fuel degradation due to fuel uncovered with water will not occur.

Maanshan NPP

The measures to increase robustness of prevention loss of ultimate heat sink are described in Section 5.1.4.3 Item 2~6.

Lungmen NPP

1. Ultimate Heat Sink Enhancement

- (1) Based on the existing design basis, the operation of only one train RBSW system can ensure the removal of decay heat and other heat generated by safety related equipment. Station already has an emergency plan if RBSW motor is unavailable, and is preparing a spare RBSW motor for emergency replacement. This motor will be placed at the warehouse at elevation 43.3 m. Once RBSW motor fails, immediate replacement can recover these systems as soon as possible.
- (2) Install above-ground piping system and upgrade piping seismic category of raw water reservoir.
- (3) Betterment proposal has been approved to install flood barrier and water tight device at the doors and openings of RB, CB, DG Fuel Oil Tank, AFB, FPH, RBSWPH pump room, ACB EL.12.3 m into RB, and RWT EL.12.3m into RB/CB and AFB. This betterment can prevent flooding.

- (4) Station will have 2- 4.16kV 1500kW mobile generators. One will be placed onsite (Another one temporarily will be placed at Chinshan station). Kuosheng station has same type diesel generators to support Lungmen. RBSW system power availability can be improved.

5.2.5 Loss of the ultimate heat sink combined with station black out

5.2.5.1 Design provisional autonomy of the site before fuel degradation

Chinshan NPP

If SBO and loss of ultimate heat sink, SFP water will lose normal cooling and make-up. The station will follow procedure 1451 “CS Station Ultimate Response Guideline” to take emergent response to restore the capability of SFP cooling and water makeup function.

Kuosheng NPP

When the function of fuel pool cooling and water makeup is lost, core water covered with fuel will be continuously warmed up and evaporated. Fuel may degrade as soon as core water level drops to the level that fuels are uncovered or cooling can't be maintained. In the most serious condition as described in section 5.2.3.3, the station still has sufficient time (about 6 days) to cope with before fuel initiate degradation.

Maanshan NPP

The design of SFP loss of cooling and the evaluation of SBO are described in Section 5.2.3.1. The descriptions of design provisional autonomy of the site are described in Section 5.2.3.3.

Lungmen NPP

In case of SBO and loss of ultimate heat sink, spent fuel pool will lost normal cooling and water makeup function. Station will follow procedure 1451 “Ultimate Response Guideline” to take emergency response to recover SFP cooling and water makeup ability.

5.2.5.2 Foreseen external actions to prevent fuel degradation

Chinshan NPP

1. Station existing equipment, e.g., equipment of other unit

- (1) If air-cooled SFPACS is available, power can be provided from newly purchased moveable/ stationary diesel generator. SFPACS has enough capability to support SFP cooling. In addition, procedure 535 “Station Black Out” can be followed. In this procedure, if one unit has SBO, emergency power can be supplied from the EDG of another unit through the distribution panel of the 5th EDG.
- (2) Backup Containment Spray System (BCSS) can make up water to SFP through RHR piping system by incorporating fire engine, or moveable fire pump.
- (3) The 5th floor of Combination Structure building has fire system. Fire water can be supplied to SFP by using fire hose. (The normal capacity is 3600 metric tons. It can be connected to two 3000 metric tons raw water storage tank. The backup of these tanks is a 100×10^3 metric tons raw water reservoir.)
- (4) Raw water is filled into DST through makeup demineralizer bypass piping by gravity. Normally, DST is maintained with 10×10^3 gallons water at least. DST pump can be powered from MCC 1A-2 or 2A-2 which is sourced from 480V removable diesel

generator. Since the cover plate of SFP buffering tank overflow port is not watertight, pool water may overflow to reactor cavity. Therefore, temporary hose shall be connected to Service Box to make up water during non-outage period.

- (5) Based on the recommendation of NEI 06-12, the station has initiated DCR-C1-3292/C2-3293 to install new SFP makeup water pipes and spray equipment (seismic grade) to increase at least 500 gpm water makeup and 200 gpm water spray capability. The implementation of this DCR will enhance the alternative to make up pool water in case of SFP normal makeup is unavailable.
2. Supports available from offsite if all onsite equipment unavailable
 - (1) If SFPACS is available, offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station. In addition, mobile diesel generators supported from Lungmen station are also available.
 - (2) Chinshan station and NewTaipei city government has signed a protocol of fire fighting (or other disasters) support. Depends on the characteristic of event, Fire Bureau will support manpower, vehicles, and equipment to site to mitigate disasters.
3. The required time for above mentioned system
Same as described in Section 5.1.3.4 Item 4.
4. Availability of qualified operators to perform the above actions
Same as described in Section 5.1.3.4 Item 5.
5. Confirming the critical time before the onset of damage in this scenario
Same as described in Section 5.2.3.3.

Kuosheng NPP

Diversified styles of mobile water makeup is used to prevent fuel from degradation when the ultimate heat sink is lost under the condition of SBO as referred to the external support measures as described in section 5.2.3.4 (loss of off-site power, backup power and other type backup power).

Maanshan NPP

1. Under this condition, unit status is same as Section 5.2.3. Offsite supports to prevent fuel from degradation are the same as described in Section 5.2.3.4.
2. Confirming the critical time before the onset of damage in this scenario:
According to Maanshan SFP Re-racking Thermal Hydraulic Analysis Report, the maximum pool water temperature increasing rate will be 5.94°C/hr in case of loss of SFP cooling. It takes 6.7 hours for pool water to boiling. As described in Section 5.2.3.1, the time that pool water level drops to 10 feet above the top of spent fuel is about 40 hours.

Lungmen NPP

1. Station existing equipment, e.g. equipment of other unit
 - (1) Connect 480 V mobile DG to the power source of fuel pool cooling system at power center (PC) to support fuel pool cooling. Alternatively, follow procedure 1451 “Ultimate Response Guideline” to provide AC power to both units by 7th EDG; or use EDG of Unit 1 and Unit 2 to support each other.
 - (2) In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or

through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines. (Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.) The backup raw water reservoir has capacity 48,000ton.

(3) Water can be made up by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.

(4) Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to make up and to spray firewater. This modification will have 500 gpm more makeup and 200 gpm more spray capacity. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.

2. Supports available from offsite if all onsite equipment unavailable

Same as described in Section 5.1.3.4 Item 2.

3. The required prestage time for above mentioned systems

Same as described in Section 5.2.4.2 Item 3.

4. Availability of qualified operators to perform above actions

Same as described in Section 5.1.3.4 Item 5.

5. Confirming the critical time on the verge of an event

Same as described in Section 5.2.4.2 Item 5.

5.2.5.3 Envisaged measures to increase robustness of the plant

Chinshan NPP

The measures to increase robustness of the plant are same as described in Section 5.2.3.5 items 1~9. There is one more measure listed below.

1. Perform design change and upgrade the seismic capability of SFPACS cooling tower CT-15A/B piping system to Seismic category I.

Kuosheng NPP

1. As for station blackout resulted in loss of ultimate heat sink condition, power enhancement program are detailed described in section 5.1.2.3 and section 5.1.3.5. The required 4.16kV/480V AC/DC power can be supplied as the above-mentioned measures to restore ultimate heat sink capacity of spent fuel pool.

2. If station power can't be restored in a short time (it means that above-mentioned power enhancement measures are all failed), it results in that ultimate heat sink can't be built-up. In this case, water makeup to spent fuel pool shall follow mobile water makeup and enhancement measures as described in section 5.2.3, section 5.2.3.4, and section 5.2.3.5. The enhancement measures are established to ensure that the spent fuel in spent fuel pool can be long-term covered with water so that the cliff edge effect of fuel degradation will not occur.

The above-mentioned power enhancement measures shall be followed to restore ultimate heat sink or spent fuel pool water makeup by means of every kind of mobile type. To maintain the spent fuel in spent fuel pool to be long term covered with water in order to ensure that the cliff edge effect of fuel degradation will not occur.

Maanshan NPP

At this condition, unit status is same as that described in Section 5.2.3 (SBO). Measures to increase robustness of the plant are described in Section 5.2.3.5.

Lungmen NPP

1. During outage, SFP and reactor cavity are interlinked. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP or reactor core through RHR system.
2. When unit is not in outage, SFP and reactor are isolated from each other. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP through RHR-C piping system.
3. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent dedicated pipe lines. (Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.) The backup raw water reservoir has capacity 48,000ton.
4. Water can be made up by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.
5. If loss of power, connect 480 V mobile DG to the power source of fuel pool cooling system at power center (PC) to support fuel pool cooling.
6. Complete SFP emergency water makeup response procedures (Procedure 515.5 “Fuel Pool Cooling and Cleanup System Failure” and 1451 “Lungmen Station Ultimate Response Guideline”). These procedures include: (1) mobile diesel generator provides power to related systems to make up water; (2) firewater system makeup water; (3) raw water reservoir makeup water by gravity; (4) fire engine makeup water.
7. Based on the recommendations in NEI 06-12, station will have the following enhancement. Install seismic designed firewater piping to make up and to spray firewater. This modification will have 500 gpm more makeup and 200 gpm more spray capacity. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.
8. Install above-ground piping system and upgrade piping seismic category of raw water reservoir.
9. Prepare fuel offload planning instruction. Define the checkerboard layout of fuels during outage and non-outage period. For example: the spent fuels with low decay heat serve as the “heat sink” of high decay heat fuels, or layout the high decay heat fuels dispersedly to delay the time of cladding degradation.

5.3 Assessment and conclusions of the regulatory body

The reports of the licensees essentially conform to the ENSREG requirements. The approach adopted by the licensee to re-assess the management of the loss of electrical power and loss of ultimate heat sink complies with the regulations of the ROCAEC that is based on the regulations of the country of the reactor vendor. However, the regulatory body identified some areas for improvement:

1. The analysis postulates that only one unit is affected. The consequences of several units in one site being affected shall be addressed.
2. During shutdown conditions, the accident scenario, the available mitigation systems and

the cliff edge effects may be quite different from those of normal operation. This is particularly important for the PWR because it was already well-known that the shutdown state and in particular mid-loop operation is the most un-favorable state in the event of SBO. If the reactor is open a few days after shutdown (for refueling), without countermeasures, core heat up is typically within the one to three hours range. However, the situations in which the reactor coolant system is open or operating with reduced inventory are not addressed in TPC stress test report. The missing assessment is considered necessary for a complete assessment.

3. Extreme external hazards (including earthquake, flooding, Tsunami, etc.) may result in SBO and complete loss of heat sink, the consequential impact to spent fuel pool (including the integrity of pool structure) should be evaluated.

Based on the assessment of the licensee's reports and the supporting documents, the technical meetings and the on-site inspections and audits, the regulatory body considers that the resulting action plan is adequate.

However, the regulatory body identified additional areas to further improve the robustness of all the units:

1. In response to the Fukushima accident, many good practices have been proposed by the international nuclear industries. Referring to these good practices, the AEC requires the TPC to accomplish the following regulatory requirements:
 - (1).After the SBO event of Higashidori NPP on April 7, 2011, NISA issued a Direction to require more than 2 emergency DGs to be in an operable state all the time even when the reactor is shut down. The same position was adopted by the ROCAEC. Currently, there are 2 EDGs per unit in the operating nuclear power plants. If one unit is in normal operation and the other unit is shut down with one EDG under inspection, the swing EDG will be assigned to the latter unit according to the new requirement. Therefore, the capability of the swing EDG to back up the unit in normal operation is restricted. Envisaged measures to resolve this issue are required.
 - (2).With respect to the SBO, the TPC is required to establish the equipment, procedures, and training necessary to implement an "extended loss of all AC" time of 72 hours for core and spent fuel pool cooling and for reactor coolant system and primary containment integrity as needed. The design of the systems supporting the 72-hour extended coping time should cover the same scope of functions as the 8-hour minimum coping time, but it can be based on realistic analysis with reasonable operator action using portable or permanently installed equipment governed by established procedures and training.
 - (3).In a case of an event caused by an external hazard, all the units on a site may be affected. Sufficient supplies of emergency AC power for coping with such events is essential for enhancing robustness because resources need to be shared. Therefore TPC is required to perform an evaluation regarding to the installation of an additional air-cooled DG at the NPP.
 - (4).TPC is required to perform an evaluation regarding to the establishment of an additional alternate heat sink such as the water fed by groundwater wells.
 - (5).Envisaged measures are required to increase robustness of the plant in dealing with the primary coolant pump seal LOCA issue during SBO.
 - (6). Referring to the emergency management and requirements in Japan, the TPC is required to enhance the off-site power system and increase its reliability.
2. With respect to the SBO, the AEC requires the TPC to strengthen SBO mitigation capability at all operating and new reactors for design-basis and beyond-design-basis external events as it is recommended in item 4 of USNRC NTTF report.
3. Regarding to the non-conventional means, the AEC requires:
 - (1) The operability of the non-conventional means should be justified on the basis of

technical data (design, operation, alignment and connections, periodic testing, preventive maintenance, etc.).

- (2) A systematic review of the non-conventional provisions should be performed, focusing on the availability and appropriate operation of plant equipment in the relevant circumstances, taking account of accident initiating events, the extreme external hazards and the potential harsh working environment they may be subject to during the entire period of operation.
 - (3) Non-conventional means including mobile equipment, fire trucks, etc. should be stored in locations that are safe and secure even in the event of general devastation caused by events (significantly) beyond the design basis. The facilities where the mobile equipment is stored should be evaluated and reinforced if necessary.
4. The importance of the justification of the URG is illustrated by the following example: In BWR, the licensee has applied for measures aimed at using a fire water pump to sustain low-pressure feed to the reactor. These measures require depressurization of the reactor beforehand. In URG, a two step depressurization strategy has been adopted for prolonged SBO. In the early stage of SBO, a slow and controlled depressurization of the reactor is performed while the RCIC is still available. In the second stage, a fast and emergency depressurization of the reactor is performed while the RCIC is no longer available. With the slow and controlled depressurization process, the reactor can be brought to and maintained at a relatively safe state (namely, a high water level and low pressure state) while at the same time, the RCIC trip set point will not be reached. Under this safe state, the impact of the emergency depressurization of the reactor following the failure of RCIC will be minimized and the reactor water inventory can be supplemented by various low pressure injection methods. On the other hand, if the reactor is at relatively danger state (namely, a high pressure state), fast depressurization of the reactor will lead to a core uncover even the water level is high before depressurization. In this example, the subtle detail matters. The controlled depressurization should not be confused with the emergency depressurization. However, the two terminologies are not well distinguished in the utility's stress test report. In summary, the operability of the URG is required to be justified on the basis of rigorous systematic review and thorough accident analysis.
 5. The hydrogen and containment pressure control strategies in the URG shall take into account various accident scenarios.
 6. The TPC is required to study the feasibility of adding the mobile heat exchanger to remove the heat from the containment and/or the reactor.

6. Severe accident management

6.1 Organization and arrangements of the licensee to manage accidents

6.1.1 Organization to manage the accident

6.1.1.1 Organization structure

The Emergency Control Team (ECT) is the kernel responsible for all management measures in case of an accident. As shown in Figure 6-1, the ECT consists of the Main Control Room (MCR), Technical Support Center (TSC), Operation Support Center (OSC), Emergency Public Information Center (EPIC), and Health Physics Center (HPC) staffs.

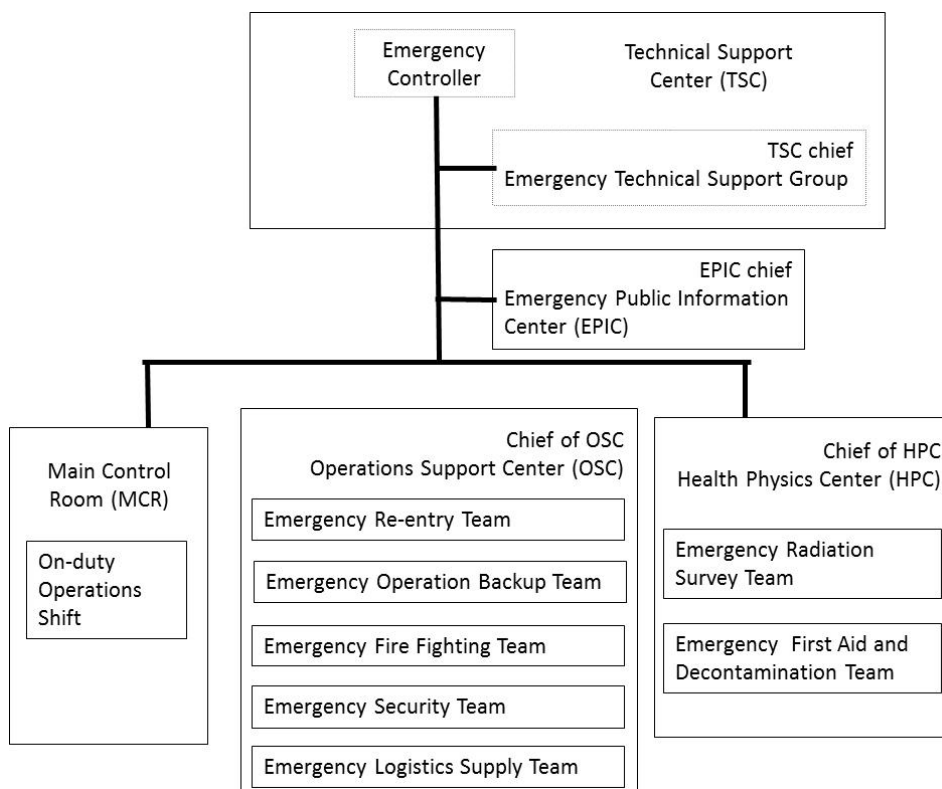


Figure 6-1 On-site Emergency Organization – Emergency Control Team (ECT)

In the case of a severe nuclear accident, TSC will be organized and all emergency responses will be conducted according to Emergency Operating Procedure (EOP) and SAMG immediately to handle the accident through assessing every contingency measure of SAMG, and adopting corresponding strategy, in order to mitigate the consequence of the accident. Under TSC, the Accident Management Team (AMT) will be held after TSC established and cooperate with the MCR for decision making of management measures, implement the measures decided, monitor the effectiveness of the measures implemented, and adjust the measures as required.

Before TSC and AMT are established, MCR staff will follow guidelines in SAMG to monitor and evaluate the plant situation and to prevent core damage until TSC is activated. Once the TSC is activated and AMT starts to support the decision making, the leadership is moved from MCR to TSC. MCR is moved from the active position to passive, i.e. supporting the decision of TSC. MCR is then responsible for monitoring the plant conditions and avoiding the possible negative effects from measures implemented, considering long-term cooling, and reporting regularly the situations to TSC.

For a multi-event and multi-unit severe accident like Fukushima, each plant duplicated the

teams in TSC and AMT. If the TSC members and the professional engineers of Mechanical Engineering, Electrical Engineering, Instrumentation & Control, and Repairing Sections can not arrive the plant because of the traffic interruption or any unexpected circumstances, TSC should be established with local staff and arranged as personal professionals for emergency plan. Also, the name list of contracting companies and local staff is available. The professionals and contacts are recorded on the list. All supporting manpower can be collected at the shortest time.

6.1.1.2 Use of off-site technical supports for accident management

Current situation

The kernel organization of severe accident response and management is the ECT. The Nuclear Emergency Planning Executive Committee (NEPEC) in Taiwan Power Company (TPC) is responsible for off-site technical supports. The governmental Central Disaster Response Center (CDRC) is responsible for coordinating rescue supporting resources outside the plant. Emergency Response Organization chart is shown in Figure 6-2.

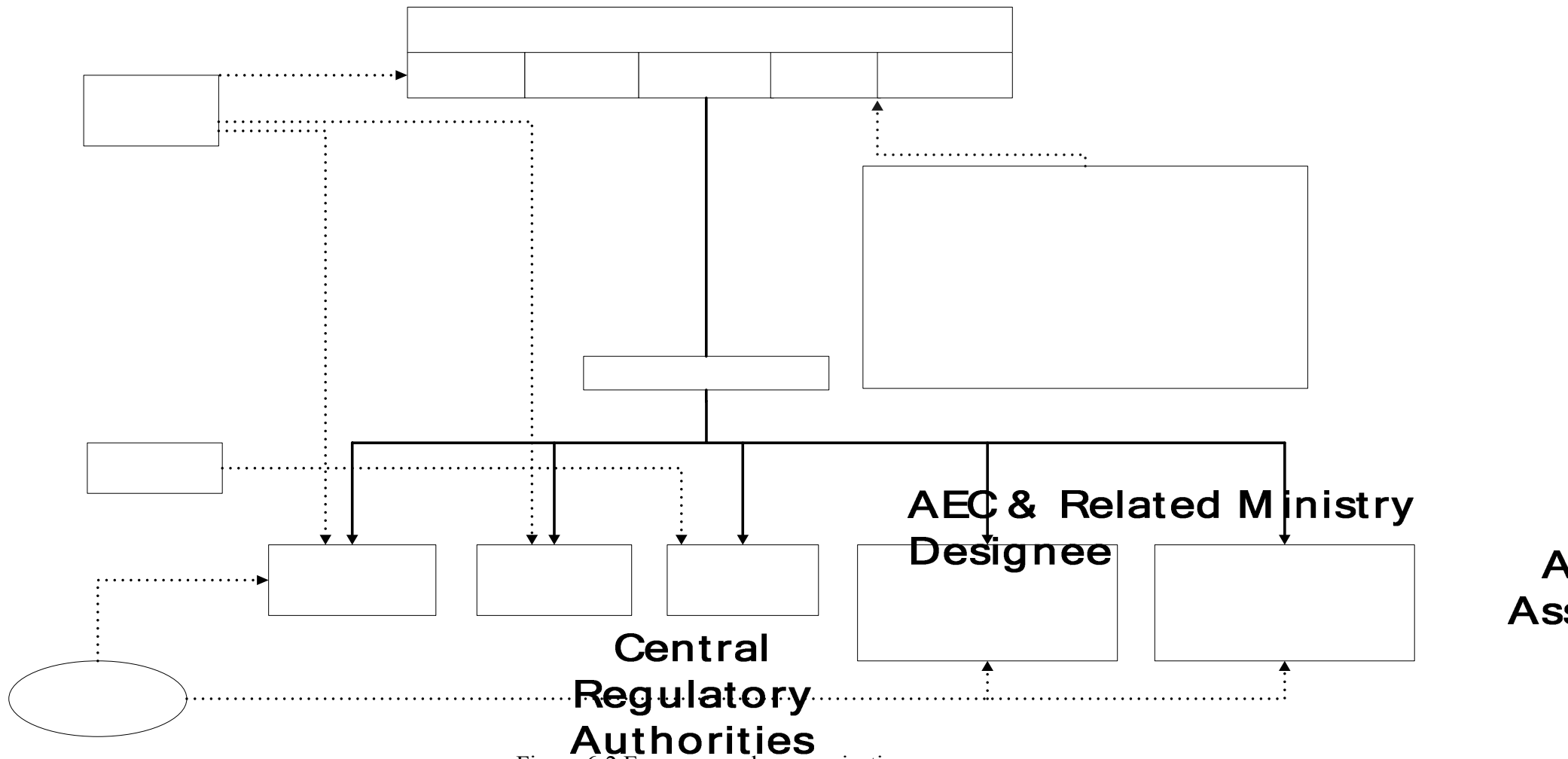


Figure 6-2 Emergency plan organization

In the case of a severe accident, ECT will immediately identify the accident type and the level of influences, and deploy corresponding technical groups to carry out the corresponding processes. At the same time, ECT shall report to the NEPEC about the evolution of the accident according to the regulation. NEPEC will support the plant in accident as soon as possible. If the requirements for off-site supports are upgraded, all external resources assembled will be allotted to CDRC and its Forward Command Post (FCP) under NEPEC. All resources and materials will be dispatched and utilized via CDRC. The supports from Interior Ministry's Fire Department, Police Department, the Military Command Units, other government departments, and those received from other countries are under the command or coordination of CDRC.

The improvements after Fukushima accident

As for the employment of the police and the military, each nuclear power plant has collaboration agreements with military, local hospitals and local police stations for supports in case of nuclear accidents. Parties communicate with each other regularly to become familiar with the contents and operating procedures of the agreement.

6.1.1.3 Procedures, Training and Exercises

Current situation

There are three operating nuclear power plants in Taiwan. All have developed the EOP and SAMG with respect to the plant specific features. The development of EOPs and SAMGs of the Chinshan and Kuosheng NPPs was based on the generic BWROG EPGs/SAGs. The development of EOP and SAMGs of the Maanshan NPP was based on the WOG generic procedures and guidelines. The EOPs and SAMGs are also reviewed and updated as the latest technologies and researches become available. The regular trainings and exercises are required for each NPPs.

The improvements after Fukushima accident

To resist compound disasters that go beyond plant design conditions such as the case of the Fukushima accident, whereas the loss of both on-site and off-site AC power and/or loss of heat sink occurred, TPC is establishing the "Ultimate Response Guideline" (URG, Procedure 1451) for each of operating nuclear power plants to strengthen the defense-in-depth. It provides guidelines for integrating resources inside/outside the plant to control accident events and to mitigate accident consequences in a timely manner, and ultimately making difficult decisions to restore core cooling capabilities and to sustain the integrity of reactor vessel, reactor containment and spent fuel pool. The drafted URGs have been issued and are briefly introduced in Section 6.1.4.

The regular trainings and exercises for such emergency preparedness are coded in law and regulations promulgated by Atomic Energy Council (AEC). The emergency preparedness exercises at the three operating nuclear power plants under the command of CDRC are implemented in the period of once a year. After the Fukushima accident, the content and frequency of these exercises and trainings are being made more extensive and frequent.

6.1.2 Possibility to use existing equipment

Chinshan NPP

Chinshan plant has followed the WANO SOER 2011-2 to verify the availability and functionality of equipment under the severe accidents, sifted the scope by SAP procedure (540.5 and 540.6) and EOP supplemental procedure (540.7), preceded the necessary tests according to the equipment characteristics (Active/Passive), and completed the verification and inspection by Walkdown. All verification results meet the requirements.

After checking thoroughly the equipment of the corresponding procedures for mitigating severe accidents, they are divided into two categories: the first category is already established in the system (fixed, used in normal and emergency conditions), the other category is used for supporting emergency situations (usually used for handling emergencies with fixed, movable and partially movable). The equipment items and check results are as follow:

(1) The important equipment already established on the system (fixed, used in normal and emergency conditions)

- A. Inject water into RPV/Primary containment: Low Pressure Core Injection System (LPCI); Core Spray System (CS); High Pressure Core Injection System (HPCI); Reactor Core Isolation Cooling System (RCIC); Condensate Transport system; Reactor Feedwater Pump (RFP); Fire Water system; Backup Containment Spray System (BCSS); Water pumps of Emergency Core Cooling System (ECCS); Standby Liquids Control System (SBLC); RHR service water connection conduits.
- B. Venting of the primary containment: Primary Containment Ventilation System; Standby Gas Treatment System; Drywell spray; Suppression pool spray.
- C. Reactor power control: MODE switch shutdown (MODE SW S/D); Repetitive Reaction Control System (i.e., Alternate Rod insertion, ARI); Control Rod (CR); Standby Liquids Control System (SBLC).
- D. RPV pressure control: Bypass valve of the main gas turbine; Water draining valve of the main steam pipe; The testing mode of HPCI; The testing mode of RCIC; Steam Jet Air Ejector (SJAE); Turbine Seal Steam Bypass Valve; Reactor Water Cleanup System (RWCU); RHR shutdown cooling mode; Safety Relief Valve/Automatic depressurization system (SRV/ADS).
- E. Primary containment hydrogen control: Hydrogen Detection System; Suppression pool Ventilation System; Drywell ventilation; Primary containment Air/Nitrogen Purge System; Hydrogen Recombiner; Drywell spray; Suppression pool spray.
- F. Primary containment air control: RHR & Suppression Pool Cooling System; Drywell Air Conditioning System.
- G. Secondary containment control & radioactive materials release control: Standby Gas Treatment System; Air Handling units in the secondary containment; Turbine building HVAC System; Waste materials buildings HVAC System.
- H. Emergency power sources: Water cooled Emergency Diesel Generator; Air-cooled 5th Diesel Generator; Gas Turbines Generator.
- I. Heat removal (heat sink): Combination Structure Cooling Water System; Essential Service Water System.
- J. Pool water cooling: Spent fuel pool; Suppression pool cooling system.
- K. Others: Instrument Air System; Combination Structure Cooling Water System; Service Water System; Emergency Chilled Water System.

The above equipment have been included in Chinshan plant's quality assurance system for regular test, maintenance, and controlled by MMCS (Maintenance Management Computer System). They are now in working conditions.

(2) The equipment for supporting emergency situations (used in response to emergencies, with fixed, movable and part of them are movable)

- A. The hardware (including PCs of the staff) and software on the working sites of AMT;
- B. The parameters indicating instruments (including ERF and board instruments panel)

needed in the accidents;

- C. The equipment for alternate boron injection;
- D. Inject raw water into reactor core (including raw water reservoir, corresponding conduits and caps);
- E. EOP interlock that need to be crossed over or disconnected, verify the numbers of cross-over lines and positions;
- F. Mobile air compressor (EDG start-up air for backup);
- G. TSC/OSC diesel generator;
- H. Firefighting (including water sources, CO₂ storage quantity, generators, fire hydrant water pump, water pumps, fire engines, etc.).

The above equipment has been checked through Test or Inspection / Walkdown to confirm their availabilities and functionalities according to their (Active or Passive) characteristics. The results of all equipment are good. For those extreme rare items excluded in the prevention and maintenance, they are reviewed and modified by MMCS. These protection and maintenance works will be regularly performed.

- (3) Field inspection or check the equipment (like firefighting equipment) for mitigating the accident consequences, and verify conduits functions if they will fail by the interaction of earthquakes/tsunami/flood, and then review and confirm the potential weaknesses.

Chinshan plant has completed the verifications of the important equipment for mitigating consequences about the locations, the grades of seismic-proof, the utilized power sources and current maintenance measures, including the equipment of reactor water injection, reactivity control, hydrogen control, containment venting, reactor venting and pressure control, emergency water supply system of the spent fuel pool, emergency service water system and firefighting equipment, etc. The verification and field inspection results based on the design bases of the plant for that equipment responding to fires, floods, earthquakes, and tsunamis are as follow:

A. Fire

Chinshan plant has completed the tests, maintenance and inspection on the corresponding facilities based on the maintenance operation of the firefighting system and found no abnormalities, including: automatic fire hydrant water spray system, Carbon dioxide automatic spray system, Fire fighting foam spray system, HaiLung automatic fire extinguish system, indoors and outdoors fire hydrants. Chinshan plant's fire fighting facilities (except for source equipment and pipes) corresponding to safe shutdown are the seismic-proof design Class 1E.

B. Floods

There has been a project proposed to improve the water-proof deficiency in the emergency service water pump rooms in which flood barrier plates will be installed at the openings. (MMR-0416/0407)

C. Earthquakes

Chinshan's reactor building and ECCS are both designed as the seismic-proof design Class 1E, the same for the cranes in the reactor building. They are all installed with the mechanical brakes to prevent falling from slipping.

“The project team of the seismic proof evaluation for nuclear power plants” has completed Chinshan plant's inspection of start-up of gas turbine system in station blackout, oil storage tanks and raw water tanks.

In the buildings of Chinshan plant's generator and transformer, equipment, materials, miscellaneous that don't belong to the system have management measures for temporary or long term storages in order to assure the storage locations will not damage the safety equipment in normal time or during earthquakes.

D. Tsunami

National Science Council has performed the tsunami simulation, to evaluate if Taiwan's nuclear power plants can stand the tsunami attacks. According to the current data and scientific evidences, it shows all current 4 nuclear power plants are not affected by the attacks from earthquake-induced tsunami. In which if the earthquake magnitude 8.5 happened in Ryukyu Islands Arc attacks Chinshan plant, the water will rise to 2.8 meters, and it is still much lower than the 9 meters stated in Chinshan plant's FSAR, even if 1.73 meters added by storm tide, it is still much lower than Chinshan plant's ground level of 11.2 meters. [However, there are still significant uncertainties in tsunami run-up predictions due to the definition of tsunami sources. They will build the tsunami wall to cover the uncertainty of the tsunami run-up predictions.](#)

[Kuosheng NPP](#)

Current situation

After the Fukushima accident in Japan, Kuosheng NPP immediately followed all the recommendations in WANO SOER 2011-2 to perform the verifications and countermeasures. For recommendation item 1.a, Kuosheng NPP comprehensively checked the availability and function of equipment and instrumentations designed for present procedures of severe accident mitigation, including the SAMG, the EOPs and spent fuel pool cooling. The functions of the reactor water makeup, the RPV vent and pressure control, the reactivity control, the hydrogen control, the containment vent, the emergency water makeup system of spent fuel pool, the emergency power supply, the emergency circulating water (ECW) system, the necessary instrumentation and indication for post-accident management (including ERF and the panel instrument meters) and others were confirmed. The availability of systems required in the Technical Specifications was verified through tests or inspections. The active items of other equipment which are not scheduled in a periodic inspection were tested. The passive items of other equipment which are not listed in a periodic inspection were inspected and walkdown.

The improvements after Fukushima accident

The comprehensive inspection was completed by April 30, 2011. The availability and function of equipment and instrumentations designed for present procedures of severe accident mitigation are verified. The results indicate the service life of “fire water tanker” has been expired, but the functions are normal. Kuosheng NPP has purchased more fire water tanker after this checkup (details in the chapters 2 and 3). The verified equipment has been integrated into Kuosheng’s routine test and maintenance program per Quality Assurance Program to assure their availability and function.

[Maanshan NPP](#)

Current situation

Once a severe nuclear accident occurred in Maanshan NPP, EOPs and SAMG will be initiated. The establishment of TSC and AMT is followed for mitigating the accidental consequences. For the incident of spent fuel pools, procedure 597.1 “Treatment and recovery of spent fuel pool from loss of cooling capability and loss of pool water” is followed to assure the spent

fuels are submerged in water. The fuels exposure can be avoided.

Maanshan NPP has scrutinized the corresponding equipment of procedures for mitigating the severe accidents. Two categories are identified. One is categorized as safety-level equipment/systems (fixed, used for normal or emergency operation). The other is categorized as emergency-level equipment (fixed and mobile, generally used for emergency operation).

(1) Safety-level equipment/systems

- A. RCS/Containment water injection: Residual Heat Removal system (RHR); High Pressure Injection System (CCP); Medium Pressure Injection System (ACCUMULATOR); Condenser Storage and Transfer System.
- B. Steam generator make-up and steam discharge: Main Steam Isolation Systems (MSIV); Auxiliary Feedwater system; Feedwater Isolation system (FWIV).
- C. Containment Cooling system: Containment Hydrogen Analyzer; Containment Fan Cooler; Post Accident Hydrogen Release System; Hydrogen Recombiner System; and Containment Low Volume Purging System.
- D. Emergency power: Emergency Diesel Generator A; Emergency Diesel Generator B; the 5th Diesel Generator; Gas Turbine Generator.
- E. Residual heat removal (ultimate heat sink): Normal Service Water System (NSCW).
- F. Spent fuel pool cooling systems: Spent Fuel Pool Cooling System; Spent Fuel Pool Make-up Water System.

All these equipment/systems are periodically tested and maintained according the procedures under the quality assurance program in Maanshan NPP. And the tests and maintenance are scheduled and recorded in MMCS. The availability of all those equipment/ systems is guaranteed.

(2) Emergency-level equipment

- A. The hardware of AMT working environment (including personal computers)
- B. Accidents situation reflection parameters showing facilities (including ERF and panel)
- C. Spare boric acids
- D. Systems/components for supplying raw water into reactor core at urgent condition (including raw water reservoirs, corresponding piping and caps)
- E. Quantities and locations list of cross connections and tie line between units on which disconnect, cross-connect, and welding are required for supporting across unit during accident, and described in EOP procedure.
- F. TSC diesel generator
- G. Fire protection facilities (including water sources, CO₂ storage, generators, fire water pumps, water pump, fire engines, etc.)

The emergency-level equipment is classified as active and passive groups. All equipment are required to periodically test or inspect/walkdown to check their availabilities and functionalities. The results show they are all available and functional.

However, if a compound disaster of earthquakes/tsunami/flood occurs and causes a long period loss of AC/DC power and ultimate heat sink, the above systems/equipment are classified as unable to sustain their intended function of mitigating accidental consequences.

The improvements after Fukushima accident

It's possible to lose the availability and functionality of corresponding equipment for mitigating severe accidents in case of long-term loss of AC/DC power and ultimate heat sink. Maanshan NPP implemented the following improvements:

- (1) Establish the ultimate response guideline (URG, introduced in Section 6.1.4)
- (2) Improve tsunami resistance of Service Water Pump Room
 - A. Add grills and cover above the service water intake pool to prevent garbage from falling into the pool during tsunami attack. (Completed by 2011/06/30)
 - B. Add water-tight door and water retaining wall of the service water pump rooms of individual unit and loop. After this improvement, loss of all service water pumps during tsunami attack may be prevented and the protection height for tsunami is increased from 9.12 m to 12.9 m. (Completed by Aug 31, 2011)
- (3) Strengthen the prevention capability from flooding
 - A. Install flood protection plates (over 1 m height) or change the doors to water-tight ones at the openings of the important buildings.
 - B. Increase the water draining capability of buildings after flooding. Maanshan NPP was originally equipped with 20 submerged pumps for draining. Additional 30 diesel engine draining pumps are purchased after Fukushima accident.
- (4) Establish the monitoring and controlling capability during total loss of DC power
 - A. Maanshan NPP already has procedures to monitor the important parameters during emergency DC power loss. These parameters are indicated in the control room by using instruments to convert the voltages/currents from the site transducers to readable engineering units.
 - B. Maanshan NPP has already established the procedures to manually operate TDAFWP and open PORV without the DC power.
- (5) Strengthen the capability of back-up injection water into S/G
 - A. Two strategies of back-up replenishing water into S/G, TDAFWP operation by diesel generator & Connection of fire hose to fire engines or fire hydrants, are established and two regular operator trainings are arranged each year.
 - B. Purchase one fire water tanker ([delivered](#)) to strengthen the capability of mobile replenishing S/G.

[Lungmen NPP](#)

The station major safety systems are designed as seismic category 1 and are all built at the altitude of more than 12 meters above sea level. In view of Japanese Fukushima accident, the station had carried out the assessment of "Comprehensive Safety Assessments". The station existing mobile disaster rescue equipment used for accidental conditions as well as the further expanded planned mobile equipment after Fukushima accident was proposed according to the review results of "Comprehensive Safety Assessments" under the AEC supervision. The above-mentioned relevant facilities and equipment had been planned to be stored in the place where they are not susceptible to disaster harm if beyond design basis accident occurs so that plant personnel can rapidly allocated them to achieve the goal of the emergency rescue.

6.1.2.1 Utilization of mobile devices/equipment

[Chinshan NPP](#)

Chinshan plant has already purchased 12 480V mobile diesel generators, 1 diesel generator vehicle 4.16kV , 2 mobile diesel air compressors, 3 small mobile air compressors, and 8 mobile large type fire fighting pumps, etc. If beyond design basis accidents happened in the plant and the units lose on-site and off-site AC power, or the water injection into reactor, Chinshan plant has already established the procedure 1451 “units' ultimate response guidelines”, including all kinds of responding measures (like reserve power, water sources, gas sources, water injection routes, containment pressure control, hydrogen control, etc.), maneuvering all possible manpower and materials, arranging all available water sources in the shortest periods. If the evaluation results indicated that injection and cooling functions of the design base can not be restored in a short time, the available reserve water sources will be injected into reactor immediately to assure the fuels are covered by water and to avoid the damage of the fuel and the release of the radioactive materials. (Completed by June 30, 2011)

The procedure 1451 (URG) provides the guidelines and operations steps if the plants are under the compound disasters which are beyond design basis accidents like earthquakes, tsunamis, etc., or loss of essential service water (ESW) and loss of all on-site and off-site AC power. The Chinshan URG is introduced in Section 6.1.4.

Kuosheng NPP

In case of beyond design basis events, the unit would possibly lose all the AC power supplies, coolant for RPV injection, and/or heat sink. Kuosheng NPP has developed a plant-specific URG (Procedure 1451) to establish alternative core injection paths by line up all available alternative injection paths, power supplies and water sources in the shortest time. If the recovery of original cooling functions in a short term can't be anticipated, the plant will implement core injection via the established alternative paths to ensure the fuel is covered to prevent fuel damage.

Kuosheng URG provides instructive strategies and the operating guideline in cases of situations beyond design basis events (e.g. multi-hazard) or loss of ECW system and all off-site/on-site AC power sources. It is expected the following goals would be achieved:

- (1) To maintain reactor core cooling;
- (2) To maintain control room monitoring functions;
- (3) To assure the containment integrity and mitigate the radioactive release;
- (4) To maintain fuel pool cooled and the spent fuel covered by water;
- (5) To aggressively repair the emergency facilities and restore the long-term cooling capability.

Each strategy has been planned in advance and briefly introduced in Section 6.1.4.

Maanshan NPP

Current situation

The existing mobile equipment designed for accident mitigation is mobile emergency diesel generators for power supply of TSC and the fire engines. Other rescue operations don't use mobile equipment.

The improvements after Fukushima accident

For the accidents like Fukushima, Maanshan NPP established the URG, in which the strategies of using mobile power, gas and water for mitigation measures are developed. The execution steps of every strategy, locations of required equipment installed or stored, involved manpower, and schedule arrangements are all detailed in URG. All rescue operations prepared

in limit times are believed and could be implemented if required.

In Maanshan URG, there are ten strategies using the mobile equipment: (1) Steam generator water injection from fire water hydrant (raw water); (2) injection from raw water; (3) sump pumps drainage operation; (4) Connect the mobile 480V diesel generator; (5) Supply power sources to containment ventilation valves by mobile air compressors and nitrogen bottles; (6) Supply/spray water to spent fuel pool; (7) Supply water into CST from mobile water source; (8) Supply water into RWST from mobile water source; (9) Connect 4.16kV power vehicles; (10) Remove garbage at the entrance of Essential Service Water System.

Lungmen NPP

If the unit lost on-site and off-site AC power supply or reactor water makeup when beyond design-basis accidents occurred, the station already established the procedure 1451 “Ultimate Response Guideline (URG)” including alternative flooding-paths, power supply and water source. The station will also mobilize all possible manpower, materials and physical resources to complete available water source arrangement in the shortest time. If operators judge that the design basis reactor coolant injection and cooling functions cannot be recovered in short time, the available backup water sources will be injected into the reactor immediately to insure that the nuclear fuel is covered by water and to prevent fuels from damage.

In case the station experiences compound disasters beyond design-basis accidents such as earthquake and tsunami, the unit may lose Reactor Building Seawater (RBSW) or Reactor Building Cooling Water (RBCW) and all off-site (on-site) AC power sources. Due to the failure of the above-mentioned equipment, the reactor water makeup will be lost and the water level of spent fuel pool will drop and decay heat couldn’t be removed. The procedure 1451 “Ultimate Response Guideline” (URG) provides instructive strategies to take the ultimate decisive actions in order to achieve the following purposes:

- (1) To maintain reactor core cooling.
- (2) To maintain control room monitoring functions.
- (3) To prevent and to mitigate the radioactive material release to outside the containment.
- (4).To maintain fuel pool cooling and the spent fuel covered with water.

6.1.2.2 The management of logistics supply

The procedure 1411 “logistics and equipment support” defines the operational processes of logistical supply management during the severe accident. The items are as follows:

- (1) Coordinate the second team in ECT to support emergency plan;
- (2) Dispatch vehicles, materials supply, prepare/ purchase urgent materials, and arrange board and lodging for the rescuers;
- (3) Finance and accounting support;
- (4) Estimate the equipment required presently and in future;
- (5) Collect and understand the off-site information (e.g., wind direction, the available transportation paths) for arrangement of the supporting materials and manpower;
- (6) Support information communication;
- (7) Apply the logistical support to NEPEC.

If the accident duration extended, the emergency execution committee will be established by TPC and the CDRC will be established by the government.

6.1.2.3 The management of radioactive release and provision to limit them

[Chinshan NPP](#)

Chinshan plant has completed specifications in the procedures for entering the plant, radiation protection and control, and supporting manpower in the emergency repairs. Some special professionals may be needed in the compound disasters. To the extent possible, these professionals are enrolled in the working team in advance and the repair operations are performed according to the existing procedures.

Considering the emergency conditions of the timing effectiveness of the rescue, those who are not enrolled in advance, will be instructed by HPC staff for 5~10 minutes before performing their tasks. The contents provided by the HPC staff include the safety of repairing under radiation, the regulation on emergency exposure, the risks of receiving radiation, the status of on site radiation condition, and the alarming values of radiation dose. They will perform their work after signing the permission of receiving the dose. They are accompanied by HPC staff to the site and are notified the caution notes of the corresponding radiation protection.

Before the rescue staff entering the radiation control station, every rescue worker is issued a badge and a dose alarm dosimeter from HPC staff, and is instructed for how to wear the radiation protection clothes, how to utilize the radiation protection equipment, etc. After rescue mission, they are helped by health physics staff, and go to the specified temporary controlled stop for whole body contamination detection and removal. According to their exposure, implement necessary dose inspection and medical care to assure the radiation safety of the rescue staff.

[Kuosheng NPP](#)

Once severe accident occurs, the management and limitation of radioactive releases in Kuosheng NPP take are divided into two parts, radioactive gas release and the radioactive liquid release. The description of these two parts is the same as section 6.4.

The actions in the response program include:

- (1) To notify the emergency radiation survey team to enhance radiation detection and water-sampling analysis for rain-water sewers of plant district.
- (2) In case radwaste water flows out the plant building is detected:
 - A. To notify the re-entering team members to embank the out-flowed waste-water by sandbag first.
 - B. To dispatch the re-entering members to drain the high-radioactive water by the fire engines/waste-water vehicle and then to collect them in the storages of buildings.
 - C. To dispatch the emergency operation backup team to find out the leaking sources.
- (3) To dispatch the emergency re-entering members to block the leakage sources by injecting high pressure foaming leakage-proof agent into containment cracks or closing the valves.
- (4) To report to the Emergency Execution Commission (EEC) and the CDRC. If required, the CDRC would coordinate with radiation detection center to dispatch the specialists for radioactive monitor around the beach.

[Maanshan NPP](#)

Current situation

The current radiation release management and the radiation confining preparation are based on the procedure 1414 “radiation detection”. Radiation detections at plant buildings, monitor zone and plant boundary are carried out. TSC can decide the best strategy for radioactive material release and better arrangement for staff’s radiation protection actions.

The related guidelines in Maanshan SAMG (procedure 1450) for limiting releases are FP Release Mitigation (SCG-1), Containment Depressurization (SCG-2), Hydrogen Control inside Containment (SCG-3), Containment Vacuum Control (SCG-4), FP Release Reduction (SAG-5), Containment P/T Control (SAG-6), and Hydrogen Management inside Containment (SAG-7). However these rescue measures must have power sources or gas sources to carry out their missions.

The improvements after Fukushima accident

(1) Improve the availability of containment venting

The hydrogen explosions in Fukushima plants were resulted from the large hydrogen accumulation in buildings. The capability of containment venting in case of loss of all AC and DC power must be established to avoid the excessive hydrogen accumulation. In Maanshan URG the MS.2-01 and MS.2-04 strategies are established for containment venting in the accidents like Fukushima.

(2) Increase the storage capability for radioactive liquid after accidents

For the large radioactive liquid from a nuclear accident, Maanshan NPP has well arranged the storage assignment in procedure 930.2. The storage capability is sufficient for accidents like Fukushima.

(3) Increase the equipment for repairs at limited radiation

The available quantity of radiation shields and protection clothes in Maanshan NPP has been increased. It's believed that the on-site quantity plus that at other plants are sufficient.

Lungmen NPP

Once a severe accident occurs, the management and limitation for gas and liquid radioactive releases in Lungmen NPP are respectively described in section 6.4.

6.1.2.4 Communication and information systems

Chinshan NPP

The current designs of normal/emergency communication system of the plant (including power, equipment, temporary cables, PHS base stations, etc)

- (1) PA (Broadcasting system): The power is supplied by SUPS-1. The PA system can be operated independently in turbine building, reactor building and outdoors. The unavailability in any area won't result in the unavailability of the whole plant.
- (2) Satellite phone: Batteries are included. It can standby for 48 hrs and be charged from 110V AC outlet.
- (3) Plant internal phones: 48 VDC 300AH batteries are established for 8hr independent operation. The charger on the primary side is 220VAC single phase power source. The power comes from the UPS of 11kV system/monitor room (reserve). Phone system of the Alternate Shutdown Panel (ASP) system is established based on the safety levels of piping.
- (4) Personal Handy phone system (PHS)
- (5) Plant external phones: Chunghwa Telecom (except for the special lines) connects with

plant telephone central exchange. The microwave communication system has 48 VDC 300AH independent batteries and can run for 8 hours. The charger on the primary side is 220VAC single phase power source.

The responding measure and the strengthening plan of the normal/emergency communication system corresponding to the beyond design basis accidents

- (1) The central exchange charger can use the established single phase 220V mobile diesel generator as the reserve power source to keep plant internal phones and PHS available.
- (2) Previously the central exchange room is located at the basement of the administrative building outside the main guards' room and is easily flooded by tsunami and lose its function, now it has been relocated to a higher place.

Kuosheng NPP

Current situation

- (1) The satellite telephone (battery attached, time standby 48 hr, the mainframe is located in the office of TSC Manager. The extension telephone is located in the MCR and powered by mainframe). Kuosheng NPP performs functional test every month. If necessary, the phone may be moved and used outdoors, and mainframe's battery is charged by AC 120V power source.
- (2) The power source required by PA system is from UPS, when station blackout occurs, battery bank may supply power to continuous maintaining its function.
- (3) The telephone system inside Kuosheng NPP, the PHS telephone system exchange and plant-specific long-distance telephone (microwave system) exchange are all located in the first administration building ground floor. When station blackout occurs, self-provided battery may provide 10 hours for continual operation.
- (4) CHT out-wired telephones do not need the externally-connected power source, and telephone call is available when lines are kept connected.
- (5) Straight-forward walkie-talkie (mainframe attaches with battery, AC supply not necessary) are available between TSC and each support center, the fire-fighting shift, the Simulation Center control room and the MCR.
- (6) The information system facilitates data and video transmission by networks, and transfer media is utilizing Plant-specific long-distance telephone (microwave system) and CHT ADSL transmission. The microwave system exchange is equipped with self-own battery to provide 10 hours for continuous operation

Communication enhancement plan of on-site and off-site

- (1) Satellite telephone mainframe: The TSC diesel generator has already been improved to be started up automatically in case of SBO accident. If the TSC diesel generator fails to start up automatically, the small-sized gasoline generator can take over.
- (2) PA system: In case the electric power of battery exhausts, the additional power source can supply power to 1/2B3 or 1/2B4, then the 1/2DE battery charger can be supplied with power. Under the situation the 1/2DE buses are with electricity power, the PA system can restore its function.
- (3) The Kuosheng's on-site telephone system, PHS telephone system switch and plant-specific long-distance telephone switch (microwave system): When the Station Blackout event occurs, self-backup battery may provide 10 hours power for continually operating needs. Moreover, OSC diesel generator has been improved to start the supplies to need of the power source automatically so that the continuous communication could be

attained.

- (4) Network information system: In case the SBO occurs, The OSC diesel generator has been modified to automatically start up in case of a SBO accident.

[Note]: The related enhancement plans on electric power are described in the chapter 5.

[Maanshan NPP](#)

Current situation

Current communication equipment of Maanshan NPP include loud telephone broadcasting system (PA), microwave telephone systems, plant's internal telephone systems, DECT (same as PHS) telephone systems, Chunghwa telecom external telephone system, direct communication intercom and satellite telephone.

- (1) Main frame of satellite telephone: Battery life is 48hr for standby. The main frame located by TSC leader's seat. The extensions are located at the each MCR and powered by TSC's main frame. Maanshan NPP tests its function monthly. It can be used outdoors if necessary.
- (2) PA system's power comes from NH-E26-C2 (QF-UPS01), NH-E25-C2 (QF-UPS02), NH-E05-B2 (QF-UPS03), and NH-E12-B2 (QF-UPS04). UPS can supply power to PA in a SBO accident.
- (3) The exchange center between telephone systems and DECT telephone systems and the exchange center of Maanshan's special long-distance telephone (microwave telephone systems) are located at the first floor of the administrative building. The battery can sustain 20 hours in a SBO accident.
- (4) Chunghwa telecom's external telephones don't need additional power. The communication will be available if the circuits are in good conditions.
- (5) Direct communications (hot lines) telephones work as TSC talks directly to every support center OSC, radiation HPC, Simulation center control room and unit 1& 2 MCR can communicate mutually. Microwave exchange center provides this function. If the whole plant blackouts, the battery can sustain 20 hours.
- (6) The information systems, internet and video communications utilize Maanshan's established fiber-optic networks, microwave systems and Chunghwa Telecom's ADSL. These systems are equipped with batteries for 10 hr continuous operation. The power that Chunghwa Telecom's ADSL needs comes from TSC, the communication will be available if the circuits are in good conditions.

The improvements after Fukushima accident

- (1) Main frame of the satellite telephones: If the whole plant has blackouts and, if the battery uses up, the 480VAV mobile diesel generator can supply power for satellite telephones.
- (2) PA system: Considering the prolonged situation that battery uses up, the 480VAC mobile diesel generator can combine with the UPS of loud telephones to ensure the continuous availability of the PA system.
- (3) DECT telephone system: Considering the prolonged loss of power that battery uses up, Maanshan's 480VAC mobile diesel generator can connect to N1E-NH-F001A, make sure the communication is available.

[Lungmen NPP](#)

1.PA System

PA System is powered from Uninterruptible Power Source and independently used in each building and outdoors. When a PA system in a certain building become unavailable, it will not affect the availability of the other PA systems.

2. On-site telephone system

On-site telephone system has a 48 VDC 400AH independent battery and charger which is at least 8 hours capacity and it is fed from 110VAC 1F43-CVCF-5001 (1R12-NPPL-5062A2-5) single phase power and its backup power source is fed from mobile diesel generator.

3. Low power DECT

Low power DECT which is attached on plant telephone system is under setup.

4. SP telephone system

There are four loops of SP telephone systems provided for the communication purpose among Control Building, Turbine Building, Reactor Building, Main Guard House, Auxiliary Fuel Building, and Switchgear Building.

5. VHF radio system

VHF radio system has total three channels. The on-site Uninterruptible Power System (UPS) can provide 8 hour power supply capacity during station blackout and it can be transferred from the backup relay station in radioactive Laboratory for continuous use if its relay station is malfunctioned. Besides, eight operator consoles which are separately installed in unit 1 & 2 Reactor Building, Control Building, and Technical Support Center in Switchgear Building can be used to communicate with off-site radio cell phone and automobile cell phone. Moreover, 204 sets of hand type radio cell phones (equipped with chargeable Lithium battery) and 16 sets of automobile cell phones are provided for off-site communication.

6. Off-site telephone system

The station switchboard is connected with Chunghwa Telecom via dedicated line and its power is fed from Uninterruptible Power Source 0Y86-CVCF-5002 and its backup power source is fed from security diesel generator. The TPC microwave communication system has 48 VDC 1300AH (800AH + 500AH) independent battery set with at least 8 hours capacity and support each other and its charger is fed from 220VAC single phase power. The off-site telephone system is directly connected from Control Room to Aoti Police station and Gong-Liao Fire Brigade and its power is provided by Chunghwa Telecom.

7. Satellite telephone

The satellite telephone is powered by 1R15-NPPL-0112B2-8 equipped with 1000VA capacity Uninterruptible Power Source and its backup power source is fed from mobile diesel generator.

6.1.3 Evaluation of factors that may impede accident management and respective contingencies

6.1.3.1 Extensive destruction of infrastructure around the installation

[Chinshan NPP](#)

The emergency response plan (The procedures of 1400 series) has clearly specified the responsibilities and maneuvering ways for those organizations of the ECT, including the staff on duty, and emergency operation backup team.

Accidents occur during office hours

If accidents occur and the operators on duty can not access the plant and back up the shift, the simulation center has manpower of the training shift. Additionally, a staff of 7 in the stand-by support shift (all hold operator license) and the manpower of the operation team can back up and support the units' operation. In addition to the maintenance staff on-site and outside the plant, there are more than 100 maintenance manpower of the contractors stationed in the plant with normal long term contracts. The requirement of the emergency situation can be met.

The Fire Brigade has a staff of 8 in the second shift, and according to the organization of the emergency plan there are 25 reserve firefighters in the normal shift. They can be grouped to support the fire fighting.

Accidents happen during off-duty hours

By survey, a staff of 23 is (including operation section) resided in the standby duty dormitory of the Maolin. They will be first notified to support the operation of the units in the situation that backup team can not arrive at the plant in time. Moreover, a staff of 102 is resided in Tamsui standby duty dormitory, Tamsui, Chinshan, and Shimen neighborhood. They can enter the plant to support the emergency response operation before the external rescue teams arrive.

By survey, a staff of 45 is resided in reserve dormitory of the Maolin district. They can be maneuvered to carry on equipment-repairing work. Moreover, a maintenance staff of 186 is resided in the reserve dormitory of Tamsui district, Tamsui, Chinshan, and Shimen neighborhood. They can be notified to enter the plant to support the emergency response operation. Furthermore, since there are emergency repair items listed in the contracts, there are many maintenance suppliers lived in Chinshan, Shimen areas, and they can be notified to enter the plant if emergencies happen.

The Fire Brigade has a staff of 8 in the plant during off-duty hours. All the firemen live in the Chinshan and Shimen districts. They can be notified to enter the plant urgently under emergencies. There are also securities guards stationed in the plant and can support the rescue operation. Chinshan plant has signed "Fire fighting and rescue agreements" with the fire department of New Taipei City government. The supporting department's manpower, vehicles, equipment will enter the accidental areas to support the rescue according to the characteristics of the disaster.

If accidents happen during off-duty hours and off-site staff can not arrive at the plant, the impact on the maintenance manpower is larger, and the assistance of the suppliers lived in the Chinshan, Shimen, Kilungareas are needed.

[Kuosheng NPP](#)

Kuosheng's emergency response plan (procedures 1400 series) has already clearly defined the task, responsibility and personnel-activation method for each unit of emergency control task-force, including on-duty shift and the emergency operation backup team.

(1) The event occurs in the office hour:

- A. If the operation shift personnel are unable to access the power plant to back up, a training shift in the Simulation Center with a standby support shift which consists of ten members (most are licensed personnel) could replace and assist on unit operation.
- B. The maintenance personnel of each department are all within the plant, with the on-site long-term contractors work at the plant, there would be about a hundred of maintenance manpower could be available. This should possibly meet the

requirement of equipment maintenance under emergency case.

- C. On-site fire-fighting shift has 8 peoples on-duty in two-shift each day. According to the emergency plan organization, there are 48 peoples allocated in the emergent backup fire-fighting team during the normal work-time interval who may assist the fire-fighting task.

(2) The event occurs during off-duty hours:

- A. Survey shows that in total there are 48 on-duty peoples live in single standby duty dormitory of the plant and these people may first be notified to assist operation. There are 14 on-duty personnel live in Chin-Shan, Wan-Li districts and they can enter plant to provide assistance for responding the case when operation on-duty replacement manpower can not arrive.
- B. Survey shows that the maintenance personnel live in single standby duty dormitory of plant is 24 peoples totally, and these peoples may be emergently to carry out equipment-repairing work. Those maintenance division personnel who live in Chin-Shan, Wan-Li districts are 23 peoples, and they may be notified to enter plant to assist in emergency response handling. Many skilled personnel of other maintenance subcontractors' manpower of Kuosheng NPP also live in Chin-Shan, Wan-Li districts (list in 1408 and 1409 procedures), and the emergency repairing items are all described in the maintenance contract. In case the accident occurs, plant can contact with subcontractors to provide nearby support.
- C. At present, the fire-fighting shift manpower is under contract, it keeps 8 fire-fighters at the plant during off-duty hours, and these contracted fire-fighting personnel are all residents of Chin-Shan area, and they can be urgently notified to enter the plant when accident occurs. Besides, the plant-resided security police manpower may also assist the disaster-rescued matters concerned.
- D. If roads outside the plant are obstructed, Kuosheng NPP will ask for support of the central government' authority "the CDRC" to recover the damaged roads, or ask for helicopter to carry personnel, materials and equipment for repair as well as emergent delivery of personnel for medical care.

Maanshan NPP

When the peripheral area of the plant (including the outside road) are widely damaged, the plant must rely on the staff, manpower, and materials in the neighborhood to proceed the short term urgent rescue and to communicate with CDRC and NEPEC for situation report and requests for long term rescue supports.

Current situation

(1) Manpower arrangement

A. manpower maneuver of emergency plan

- (a) In the office hours, the shift manager on duty will ask the shift supervisor to proceed with the maneuver according to the procedure 1400 for corresponding procedures to cope with the emergencies. The manpower of each maintenance department is inside the plant. The contractors stationed inside the plant can provide the maintenance manpower up to 100. It's enough to meet the maintenance requirement during the emergencies. If the operators to be on duty can not access the plant to work on his/her shift, the training staff in the simulation center and the staff of the standby supporting team (most of them have

reactor operator license) can back up and assist the operation of the units.

- (b) In the holidays or during the nights, the shift manager on duty will ask immediately the shift supervisor on day-shift and night-shift to proceed with the maneuver according to the procedure 1400 for the corresponding procedures to cope with the emergency.

B. Manpower of firefighting

The number of firefighting manpower is 29. Except the leader, 3 firefighting inspectors, and 1 multifunction water accumulation pools inspectors, the others are divided into 4 groups. These 4 groups will rotate in 3 shifts in 24 hours everyday. The minimum number of persons on duty is 6 (including group leader, fire engine driver and firemen) and they carry out their assignments according to the duty table. Moreover, the firemen are all residents of Hengchun district. They will be notified to enter the plant to assist the rescue if emergency occurs.

If additional needs require, 58 firemen can be gathered according to the urgent plan 1408 「OSC procedure of maneuvering and responding」, 1420 「procedure of firefighting」 after TSC established. Maanshan NPP currently carries out one uninformed (unnoticed) communication or maneuver test per 3 months and cooperates with urgent plan to do firefighting exercise or training annually.

(2) Materials arrangement

- C. Maanshan NPP also has 2 tow trucks, 7 hoist trucks, and 10 stackers. They will be utilized in rescuing the plant's peripheral areas during the accident to maintain the normal traffic and make sure a smooth rescue operation.
- D. Maanshan NPP has one firefighting commander vehicle, firefighting equipment vehicle, one firefighting water tanker, and one firefighting chemical vehicle to make sure the rescue work can be carried out in a very short notice.

(3) Review of communication capability

The communication systems of Maanshan NPP include: plant's internal telephone, microwave telephone, DECT (same as PHS) wireless telephone, PA loud telephone, Sound Power telephone, etc. Except for the Sound Power telephone which doesn't need power, the others will require UPS for long-term usage. In a SBO event, the plant's internal telephone, microwave telephone and DECT wireless telephone can sustain 20 hours and PA loud telephone can sustain 4 hours.

If the plant's internal telephone, microwave telephone, DECT wireless telephone, PA loud telephone are available, the satellite telephone can provide outside communication and Walkie Talkie and Sound Power telephone can provide inside communication. With the completeness of the above mentioned communication equipment, Maanshan NPP can reach CDRC immediately, report in details about the damage, the rescue situation and request for support about manpower and materials in time.

The improvements after Fukushima accident

(1) Review about manpower arrangement

If external rescue resources are not available, the improvements of independent response capabilities are as follows:

- A. The department of nuclear generation in TPC decides to add 2 members in a firefighting squad starting April of 2012.
- B. Maanshan NPP has already recorded 103 experts of all specialties resided in the Hengchun district (including operation). They will be first notified to enter the plant

during the accident. Contractors with various specialties are all listed correspondingly and permission acquired to enter the plant to assist the maintenance.

- C. Depending on the traffic situations, the reserve maintenance staff (mechanical, electrical, instrument, repairing) reside at Fengshan, Wujia dormitories will be transported by all means into the plant to do the maintenance jobs. Moreover, many suppliers of the plant have a lot of technical experts also live in Pingtung district, Kaohsiung. Their maintenance contracts include the urgent repairs. They can be included for supporting if emergencies occur.

(2) Review of materials arrangement

Maanshan NPP purchased one fire fighting chemical foam vehicle on December 31, 2011 and a water tanker (delivered). According to the lessons learned from Fukushima accident, Maanshan NPP reviewed the list of current resources and equipment.

(3) Review the communication capability

- A. Mainframe of the satellite telephones: If station blackout occurs and the battery uses up, the 480V AC mobile diesel generator can supply power for satellite telephones.
- B. PA system: Considering the prolonged situation that battery uses up, the 480V AC mobile diesel generator can combine with the UPS of loud telephones to ensure the continuous availability of the PA system.
- C. DECT telephone system: Considering the prolonged loss of power that battery uses up, Maanshan's 480V AC mobile diesel generator can connect to N1E-NH-F001A to make sure the communication is always available.

Lungmen NPP

Response for the difficulty of Off-site supports

The station 1400 series procedures for emergency response plan had already explicitly stipulated the division responsibilities and mobilization methods for Emergency Control Team including on-shift operator, emergency backup operation team. Moreover, the emergency response manpower during the accident time period falling on office hour or off-duty hours is reviewed and described as follows:

(1)The accident occurs during office hours:

- A. If the operation shift personnel are unable to arrive at site to back up there are training shift manpower in the Simulation Center and approximately ten mobile support shift people (most of them are licensed personnel) can back up and assist unit operation.
- B. Maintenance manpower of each division is all at site and there are long-term contractors resided at the site. Therefore, the maintenance manpower can reach hundred peoples to meet equipment maintenance need under emergency condition.
- C. On-site Fire-Fighting Station allocates 8 peoples on the day shift and Emergency Backup Fire-fighting Team allocates 45 peoples who can assist the fire-fighting task during office hours according to the emergency plan organization.

(2)The accident occurs during off-duty hours:

- A. In future before fuel loading, the station shall follow the precedence of other plant to investigate the shift operation personnel including Operation Team who lived in station district single standby duty dormitory and they may be first informed to assist unit operation work in order for response to insufficient shift operation

manpower in case takeover operation manpower can't arrive at site. Moreover, the station had already planned to build family apartment at Gong-Liao, Shungsi district such that shift operation personnel can be informed to enter into site for operation assistance if necessary.

- B. In future before fuel loading, the station shall follow the precedence of other plant to investigate the maintenance personnel (Mechanical Section, Electrical Section, Instrumentation Section, Machine Shop Section) who lived in station district single standby duty dormitory and they can be emergently mobilized to do rush repair work. Moreover, the station had already planned to build family apartment at Gong-Liao, Shungsi district such that maintenance personnel can be notified to enter into site for maintenance assistance if necessary.
- C. The fire-fighting manpower on off-duty hours maintains 6 people at site. Out-contracted fire-fighting manpower has priority to recruit the residents in Gong-Liao, Shungsi, Refine, and Keelung District etc and they can be urgently notified to enter site in case of accident condition. Besides, the plant-resided security police manpower can also assist the disaster rescues.
- D. If off-site roads are obstructed, the station shall apply for army engineer corps' support to rush repair the damaged roads from National Nuclear Emergency Response Centre led by Central Government or apply for helicopter to transport rush repair personnel, materials and facilities as well as emergency delivery of personnel for medical care.

Utilization of off-site technical support as accident management (including off-site unavailable emergency response measures)

In responses to the compound disaster accident, the station has planned shift personnel arrangement and three phase check list in URG appendix 05 & 06. Its relevant items at phase-1 including reactor depressurization, alternative water injection, and rush repair to restore power supply for essential systems and instrumentation via mobile power source, etc which shall be completed in a short time (within 1 hour) shall be finished by the station itself so as to effective control in order not to let the accident become worsen. If off-site supports are not available due to off-site road interrupted, the station had reorganized Emergency Response Organization into 2~3 subwork teams for alternative turnover and rush repair unit by ways of on-site existing backup equipment.

The time limits of phase-2 action items and that of phase-3 action items in URG appendix 06 are 8 hours and 36 hours respectively. At the moment, each emergency response organization had gradually been mobilized and the fore-mentioned staff who lived in station district single standby duty dormitory, Gong-Liao, and Shungsi district as well as the subcontractors might as well arrived at site one after another. The manpower can continuously carry out the disaster-rescue and disaster-mitigation tasks. In addition, the station can apply for large-scale machines and tools and manpower support from TPC Nuclear Emergency Planning Executive Committee depending on the disaster condition. TPC Nuclear Emergency Planning Executive Committee will overall command TPC overall manpower and material resources to support the emergency accident management. The Central Disaster Response Center shall dispatch the army engineer corps to rush repair the damaged road or utilize the helicopter to transport personnel and the commodity equipment for rush repair, as well as delivery the personnel to hospital for emergency medical care if necessary so that the compound disaster accident condition can be overall and long term controlled.

Possibility to use the existing equipment

The station major safety systems are designed as seismic category 1 and are all built at the

altitude of more than 12 meters above sea level that they are enough to prevent from loss of their intended function resulted from anticipated natural hazards such as earthquake, Tsunami, and extra heavy rain, etc. Please refer to relevant chapters of this report for relevant review and enhance programs. In view of Japanese Fukushima accident, the station had carried out the assessment of “Comprehensive Safety Assessments”. The station existing mobile disaster rescue equipment used for accidental conditions as well as the further expanded planned mobile equipment (Details please refer to chapter 2 Attachment 2-6 “The existing disaster rescue equipment” and Attachment 2-7 “Additional procurement disaster rescue equipment in response to Fukushima accident”) after Fukushima accident proposed by the review results of “Comprehensive Safety Assessments” under the AEC supervision. The above-mentioned relevant facilities and equipment had been planned to be stored in the place where is not susceptible to disaster if beyond design basis accident occurs so that plant personnel can rapidly allocated them to achieve the goal of the emergency rescue.

Communication enhancement plan on-site and off-site

- (1)The switchboard charger for plant telephone and DECT use is currently equipped with backup power fed from single phase 110V mobile diesel generator.
- (2)The base station of the VSAT satellite telephone system installed by TPC Communication Department is designed as seismic class.
- (3)The frequencies of ten sets of radio cell phones for emergency communication use are CH1:158.2875/167.3375 MHz, CH2:167.3/167.3 MHz, CH3:167.325/167.325 MHz, CH4:167.35/167.35 MHz that are appropriated by TPC Communication Department.
- (4)Cellular Phone is planned and under procurement for emergency communication use.

6.1.3.2 Impairment of work performance due to high local dose rates, radioactive contamination and destruction of some facilities on site

Chinshan NPP

For the severe accidents resulting in the local high dose in the plant, radioactive contamination and many damaged facilities, the responding measures for radiation protection are as follows:

- (1) Before the rescue, HPC will send the staff to the site/MCR to carry out the detection of radiation, contamination and radioactive air concentration.
- (2) According to the radiation detected on the accidental site/MCR and considering the habitability and the accessibility of the MCR, the radiation protection measures are specified as follows:
 - A.For those areas of high dose, radioactive contamination, the installment of radioactive shields or proceeding cleaning are evaluated to reduce the radiation dose and protect the working personnel.
 - B.Evaluate the longest working hour and then control the working hour if necessary.
 - C.Chinshan plant has 140 lead clothes and 2500 lead blankets, and they are biannually checked as per procedure 113.5. They should be enough to meet the requirement of short term accidents if the numbers of the rescue workers and lead clothes and blankets are carefully regulated. If the accidents are very serious and long term, Chinshan plant will request others plants for support.
- (3) According to procedure 1415, the radiation control during accidents such as the contamination detection and removal operation for rescue workers and evacuation personnel will be implemented to protect the personnel and avoid the expansion of the

contamination in Chinshan plant.

Kuosheng NPP

The rescue works regarding the facilities (including spent fuel pool) are mainly carried on in the control room. The functions of related safety facilities/equipment will not be affected because of the contamination. If the compound disaster causes the normal safety system of the power plant lose its function, the power plant personnel must enter the site and make emergency repairing, or implement strategies in the Kuosheng URG. Then each mobile facility/equipment must be used to carry on the rescue action. Regarding the high local dose rates or radioactive contamination within plant building/facilities district, the radiation-protection response measures of Kuosheng NPP are shown as follows:

- (1) Before carrying on the emergency repair work, the health physics division first dispatches personnel to perform the detections of radiation, contamination and the concentration of radioactive air.
- (2) To plan the radiation-protection measures according to the site radiation condition:
 - A. Evaluate the possibility of setting up the radiation shield, to reduce the radiation dose rates on site, therefore reduce the doses received by the workers.
 - B. Provide the necessary radiation-protective equipment such as radiation protection clothes, breathing masks, and lead clothes, etc. When necessary, instruct repairing personnel how to wear the radiation-protective equipment.
 - C. Evaluate the longest working hour of the workers and control the working hour if necessary.
- (3) Provide 1 alarm dosimeter (EPD) for each repairing personnel, and request immediate evacuation when alarm is sounded.
- (4) The portable area radiation monitor (ARM) can be set up on site to provide the instant information to the workers. They can evacuate immediately if the radiation situation deteriorates.
- (5) After leaving the site, the repairing personnel must arrive at the assigned location for external exposure detection to assure no contamination exists.

For the radiation contamination in control room:

- (1) Regularly execute the detections of radiation, contamination and radioactive air concentration in the control room.
- (2) Plan the radiation-protection measures according to control room radiation condition:
 - A. Evaluate the feasibility to install the radiation shielding walls to reduce the radiation dose rate on site, therefore reduce the doses received by the workers.
 - B. Provide the necessary radiation-protective equipment such as radiation-protective suit, breathing masks, and the lead clothes, etc. When necessary, instruct on-duty personnel how to wear the radiation-protective equipment.
 - C. Evaluate the longest working hour of on-duty personnel and control the working hour if necessary.
- (3) Install the doorframe detection for personnel contamination in the proper location to assure no contamination exists in leaving on-duty personnel.

Maanshan NPP

Responding measures to the radiation protection of rescue operation

(1) Current situation

- A. Before the rescue operation, the health physics team will carry out the on-site radiation detections.
- B. Plan the protection measures according to the radiation situation on site:
 - (a) Evaluate the possibility of setting up the radiation shields, to reduce the radiation dose rates on site, therefore reduce the doses received by the workers.
 - (b) Provide the necessary radiation protective equipment, e.g., radiation protection clothes, breathing masks, lead clothes, etc., and instruct the repairer how to wear the radiation protective equipment if required.
 - (c) Evaluate the longest working hour of the workers and control the working hour if necessary.
- C. Provide EPD to each repairer personnel and require him/her to leave the site while alarming to avoid overdose.
- D. The portable area radiation monitor (ARM) can be set up on site to provide the repairers the instant information. They can evacuate immediately if the radiation situation deteriorates.
- E. After the repairers evacuate from the scene, they should go to the specified location for external exposure detection and make sure there is no contamination.

(2) The improvements after Fukushima accident

For the available radiation shields and protection clothes, Maanshan NPP reevaluated the capacities. The storage on site and supports from other plants would be enough to meet the requirements of the rescue mission.

Responding measures for the radiation protection of the control room

(1) Current situation

- A. Regularly carry out radiation detections.
- B. Plan the protection measures of the control room according to the radiation situation:
 - (a) Evaluate the possibility of installment of the radiation shields to reduce the radiation dose rate of MCR.
 - (b) Provide the necessary radiation protective equipment, like radiation protective clothes, breathing protective masks, lead clothes, etc. and instruct the MCR staff how to wear the radiation protective equipment.
 - (c) Evaluate the longest working hour and control the working hour if necessary.

(2) The improvements after Fukushima accident

For the habitability of the control room, Maanshan NPP has purchased 480V mobile diesel generators to sustain the power in a long-term manner.

Lungmen NPP

The rescue works regarding the facilities (including spent fuel pool) are mainly carried on in the control room. The functions of its relevant safety facilities/equipment shall not be affected by radiation or contamination. If safety system lost its intended function due to compound disasters, the station shall dispatch personnel to enter the site for rush repair or take URG strategies to carry out rescue works via each kind of mobile facilities and equipment. The station radiation protection countermeasures for building and area local high dose rate or radioactive contamination are described as follows:

- (1) Before rush repair, HPC shall first dispatch personnel to detect site radiation, contamination and radioactive air concentration.
- (2) The radiation protection measures according to the site radiation condition are planned as follows:
 - A. The feasibility of installation of radiation shielding on site is assessed to reduce site radiation dose rate and further reduce worker's acceptable dose rate.
 - B. The necessary radiation protection equipment such as radiation protection suit, breathing protection mask, and lead clothes so on are provided and rush repair personnel are instructed how to wear each kind of radiation protection equipment if necessary.
 - C. The longest working time is assessed and timing control is carried out if necessary.
- (3) To provide one EPD for each rush repair personnel and to instruct them to immediately leave the site to avoid over dose when alarm appears.
- (4) To set up the mobile Area Radiation Monitor (ARM) at site to provide rush repair personnel with immediate radiation information. Once site radiation condition is changed, rush repair personnel can be immediately evacuated to protect the personnel safety.
- (5) After rush repair personnel leaving the site, they must go to the assigned place for external exposure detection in order to assure no contamination.

The enhancement programs of Control Room Habitability and its access control shall be prepared when Control Room may have radiation contamination:

- (1) The detections of radiation, contamination and radioactive air concentration in the control room are regularly executed.
- (2) The radiation protection measures are planned according to control room radiation condition:
 - A. The feasibility of the installation of radiation shielding is assessed in order to reduce site radiation dose rate and further reduce on-shift personnel acceptable dose rate.
 - B. The necessary radiation protection equipment such as radiation protection suit, breathing protection mask and lead clothes so on are provided and instruct rush repair personnel how to wear each kind of radiation protection equipment if necessary.
 - C. The longest working time is assessed and its timing control is carried out if necessary.
- (3) The personnel radiation detection portal is installed in the proper place to assure no contamination while on-shift personnel leaving.

6.1.3.3 The feasibility and effectiveness of the accidental managements under the external hazards

Chinshan NPP

Considering the changes of the terrain and the associated impacts resulted from the external natural disaster, Chinshan plant has strengthened the monitoring mechanisms and modified/established the corresponding procedures about the monitoring of the mudslide in the ChienHwa River of the plant. Regular and irregular monitoring is required. If the mudslide reaches an alarming level or the rainfall reaches a torrential rainfall, a crisis management team will be established accordingly. The impact on the plant will be evaluated in order to foresee the crisis and fully understand the possible changes and take the responding measures in advance to reduce the harmful effects.

To understand the changes of the terrain shapes, one on site measurement has been performed and the impacts of the changes on the plant have been evaluated. Furthermore, TPC is currently processing a couple of projects for geological investigation and reevaluation on the potential threats of the earthquakes. If any changes resulted from the external hazards are discovered, Chinshan plant will evaluate and monitor regularly on the changes to confirm and control the impact on the plant before the situations are improved and recovered.

Based on the Fukushima accident, the plant has performed “Comprehensive Safety Assessments of nuclear power plants”. In the evaluation, the plant reviewed the situations of beyond design basis accidents and proceeded with the corresponding improvements. These improvements include the establishment of procedure 1451 “URG”. In this procedure, in addition to the arrangements of all the available resources, the processing time limits and flow charts are included to carry out the “decisive actions” in the shortest time. All the available water resources are arranged to inject water into the reactor (or spent fuel pools) in time to assure the fuels are covered by water. The radioactive releases and public evacuation are thus avoided.

Timeliness

URG is different from the symptom-based EOP/ SAMG strategies. The goal of URG is to take the decisive actions in the shortest time to avoid the deterioration of the situation and to bring the plant to a controllable state. The public safety and health can thus be ensured.

Feasibility

The Chinshan plant has established multiplied and diversified rescue systems/equipment to respond to various design basis accidents. When beyond design basis accidents occur, the Chinshan plant will not only aggressively recover the rescue systems/equipment, but also accomplish the above goals by utilizing the mobile facilities (including power, and water resources) which can be deployed easily and are stored in places unlikely to be damaged by the compound disasters.

Effectiveness

The URG, established from the various evaluations of the Chinshan NPP, incorporates the concept of defense-in-depth in the corresponding strategies and plans. It also sets up multiplied and diversified strategies (like various water resources, power, etc.) to make sure the effectiveness of the rescue operation responding to the compound disasters.

Kuosheng NPP

The major safety systems of Kuosheng NPP are designed as seismic category 1 and are established at the height of 12 meters above sea level so that it is protected against the anticipated natural hazards (tsunami, heavy rain, etc.). After Fukushima accident, Kuosheng

NPP has already carried on “Comprehensive Safety Assessments”, and made the self-evaluation on the situation resulted from beyond design basis events. The corresponding improvements for the power plant capabilities are carried out. The plant-specific procedure 1451 (URG) is developed.

Timeliness

URG is different from the symptom-based EOP/ SAMG strategies. The goal of URG is to take the decisive actions in the shortest time to avoid the deterioration of the situation and to bring the plant to a controllable state. The public safety and health can thus be ensured.

Feasibility

Kuosheng NPP has already equipped with mobile rescue equipment before Fukushima accident. After Fukushima accident, the mobile equipment for severe accident managements is further extended in the Comprehensive Safety Assessment project. The related facilities/equipment has been planned and is stored in places unlikely to be damaged by the compound disasters. If beyond design basis events occur, the facilities/equipment can be lined up in the shortest time in accordance with the Kuosheng URG.

Effectiveness

The URG, established from the various evaluations of the Kuosheng NPP, incorporates the concept of defense-in-depth in the corresponding strategies and plans. It also sets up multiplied and diversified strategies (like various water resources, power, etc.) to make sure the effectiveness of the rescue operation responding to the compound disasters.

Maanshan NPP

Current situation

Fukushima accident was a beyond design basis accident and the consequences of the accident are catastrophic. Maanshan NPP made a review after Fukushima accident. With one additional air-cooling emergency diesel generator and two additional gas turbine generators, it is believed that a complete loss of AC power is very unlikely to occur in Maanshan NPP. However, the current equipment and management measures may be lack of mobility and fail to implement in time (timeliness) in multi-event accidents.

The improvements after Fukushima accident

Maanshan NPP is establishing the URG and a draft have been issued. Once a beyond design basis accident happens, the URG shall be adopted in the shortest time to arrange all the available water resources and to inject water into the S/Gs and SFPs if required. The decay heat removal and fuel integrity can therefore be ensured. The radioactive releases and public evacuation are thus avoided.

(1) timeliness

URG is different from the symptom-based EOP and SAMG. The goal of URG is to take a decisive action in the shortest time to avoid the deterioration of the situation and to bring the plant to a controllable state. The protection of public safety is ensured.

(2) Feasibility

Maanshan NPP has been equipped with multiple and diverse rescue protection systems and equipment for design basis accidents. When a beyond DBA occurs, the plant will not only recover the rescue systems/equipment, but also accomplish the above goals by utilizing the mobile facilities (including power and water resources) which can be deployed easily and are stored in places unlikely to be damaged by the compound disasters.

(3) Effectiveness

The URG established from the various evaluations of the Maanshan NPP has the concept of defense-in-depth in the corresponding strategies and plans. It also sets up various and multiple strategies (like various water resources, power, etc.) to make sure the effectiveness of the rescue operation responding to the compound disasters.

Lungmen NPP

The station major safety systems are designed as seismic category 1 and are all built at the altitude of more than 12 meters above sea level that it is enough to prevent from them loss of their intended function resulted from anticipated natural hazards (tsunami, heavy rain, etc.). After Japanese Fukushima nuclear accident, the station had already carried out the assessment of “Comprehensive Safety Assessments” to review the beyond design basis conditions and carried out their corresponding improvements including setup of Ultimate Response Guidelines (URG).

Effectiveness

The major strategies of URG are to take actions in the shortest time to prevent the accident from worsening and are different from the strategies in EOP/SAMG which is based on the consideration of symptom via item by item assessment, It also sets up multiple and diversified strategies (like various water resources, power, etc.) to make sure the effectiveness of the rescue operation responding to the compound disasters.

Feasibility

As above-mentioned descriptions in “The existing disaster rescue equipment”, the station existing mobile disaster rescue equipment used for accidental conditions as well as the further expanded planned mobile equipment after Fukushima accident was proposed according to the review results of “Comprehensive Safety Assessments”. The above-mentioned relevant facilities and equipment had been planned to be stored in the place where they are not susceptible to disaster harm if the beyond design basis accident occurs so that plant personnel can rapidly allocate them to achieve the goal of the emergency rescues.

Validity

According to each assessment result, the station had set up its Ultimate Response guidelines whose relevant strategies had already considered defense-in-depth concept and set up diversity and redundant strategies (e.g. each kind of water source, electric power, gas source etc.) so as to assure the validity of rescue action capability for responding compound disaster.

6.1.3.4 Unavailability of power supply

Chinshan NPP

DC power

Under the SBO event, the 125V DC power supply can sustain 8 hours as specified in design. If 125V DC Battery #6 charges Battery #1, Battery #2 via the currently equipped three 125V DC power distribution panels, the power can sustain 24 hours during station blackout.

AC power

Under the station blackout of the plant, the corresponding evaluations and improvement have been done for urgently supplying 4.16kV/480V AC power, include:

- (1) The procedures have been modified for guide the 5th EDG to supply powers to two units simultaneously.
- (2) The power cables and corresponding procedure have been prepared to provide emergency

power for the units' 4kV BUS from 2 black-start diesel generators (4.16kV 1100kW) belong to Gas Turbine Generator. (Completed by June 30, 2011)

- (3) 12 mobile diesel generators (480V) have been purchased and DCR for installment like power supply connectors and cables have been established. (Completed by June 30, 2011)
- (4) 6 diesel generators vehicles (4.16kV 1500kW) have been purchased by the TPC headquarters; one of them is for Chinshan plant. (Completed by June 30, 2011)

Kuosheng NPP

After Fukushima accident, Kuosheng NPP reviewed the availability of power supply in the accidents like Fukushima and proposed the enhancement plan (detailed in Chapter 5). After the improvements are finished, the redundant supplies of electric power could guarantee the long-term core cooling so that the fuel damage could be avoided.

Maanshan NPP

Current situation

In case of loss of all AC power, the original design of the Maanshan NPP can sustain operation with 125V DC battery. The TDAFWPs could operate for 8 hours with battery. The AC power of the units must be recovered in 8 hours to avoid the deterioration of the situation.

The improvements after Fukushima accident

The URG of Maanshan NPP can assure the power recovery in 8 hours and the usage of the TDAFWPs to inject water to the steam generators for decay heat removal from the core.

(1)The power recovering strategies in URG

A. Power supply to two units by 5th diesel generator (MS.1-02)

Arrange the 5th diesel generator to supply 2 units when the external power and A/B diesel generators are not available.

B. Prolonging DC power supply (MS.2-01)

Charge the battery with the mobile diesel generators; Power supply to two units by 5th diesel generator (MS.1-02); build up the 3rd power source; Connection of 4.16kV power vehicles (MS.2-08).

C. Connection of mobile 480V diesel generators (MS.2-03)

When all external powers and emergency diesel generators are unavailable, the 480V mobile diesel generator can be used to charge the DC power and transported to EC-P102/P112, AP-P100/P101, and KC-P006/ P007 as back-up power.

D. Connection of 4.16kV power vehicles (MS.2-08)

When all the external power, emergency diesel generators and gas turbine generators are unavailable, the 4.16kV power vehicle can be used to supply power to 4.16kV BUS

E. The guideline of connecting mobile diesel generator in URG: Supply power to hydro test pump BH-P020 to establish alternate primary pumps' seals injection; to auxiliary buildings for the important hydrogen analyzing equipment and PA loud telephone, and for EC-P102, 122 to add water to spent fuel pool; to control building for safety-related batteries charging, control room emergency venting and lighting; to administrative building for internal telephones, microwave telephones and PHS wireless telephones; and to TSC.

(2)URG builds up the operation capability of the turbine driven auxiliary feedwater pump under the situation of loss DC power.

According to guideline in URG, the operation guidelines of TDAFWPs in loss of control power, the TDAFWPs can be operated and controlled without DC power.

Lungmen NPP

The station had carried out the review of power supply capability and its enhancement plans in response to the accident similar to Fukushima accident and it is described in detail as this report chapter 5 “ Loss of power source and the Ultimate Heat Sink”. Thus it can provide redundant power supplies under the accident condition to achieve the goals of maintaining long-term core cooling so as to avoid fuel damage.

6.1.3.5 Potential failure of instrumentation and control system

Chinshan NPP

All the instruments related to safety in the plants are Class 1E and are designed as seismic category 1. However, similar to the compound disasters of Japan Fukushima Nuclear Power Plant, major instruments may lose their monitoring capability by the interruptions of power supply. The DC power (including UPS) designed for the instruments are able to provide power for 8~24 hours in the early stage of SBO. In the URG there are many power recovery plans to restore the power supply for the instruments.

Furthermore, the major rescue strategies of URG are the emergency RPV depressurization, emergency water replenishment and containment venting. Therefore, even the instruments are not available, the plant needs only to take “decisive actions” according to the situations of the accidents (like earthquakes, tsunamis or SBO) to achieve the goal of covering reactor core by water and to stop the deterioration of accidents.

When the accidents occur, the plant will set up TSC (including the AMT). Depending on the actual situation, the leader of the AMT can request more staff for SPDS communication in order to analyze and evaluate the availability and reliability of the instruments which are required to monitor the controlling parameters in EOP. The AMT team members make the evaluation and prediction to every parameter to their best, and submit the evaluation results to the AMT leader as well as the Emergency Control team leader so that they can fully understand the status of the plant and increase the accident management capability of the plant.

Kuosheng NPP

All the safety related instrumentation is designed as seismic category 1. However, under the condition similar to the compound disaster accident in Fukushima power plant, the instruments may lose their control functions due to loss of electric power. The DC power supplies including UPS are designed for first 24 hours in a SBO accident. In the URG there are various power coping and extension programs (URG “Setup of power supply”, its relevant description please refer to chapter 5 “Loss of power and ultimate heat sink”). URG is established to ensure that the electric power for instrumentation and control systems can be recovered in a timely manner.

In case of high room temperature or buildings are flooded, the SPDS personnel of AMT shall estimate the correctness of the temperature and water level instruments by comparing the parameter assessment table (PAT) and readings from redundant instruments. After verifying the effectiveness and accuracy of the estimated results, the results shall be submitted to AMT leader and Emergency Control Team to update the plant status. It's helpful to ensure the

management capability for severe accidents.

Maanshan NPP

Current situation

The important instrumentation and control system and power system are under regular tests according to the operation specifications (Most of test periods are 3 months), and regularly maintained according to the preventive maintenance plan. These instrumentation systems and power have been verified for their availability.

However if the compound disasters like Fukushima happen, resulting in the DC power loss of the instruments, the instrument and control system will fail, therefore increase the difficulties and complexities of the rescue missions. For example under the loss of all DC power, if Maanshan NPP decides to manually control turbine driven auxiliary feedwater pumps to replenish water into steam generator, the operators must know the pressure of the steam generator secondary side, water level and flow rate of the feedwater and the pressure, temperature and water level of the primary side, otherwise the effectiveness of the heat removal by replenishing water will be unknown.

The improvements after Fukushima accident

Maanshan NPP based on the scenarios of total loss of DC power under the accident like Fukushima, the operators will lose the capability of monitoring the important parameters, and therefore two improvements are planned:

- (1) In URG, two guidelines are set up to monitor the thermal couple readings in the reactor and to monitor the important parameters of the primary and the secondary sides under the loss of all power condition.

Utilize instrumental calibrator to provide working voltage of the transducer, to measure the current of the instruments' circuits, and then to transform them into engineering values. These important parameters include the pressure and water level of the steam generator, the flow rate of the auxiliary feedwater, the pressure and water level of RCS, the thermal couple's measurement at the exit of the reactor core, the pressure and water level of the containment, the water level of the condensed water tank, the level of Refueling Water Storage Tank (RWST), and the temperature and water level of the spent fuel pool. The measurement locations and instrument calibrators are all written in the procedures of URG.

- (2) In URG, set up the procedure of establishing the reserve power of the DC recharger.

Maanshan NPP has purchased 480V mobile diesel generator and the strategy MS.2-03 in URG is established to prepare DC charger to continuously supply power for the instrumentation and control system.

Lungmen NPP

The major safety related instrumentation for the station are all seismic category 1 design. However, major instrumentation may lose its monitor and control functions due to loss of power as occurred in Fukushima compound disaster accident. The DC powers including Uninterruptible Power Systems (UPS) for instrumentation and controls are designed to cope with 24 hours power supply capability at the initial stage of station blackout condition. Various power restoration and extension programs have been programmed in the station URG, please refer to chapter 5 "Loss of power and ultimate heat sink" for detailed description. It will have enough time to restore the power supply for I&C system.

Except for power supply, the SPDS personnel of Severe Accident Management Team (AMT)

230 will evaluate instrument reading from similar instruments and compare each other per parameter assessment table (PAT) for the effectiveness of the measured data in case of high room temperature in the building or flooding (or intentional containment flooding). The evaluation result will be submitted to AMT Leader and Station Emergency Control Team Brigades for them to grasp the status of the plant and to ensure the accident under control.

For the enhancement of the Spent Fuel Pool monitor and control capability, the type of water level instrument G41-LT-0012A/B shall be changed to improve its monitor range to at least the height of TAF and its power is fed from essential AC power (R13) as well as its temperature indicator G41-TE-0013 shall be changed to improve its depth of measuring point and monitoring range to at least the height of TAF.

6.1.3.6 Potential effects from the other installations at site

Chinshan NPP

To respond to the situation that the compound accidents occur simultaneously on both units:

(1) The review and strengthening plan of the equipment:

In the overall review of the safety protection of Chinshan plant, the water sources, power sources, gas sources are classified in the program “Responding measures of mutual supports between units #1 and #2.” The measures include ,the connection of service water of the plant, Condensate Storage Tank (CST) and Demineralization Storage Tank (DST) transport system, cooling systems for air compressor during outage, raw water (fire water) system, waste fluids processing system, the connection of instrument air, the instrument air systems supported by the compressors outside of the plant, the power supply of water-cooled emergency diesel generator (EDG-1A/1B/2A/2B) or the 5th air-cooled emergency diesel generator for the essential buses of damage units, the 69kV start-up transformer ST-A(S) and 345kV start-up transformer ST-B(S) to the essential buses of accident units, one of the two gas turbine generators is required to provide all the power needed for both units in case of loss of the external power.

The mutually supporting measures for the current equipment and the functions of rescue and mitigation of accidents have all been verified. The corresponding self-examination and strengthening plans have been proposed.

(2) When accidents occur on both units simultaneously, the outside environments may be damaged seriously and impede the effectiveness of maneuvering the manpower of the ECT. Chinshan plant has fully reviewed to expand the manpower arrangements of the TSC, ECT, AMT, etc. and finished the modifications of the procedures 1406 “procedure for emergency organization manpower maneuvering” and 1407 “TSC procedure for manpower maneuvering and responding”. The appropriate plan has been established to rotate manpower on duty during the operation of two ECTs and to assure the handling of the accidents will not be affected by the long term effects.

(3) For the multi-unit events, the equipment in the TSC and backup TSC have been strengthened and improved. The status of two units can simultaneously be displayed in the separated monitors. Therefore both units' situations can be acquired and different situations can be handled instantly. Moreover, the AMT members are trained twice a year to strengthen their operation capability and make sure no problem of two units' accident situations.

Kuosheng NPP

Regarding two units in responding to the compound disaster, four aspects are reviewed:

(1) The discussion on mutual supports among equipment

Kuosheng NPP has carried out the project “Comprehensive Safety Assessment.” On the item “The responding measure of mutual support between unit No.1 and unit No.2”, the associated measures about current mutual-support equipment, as well as the verifications of accident-mitigations and rescue-functions are completed for:

A. Condensate water and related system: mutual supports of ACST and CST system; makeup CSTs of both units from DST and ADST systems by water pump.

B. Sea Water system

(a) RHR BOOSTER PUMP, pumps the water from external circulating water, and provides water to the RHR heat exchanger to remove heat;

(b) ECW A/B LOOP, mutual supports of the cooling seawater for RHR heat exchangers for both units by ways of rearrangement of pipeline;

(c) The external circulating water (opening connection valve for use), may provide the cooling water for TPCCW and NCCW.

C. Essential Bus system

The 5th diesel generator may simultaneously supply power for two units by manual control. Moreover, it has been arranged that DIV I/DIV II/DIV III EDG of two units can mutually support to each other.

D. Compressed Air system

(a) The instrument air system may be supported by the off-site air compressor;

(b) The Compressed Air system of unit one and unit two may activate connection valve of Pressurized Air Storage Tank located at the 1st floor of control building to achieve the mutual support.

E. Others

(a) CRD system may support another unit by connecting the outlet of water pump;

(b) The Hydrogen Recombiner equipment may be transported to another unit.

(2) Regarding the equipment above, Kuosheng NPP also carries on the following enhancement plans after the Comprehensive Safety Assessment project.

A. Kuosheng NPP has installed an additional 6 inch removable cover on the CST manhole-cover of two units. Thus, the water of one CST can be delivered to the CST of another unit by the engine-driven pump, or the water from other water sources can be delivered to the CST by the engine-driven pump and then be delivered to the systems required water makeup.

B. Change the Drain of ADST and DST into the quick adapter type which can tie in the firefighting pipe to supply water to the condensed water storage tanks of both units.

C. The power source enhancement plan, including the 5th EDG power supply for two units, the DIV I/DIV II/DIV III EDG mutual support for two units, the essential power supply generated from two gas turbine associated 4.16kV/1100kW diesel generators, the connection of two 480V/200kW diesel generators of TSC/OSC to the LC 1B3/2B3, the purchase of four 480V/200kW mobile diesel generators and the enhancements on 4.16kV/1500kW diesel generator power supply vehicle, which are all explained in detail in chapter 5 of this report.

D. Kuosheng NPP has additionally purchased the mobile diesel-engine-driven air compressor, which can provide high pressure air for two units.

(3) Assessment on manpower dispatch of operation shift

- A. Except for the surrounding-position personnel, the operators of two units are all assembled at the MCR and the equipment-operators are assembled in standby area of the MCR. The principle of manpower resources utilization is based on the unified command of on-duty shift manager and the mutual support among on-duty shift supervisors of units so that the man-power can be used in the operation for the system which requires most needs.
- B. The two units with equipment adopt the same arrangement, and the manpower resources may assign mutually to support the most critical system's operation.
- C. During the outage of unit 1 and unit 2, one shift personnel and one person from each other shift are assigned to support outage work, then the on-duty personnel can experience the operation of different position so that once the accident occurs to support the work of different posts is possible.
- D. The normal operation training for two units adopts the same standard to carry on, and personnel of two units may support mutually.

(4) Enhancement on man-power activation

Kuosheng NPP has checked the numbers of staff residing in the plant district and neighborhood area, and re-inspected the emergency plan mobilization system, the test/drill plan, and the effectiveness and man-power of mobilization enhancement. For the procedure 1406 “the procedure of emergency organizations mobilization,” the mobilization manpower name list of emergency response center was established. The procedures 1408 “OSC activation and response procedure” and 1409 “HPC mobilization and response procedure” were revised. The related supporting man-power name list for the situation when repairing man-power is not enough and resorting to off-site support is required was established. Besides, the name lists mentioned above are incorporated into the name lists of backup re-entry team of OSC, HPC, and off-site subcontractor support team.

[Maanshan NPP](#)

Current situation

Maanshan NPP has two units. The original emergency plan didn't consider the simultaneous accidents occurred at two units. Current arrangements and designs may be insufficient for multi-unit accidents, e.g. the manpower of TSC and AMT, the amount of repairers, the SAMG display panel in the AMT meeting room, etc.

The improvements after Fukushima accident

(1) Improvements on equipment

- A. Maanshan NPP establishes the URG based on consideration of multi-unit accidents. The quantities of the mobile equipment are sufficient.
- B. Maanshan NPP has improved the SAMG display panel in the AMT meeting room. The status of both units can be simultaneously monitored.

(2) Strength on manpower

- A. Maanshan NPP has reviewed the arrangement of the manpower of TSC and AMT for multi-unit accidents. Maanshan NPP plans for two groups of rotating manpower.
- B. Maanshan NPP established the name list of experts in various backgrounds such as mechanical, electrical, instrumental, repairing, etc. It makes an easy arrangement for emergency plan in a multiunit accident.

(3) Procedure improvement methods

- A. The strategy in URG, *Power supply to two units by 5th diesel generator* (MS.1-02), is established.
- B. In SAMG, there are no management measures for SFP operating at low water level. The strategy in URG, *SFP makeup/spray* (MS.2-05), is established for this drawback.

Lungmen NPP

With regard to the compound disaster conditions simultaneously occurred at both units, the following four aspects are discussed:

1.Review on inter-unit supports among Equipment:

After Fukushima first nuclear power plant accident in Japan occurs, the station had carried out self-overview of “Comprehensive Safety Assessments”. The item of “The countermeasures of inter-unit support between unit No.1 and unit No.2” had been already reviewed and verified in connection with those items: (1) RBCW system, (2) CSTF system, (3) Water Makeup System and Fire Water System, (4) Compressed air system, (5) Essential Bus System and had already completed the associated countermeasures to current inter-unit support equipment as well as the verifications of their accident mitigation and rescue functions:

(1)RBCW System

RBCW system train C of both units can provide cooling water to 0G42 AFPC Heat Exchanger A/B and support each other.

(2)CSTF System

CSTF System of both units can support each other by ways of Radwaste Building piping.

(3)Water Makeup System / Fire Water System

Water Makeup System / Fire Water System can support both units in ACIWA mode operation.

(4)Compressed Air System

A. Instrument air system for both units can support each other by ways of yard piping located in east side of Turbine Building.

B. Plant air system for both units can support each other by ways of yard piping located in east side of Turbine Building.

(5)Essential Bus System

The 7th Diesel Generator (SEDG) can provide power for both units Essential Bus System.

2.Regarding the above equipment, the station had already carried out the following enhancement strategies after Comprehensive Safety Assessments:

The station Instrument air system and Plant air system which are designed with a check valve 1(2) P52-UV-5069 & 1(2) P51-UV-5060 for both units had been tied-in connection. This check valve is needed to be removed so that Instrument air system and Plant air system for both units can be connected through each other. Moreover, 1(2) P52-BV-5037 /5038 & 1(2) P51-BV-5150 /5152 shall be changed from normally open to normally close.

- (1)To avoid diesel fuel oil fire pump inoperable during beyond design basis accident, baffle

plate is installed in fire pump room outward door.

- (2)The power enhancement plans include (1) the seventh EDG supplies power for both units (2) DIV I /DIV II /DIV III EDGs for both units can support each other. (3) Gas turbine associated two sets of 4.16kV 1100kW diesel generators provide the essential power supply (4) Procurement of 2 sets of 480V 200kW mobile diesel generators (5) Procurement of 5 sets of 480V 100kW mobile diesel generators and (6) 4.16kV 1500kW diesel generator power truck. They are all described in detail in chapter 5.
- (3)For compressed air system, the station will procure additional mobile engine-driven air compressors to provide SRV operation air source for both units.

3.Assessment of on-shift operation manpower dispatch:

- (1)Currently the station is under construction and commissioning test phase, the organization plan of operation shift personnel shall consult the precedence of Chinshan and Kuosheng Nuclear Power Plant. Except for those stationed in periphery, unit operators will be separately allocated on unit 1 and unit 2 Main control Room. Manpower resources shall be dispatched by Shift Manager and Unit Shift Supervisors shall support each other so that the manpower can be used in the emergency operation needs of essential systems.
- (2)The equipment layouts of both units are designed with the same arrangement so that manpower resources can be mutually assigned and support the emergency operation needs of essential systems.
- (3)During the outage of unit 1 and unit 2, one shift operation personnel and each person from the other shifts are transferred to support the outage work so that shift operation personnel can experience the operation career of different position and can support the different post operations during the accident.
- (4)Normal operation training for both units adopts the same criteria so that the operator can be familiar with the other unit equipment layout and operation if one operator is transferred or shift- substituted. Therefore, it is undoubtedly that unit shift operators can support each other.
- (5)If severe accident occurs, Shift Manager can dispatch personnel to the most required position depending on the condition at that time.(For example: When there is bad heat sink condition in Pump House or big volume of trash or fish swarm invasion, Shift Manager can immediately dispatch personnel to support. If severe accident occurs, the rule shall be followed to execute support operation.)

4.Enhancement on manpower mobilization:

The review of emergency response manpower is described as follows:

(1)If accident occurs during office hours:

- A. The condition may happen that on-shift operation personnel can't access to the station to back up; the training shift manpower in Simulation Center and Inspection Control Team members can back up and assist unit operation.
- B. Except for manpower of each maintenance division at site, the station shall follow the precedence of other plant to sign a long term maintenance manpower contract in future in order to meet the equipment maintenance need in emergency condition.
- C. The station fire-fighting station allocates 11 persons on the second shift period including 1 leader, 1 nurse,3 fire equipment supervisors, and 6 team members and allocates 6 persons in each shift. During office hours, Emergency Backup Fire Fighting Team allocates 46 persons to assist fire fighting tasks as per emergency

plan organization.

(2) If accident occurs during off-duty hours:

- A. In future before fuel loading, the station shall follow the precedence of other plant to investigate the shift operation personnel including Operation Team who live in single standby duty dormitory of the plant and they may be first notified to assist unit operation work in order for response to insufficient shift operation manpower in case next shift operation manpower can't arrive at site. Moreover, the station had already planned to build a family apartment at Gong-Liao, Shungsi district such that shift operation personnel can be notified to enter into site for operation assistance if necessary.
- B. In future before fuel loading, the station shall follow the precedence of other plant to investigate the maintenance personnel (Mechanical Section, Electrical Section, Instrumentation Section, Machine Shop Section) who live in single standby duty dormitory of the plant and they can be mobilized to do rush repair work. Moreover, the station had already planned to build a family apartment at Gong-Liao, Shungsi district such that maintenance personnel can be informed to enter into site for maintenance assistance if necessary.
- C. The fire-fighting manpower on off-duty hours maintains 6 persons at site. Out contracted fire-fighting manpower has the priority to recruit the residents in Gong-Liao, Shungsi, Refine, and Keelung District etc and they can be urgently notified to enter into site in case of accident condition. Besides, the site-resided security police manpower can also assist the disaster-rescues.

6.1.4 Plant improvements and Ultimate Response Guideline (URG)

Improvements on Chinshan NPP

In 1960s, GE developed the design of the Mark-I containment with the advantages of easy construction, small volume, and low costs. BWR3 and BWR4 nuclear power plants were built with Mark-I containment. At the same time, the mitigation capability of the Mark-I containment was challenged with its small volume feature. Thus, GE proposed several recommendations on improving the containment venting system to prevent the containment failure in case of core overheating. With the recommendations in NUREG-0061 set forth in 1982, TPC implemented improvements in Chinshan NPP (Mark-I containment), including the strengthening of the downcomers, the additions of containment hardened vent pipes, the inerting with nitrogen in normal operation, etc., which were completed at the end of 1990.

Coolant resources for management measures

In Taiwan, TPC built a large raw water reservoir in each of nuclear power plants. It's believed the water inventory is sufficient for long-term cooling.

Mobile devices/equipment

In Taiwan, each unit was equipped with two water-cooled and one additional air-cooled 4.16kV emergency diesel generators. In addition, two gas-turbine generators were equipped for each of three operating nuclear power plants. After Fukushima accident, TPC will purchase six 1500kW 4.16kV power vehicles and twenty six 480V mobile diesel generators. The quick connections for mobile power supplies will be established and the emergency access routes to important equipment will be identified.

Electrical power and compressed air for severe accidents

In case of extended SBO accidents, the original designs didn't include additional emergency power and air supplies so that the RPV couldn't be depressurized if on-site emergency power

and air supplies are unavailable. It may lead to delay of the core cooling by low-pressure injection equipment (e.g. fire engines). After Fukushima accident, TPC added mobile equipment/devices, including power vehicles, diesel generators, air compressors, nitrogen bottles, etc.

The development of ultimate response guideline (URG)

After Fukushima accident in 2011, TPC established the procedures of manual depressurization and well arranged the mobile power supplies for the long-term loss of electrical power. Also, TPC is establishing the plant-specific ultimate response guideline (URG) for each operating plants, in which the goal is to prevent fuel damage as possible. The drafted URGs are issued.

- (1) If URG is available, for the accidents like Fukushima, the decay heat in the core will be released to atmosphere before core damage, through opening RPV SRVs and containment venting. The decay heat accumulation in RPV and containment would be avoided. The impacts on containment integrity will be limited, especially for Chinshan NPP (Mark-I containment).
- (2) At the beginning of severe accident, the core will be maintained at high water level (with high- and low-pressure injections).
- (3) In the first one hour of severe accident, the pre-arranged alternative lines and water sources will be lined up with emergency power (power vehicles). The on-site alternative injections could be implemented if required.
- (4) In the first one hour of severe accident, the injections from fire engines or gravity injection of raw water reservoir will be connected with the pre-arranged lines. The injections with off-site water sources could be implemented if required.
- (5) The primary containment is inerted with nitrogen (Chinshan NPP, Mark-I containment) or equipped with igniters (Kuosheng NPP, Mark-III containment), so that the hydrogen explosion inside containment is prevented. The strategy to replenish the nitrogen or to supply sparks is already identified.

TPC has the regular exercises of EOP and SAMG for operators in all operating plants for many years. The EOPs and SAMGs are also reviewed and updated if the latest technologies and researches are available. The goal of URG strategies is to prevent core damage. URG is established based on the concept of mitigating consequence as early as possible. The URGs of three operating plants have been verified by analytical results. The URG will be included in regular exercises.

[The Chinshan URG](#)

The Chinshan URG is divided into 3 phases at the urgent level itself. The strategies in each phase are summarized in Table 6-1. The entry point of the URG activation is one of three conditions: C1. Loss of ultimate heat sink; C2. Loss of AC power (station blackout); C3. Reactor scrammed with earthquake and tsunami alarmed. The first level is to maintain the core at high water level and lower pressure and to prepare for RPV injections, RPV depressurizations, and containment vent. The second level is to line up mobile power, equipment, and water sources for long-term cooling. The third level is trying to restore the ultimate heat sink. The strategies in the 3 phases should be completed in 1, 8, and 36 hours, respectively. The trigger point of implementing RPV injection, RPV depressurization, and containment vent is both C1/C2 and C3 are satisfied. All strategies in URG are arranged in a regular training of two years and a regular exercise of three years.

[The Kuosheng URG](#)

The Kuosheng URG is divided into 3 phases at the urgent level itself. The strategies in each phase are summarized in Table 6-2. The entry point of the URG activation is one of three conditions: C1. Loss of ultimate heat sink; C2. Loss of AC power (station blackout); C3. Reactor scrammed with earthquake and tsunami alarmed. The first phase is to maintain the core at high water level and lower pressure and to prepare for RPV injection, RPV depressurizations, and containment vent. The second phase is to line up mobile power, equipment, and water sources for long-term cooling. The third phase is trying to restore the ultimate heat sink. The strategies in the 3 phases should be completed in 1, 8, and 36 hours, respectively. The trigger point of implementing RPV injection, RPV depressurization, and containment vent is both C1/C2 and C3 are satisfied. All strategies in URG are arranged in a regular training of two years and a regular exercise of three years.

[The Maanshan URG](#)

The Maanshan URG is divided into 3 phases at the urgent level itself. The strategies in respective phases are summarized in Table 6-3. The entry point of the URG activation is one of three conditions: C1. Loss of ultimate heat sink; C2. Loss of AC power (station blackout); C3. Reactor scrammed with earthquake and tsunami alarmed. The first level is to maintain the core at high water level and lower pressure and to prepare for RPV and S/G injections, RPV and S/G depressurizations, and containment vent. The second level is to line up mobile power, equipment, and water sources for long-term cooling. The third level is trying to restore the ultimate heat sink. The strategies in the 3 phases should be completed in 1, 8, and 36 hours, respectively. The trigger point of implementing RPV and S/G injections, RPV and S/G depressurizations, and containment vent is both C1/C2 and C3 are satisfied. All strategies in URG are arranged in a regular training of two years and a regular exercise of three years.

[The Lungmen URG](#)

The Lungmen URG is divided into 3 phases at the urgent level itself. The strategies in each phase are summarized in Table 6-4. The entry point of the URG activation is one of three conditions: C1. Loss of ultimate heat sink; C2. Loss of AC power (station blackout); C3. Reactor scrammed with earthquake and tsunami alarmed. The first phase is to maintain the core at high water level and lower pressure and to prepare for RPV injection, RPV depressurizations, and containment vent. The second phase is to line up mobile power, equipment, and water sources for long-term cooling. The third phase is trying to recover the ultimate heat sink. The strategies in the 3 phases should be completed in 1, 8, and 36 hours, respectively. The trigger point of implementing RPV injection, RPV depressurization, and containment vent is both C1/C2 and C3 conditions are met. All strategies in URG are arranged in a regular training of two years and a regular exercise of three years.

Table 6-1 Strategies of the Chinshan URG

Phase	Strategies	Time Limit
First	<ul style="list-style-type: none"> ●CS.1-01: Raw water (fire water) injection into reactor ●CS.1-02: Reactor depressurization under SBO ●CS.1-03: Containment venting under SBO ●CS.1-04: Water injection from fire engine ●CS.1-05: RCIC manual operation ●CS.1-06: Supply power to both units from 5th diesel generator ●CS.1-07: Supply power from 480V mobile diesel generator 	1 hr
Second	<ul style="list-style-type: none"> ●CS.2-01: SRV/ADS air supply from mobile air compressor / nitrogen bottle ●CS.2-02: Supply power to both units from gas turbine diesel generator ●CS.2-03: Supply power from 4.16kV mobile power ●CS.2-04: Prolong DC power supply ●CS.2-05: Spent fuel pool water makeup/spray ●CS.2-06: Operating submerge pump ●CS.2-07: Injection water into CST from mobile water source 	8 hrs
Third	<ul style="list-style-type: none"> ●CS.3-01: Emergency sea water intake trash cleaning ●CS.3-02: ESW motor replacement ●CS.3-03: Alternative of long term cooling 	36 hrs

Table 6-2 Strategies of the Kuosheng URG

Phase	Strategies	Time Limit
First	<ul style="list-style-type: none"> ●KS.1-01: Raw water (fire water) inject to reactor ●KS.1-02: Reactor depressurization (reactor decay heat removal) ●KS.1-03-01: Primary containment venting ●KS.1-03-02: Secondary containment venting ●KS.1-03-03: Fuel building venting ●KS.1-04: Inject water to reactor by fire engine or mobile pump ●KS.1-05: Manually operate RCIC to inject water to reactor ●KS.1-06: The 5th D/G Power supply to both units ●KS.1-07: 4160V 1100kW interconnection from G/T to D/G ●KS.1-08: 480V TSC/OSC Diesel Generator interconnection to 1(2)B3 ●KS.1-09: AP-HV-203/204 fixed position in open position 	1 hr
Second	<ul style="list-style-type: none"> ●KS.2-01-01: Mobile air Compressor supply air to SRV/ADS ●KS.2-01-02: Supply nitrogen gas to open pneumatic valve ●KS.2-02: 480V 200kW mobile D/G interconnection ●KS.2-03: 4.16kV power supply vehicle interconnection ●KS.2-04-01: Extension of DC power supply time (DE to DA) ●KS.2-04-02: Extension of DC power supply time (5KW diesel generator) ●KS.2-05-01: Spent fuel pool water makeup and spray by fire engine ●KS.2-05-02: Spent fuel Pool water makeup and spray by mobile water pump ●KS.2-05-03: Spent fuel Pool water makeup and spray by fire box in fuel building ●KS.2-06: Operation of submerged pump to drainage ●KS.2-07: Water injection of CST by mobile water source 	8 hrs
Third	<ul style="list-style-type: none"> ●KS.3-01: Trash clean up and transportation for emergency water intake ●KS.3-02: Emergency Circulating Water (ECW) pump replacement ●KS.3-03: Reactor long term cooling 	36 hrs

Table 6-3 Strategies of the Maanshan URG

Phase	Strategies	Time limit
First	<ul style="list-style-type: none"> ●MS.1-01: Manual operation of TDAFWP or diesel-driven AFWP ●MS.1-02: Power supply to two units by 5th diesel generator ●MS.1-03: Raw (hydrant extinguishing) water injection into S/Gs ●MS.1-04: RCS injection with accumulators ●MS.1-05: RPV injection by water pressure testing pump ●MS.1-06: RPV injection with raw (hydrant extinguishing) water 	1 hr
Second	<ul style="list-style-type: none"> ●MS.2-01: Prolonging DC power supply ●MS.2-02: Drain by submersible pumps ●MS.2-03: Connection of mobile 480V diesel generators ●MS.2-04: Supply containment ventilation valves with mobile air compressors and nitrogen bottles ●MS.2-05: SFP makeup/spray (must be completed in 2 hours) ●MS.2-06: Injection of mobile water into CST ●MS.2-07: Injection of mobile water into RWST ●MS.2-08: Connection of 4.16kV power vehicles 	8 hrs
Third	<ul style="list-style-type: none"> ●MS.3-01: Remove garbage at the ESWS intake ●MS.3-02: Replacing NSCW Motor 	36 hrs

Table 6-4 Three Phase Check List for LMNPP URG Strategies

Phase	Strategy	Timing Limit
Phase-1	<ul style="list-style-type: none"> ●LM.1-01 HPCF Water Makeup to Reactor via Gravity operation Guideline ●LM.1-02 RCIC Water Makeup to Reactor via Gravity Operation Guideline ●LM.1-03 Fire Water Makeup to Reactor Operation Guideline ●LM.1-04 Water Makeup to Reactor via Fire Water Reservoir Truck Operation Guideline ●LM.1-05 Manual Operation of RCIC to inject water to reactor under loss of normal DC power Operation Guideline ●LM.1-06 Reactor Depressurization (Decay Heat Removal) Operation Guideline ●LM.1-07 Primary Containment Exhaust Operation Guideline 	Within 1 hr
	<ul style="list-style-type: none"> ●LM.SFP.1-01 RB Spent Fuel Pool Water Makeup via Outdoor Fire Hydrant Operation Guideline ●LM.SFP.1-02 RB Spent Fuel Pool Water Makeup via Fire Water Reservoir truck Operation Guideline ●LM.SFP.1-03 RB Spent Fuel Pool Water Makeup via Engine-driven Fire Water Pump Operation Guideline ●LM.SFP.1-04 RB 7F Spent Fuel Pool Water Makeup via Indoor Fire Hydrant Operation Guideline 	Within 2 hrs
Phase-2	<ul style="list-style-type: none"> ●LM.2-01 SRV Operation Guideline during loss of normal DC power ●LM.2-02 Secondary Containment Exhaust Operation Guideline ●LM.2-03 Auxiliary Fuel Building Exhaust Operation Guideline ●LM.2-04 SDG simultaneously provides power for both units in case of emergency Operation Guideline ●LM.2-05 #1 EDG& #2 EDG mutual support Operation Guideline ●LM.2-06 480VAC mobile diesel generator feeds power to plant equipment Operation Guideline ●LM.2-07 On-site backup power from Security System EDG Operation Guideline ●LM.2-08 Mobile Air Compressor supplies air to Reactor Building AOV Operation Guideline ●LM.2-09 Nitrogen Supply System check valve dismantle Operation Guideline 	Within 8 hrs

Phase	Strategy	Timing Limit
	<ul style="list-style-type: none"> ●LM.2-10 Water intake from Lungmen Lover Lake/ Shi-Ding Creek / Shung Creek etc backup water sources Operation Guideline ●LM.2-11 4160V/1100kW Gas Turbine Diesel Generator Lead Connection Operation Guideline ●LM.2-12 On-site backup power from 4.16 kV Mobile Diesel Generator Operation Guideline ●LM.2-13 120VAC/125VDC rectifier Operation Guideline ●LM.2-14 Mobile Diesel Generator feeds power to SLC Motor Water Injection to RPV Operation Guideline ●LM.2-15 CST Water Makeup via Fire Water Reservoir Truck Operation Guideline ●LM.2-16 Control Room Monitoring Reactor and Containment Parameter Recovery Operation Guideline ●LM.2-18 Extract water from Discharge Well Operation Guideline ●LM.2-19 Hydrogen Detection Operation Guideline ●LM.2-20 Water makeup to Reactor via mobile fire water pump Operation Guideline ●LM.SFP.2-01 FPCU 及 CSTF Pump Water Makeup to RB Spent Fuel Pool Operation Guideline ●LM.SFP.2-02 AFB Spent Fuel Pool Water Makeup via Outdoor Fire Hydrant Operation Guideline ●LM.SFP.2-03 AFB Spent Fuel Pool Water Makeup via Fire water Reservoir Truck Operation Guideline ●LM.SFP.2-04 AFB Spent Fuel Pool Water Makeup via Engine-driven Fire Water Pump Operation Guideline ●LM.SFP.2-05 AFB Spent Fuel Pool Water Makeup via Indoor Fire Hydrant Operation Guideline 	
Phase-3	<ul style="list-style-type: none"> ●LM.3-01 Extract Sea Water from Discharge seal pit / Discharge Well for RBCW Heat Exchanger Operation Guideline ●LM.3-02 Emergency pump House trash cleanup and transport Operation Guideline ●LM.3-03 Reactor Building Cooling Sea Water (RBSW) Pump Replacement Operation Guideline ●LM.3-04 Reactor Long Term Cooling and Recovery Operation Guideline 	Within 36 hrs

6.2 Loss of core cooling: accident management measures in place at the various of a scenario of loss of core cooling function

6.2.1 Before occurrence of fuel damage in the reactor pressure vessel

[Chinshan NPP](#)

When the plant lost reactor core cooling function, the RPV pressure will be immediately depressed below 15 kg/cm², if necessary, regardless of the depressurized rate limits in EOP 540.1/540.2 procedure. In addition, the primary containment will be vented simultaneously. The essential bus can be powered by EDG, 5th DG, or gas turbines according to SBO procedure 535. The RPV water can be made up by RCIC or HPCI system.

If there is a SBO induced by a beyond DBA, the injection will be lined up first, then the 5 ADS/SRV will be opened to reduced reactor pressure below 15 kg/cm². If RCIC and HPCI systems are inoperable at the same time, the reactor pressure will further be depressed below 9 kg/cm² after the line up has been accomplished to make sure the core injection from various water sources won't be hindered by the high core pressure. (CS.1-02 strategy in Chinshan URG)

[Kuosheng NPP](#)

Strategy for preventing fuel damage

When loss of core cooling function occurs, the plant staff will follow immediately EOPs to

control the unit at stable state. The corresponding measures are trying to recover the core between level 3 and 8 by the utility of branch water injection system or alternative water injection system (e.g. fire water injection). The core damage will be prevented.

In case that the station suffered the compound disaster condition exceeding the design basis accident due to earthquake and tsunami or the condition of loss of ECW and all both on-site and off-site AC power as well as judging from that the design basis water injection and cooling functions can not be restored in a short time, the station shall take the decisive actions to ensure that core fuel is covered with water in accordance with the URG procedure 1451. The decisive actions includes: lining up all the available water sources and alternative water injection paths, providing power sources as well as mobilizing all available manpower and materials in the shortest time in order to immediately inject the available backup water to the reactor.

Strategy for preventing the risk of fuel damage at high pressure

When loss of core cooling function occurs, except for above-mentioned EOP actions of water injection, the station shall simultaneously perform reactor pressure control (RC/P) till reactor pressure lower than 9.34 kg/cm^2 (if necessary, it can exceeds the limit of 55°C temperature step-down rate) in order to make sure the core injection from various water sources won't be hindered by the high core pressure.

In case that the station suffered the beyond design basis accident and unit lost its on-site and off-site AC power or reactor water makeup function, the station shall take the actions to make up water via RCIC and to control reactor pressure (via manual operation as well) in order to depressurize the reactor to 15 kg/cm^2 (if necessary, it can exceed the limit of 55°C temperature step-down rate) in accordance with the URG "reactor pressure relief". As the alternative water injection measure as described in the URG is ready, the water from the lined-up sources will be injected to the reactor in coordination with SRV emergency pressure relief to ensure that fuel is covered with water to avoid fuel damage.

Maanshan NPP

Maanshan NPP developed the emergency operating procedures (EOPs) for avoiding the deterioration of accidents and core damage.

Strategy for preventing fuel damage

If the loss of core cooling event occurs, the operators will immediately follow EOPs (570.00~570.57) to ensure the presence of primary coolant and heat sink.

- (1) For primary coolant: The primary coolant can be supplied by secondary-side water injection via Auxiliary Feedwater System/Alternative Feedwater System (diesel AFW pumps, fire water system, etc.) The Power Operated Relief Valves (PORVs) of the steam generators will be opened for heat removal.
- (2) For loss of secondary-side heat sink: If the heat sink of the secondary side is lost, the decay heat can be removed by the bleed-feed measure of primary side. However, the containment pressure will be built up subsequently so that the corresponding containment depressurizing measures must be applied.

Strategy for preventing the risk of fuel damage at high pressure

In order to prevent the fuel damage at high pressure, EOP 570.20 for SBO accident and EOP 570.43 for insufficient core cooling capability will be followed to depressurize the RCS. If the EOPs are insufficient to deal with the event, and once the core exit temperature over 1200 deg-F and failing to recover the core cooling function, the use of SAMGs (Procedure 1450) are decided. Thus, it could be believed that the RCS pressure is below 28.12 kg/cm^2 before RPV failure. The high pressure melt ejection (HPME) effects, that may possibly damage the

containment integrity by the pressure spike, will be avoided.

Lungmen NPP

Strategy for preventing fuel damage

When core cooling function is lost, the station immediately follows EOP 581~587 to carry out the unit control including water injection via water injection subsystem or alternative water injection system (including fire water system) in order to maintain normal water level between L3 and L8 such that the core is flooded with water so as to avoid fuel damage. (The purpose of EOP is to avoid the accident worsened to the extent that reactor core fuel is melt.)

In case that the station suffered from the beyond design basis accident resulted from earthquake and tsunami etc, Reactor Building Cooling Seawater System (RBSW) or Reactor Building Cooling Water System (RBCW) may lose its intended function such that decay heat is unable to be removed, and under the conditions that reactor lost its water makeup capability, all off-site and on-site power are lost, and spent fuel pool water level dropped, the station shall follow procedure 1451"Ultimate response guideline (URG)" to take decisive actions including each kind of alternative water flooding path, power sources, and water sources etc. All possible and available manpower and materials are mobilized to arrange all available water sources in the shortest time period. Judging in the shortest time that water injection and cooling function can't be restored to the design base function, available backup water sources shall be immediately injected into reactor in order to insure that fuel is covered with water and prevent fuel from damage.

Strategy for preventing the risk of fuel damage at high pressure

When core cooling function is lost, EOP actions of reactor pressure control (RC/P) except for the above-mentioned measures shall be simultaneously performed till reactor pressure lower than 1MPa (The 55°C/h temperature decreasing rate limit can be exceeded if necessary) in order to avoid fuel damage due to reactor core high pressure.

In case that design basis accident occurred, the unit lost its on-site and off-site AC powers or reactor water makeup function, the station shall follow URG appendix LM.1-06 "Reactor Pressure Relief operating procedure" to depress the reactor pressure to 1.5 MPa as soon as possible, to make up water to reactor by ways of RCIC and to control reactor pressure (Manual operation can be used) in order. As the alternative water flooding measure is ready, the in-advanced built-up water sources shall be injected to reactor in coordination with SRV emergency pressure relief to ensure that core fuel is covered with water so as to avoid fuel damage.

6.2.2 After occurrence of fuel damage in the reactor pressure vessel

Chinshan NPP

After fuel is damaged, Chinshan NPP will follow the SAP-1 in SAMG, depending on the accident conditions (RC/F-1~RC/F-6), to implement the water makeup of RPV and primary containment and the control strategies of containment pressure, hydrogen, and residual heat removal based on radioactive material release control procedure (SAP-2), to accomplish the purpose of termination of fuel degradation. Basically, URG and SAP both consist of the control strategies of containment pressure, hydrogen, and residual heat removal for maintaining the availability of containment and reducing the possibility of radioactive material release to atmosphere.

Additionally, the URG includes establishing the backup sources of electricity, air, and water

for implementing rescue operations. Combined with SAP's best approach of injecting water into RPV/containment to maintain the reactor core covered by water, they can reduce the possibility of fuel damage, ensure the integrity of RPV and containment, reduce the possibility of radioactive material release to atmosphere, and achieve the situation of long-term stability and control. (Completed by June 2011)

[Kuosheng NPP](#)

If fuel is damaged, the station shall follow URG to timely restore the core water level to prevent fuel from further damage. Meanwhile, the station shall perform the evaluation of rescue measures and proposed actions to different conditions in coordination with SAMG so as to achieve the goal for termination of fuel degradation. Moreover, the integrity of containment can be continuously maintained and the possibility of radioactive materials release is mitigated because both the URG & SAMG include the control measures of containment pressure, removal of hydrogen and residual heat.

Furthermore, the station's overall program for ultimate response guideline covers all alternative water injection measures, mobility of all possible manpower and manpower resources that can ensure that core is covered with water and possibility of fuel damage is reduced, and it can further assure the integrity of reactor pressure vessel. The station can inject water to reactor / containment to ensure that fuel (and molten core debris) is long term covered with water and further fuel degradation is terminated.

[Maanshan NPP](#)

If the EOPs are insufficient to mitigate the event, and once the core exit temperature is over 1200 deg-F and fails to recover the core cooling function, the use of symptom-based SAMGs are decided. If core cooling is lost and the core is damaged, different strategies, e.g. S/G Injection (SAG-1), RCS Depressurization (SAG-2), RCS Injection (SAG-3), Containment Injection (SAG-4), are utilized to ensure decay heat removal and the integrity of reactor pressure vessel, and to reach a stable and controlled state in the core.

[Lungmen NPP](#)

Same as described in Kuosheng NPP.

6.2.3 Cliff-edge effects and timing

[Chinshan NPP](#)

Before occurrence of fuel damage in the reactor pressure vessel

In the situation of loss of power and reactor make-up, reactor water level can be maintained by RCIC system. By the design basis, RCIC system can be operated continuously at least 8 hours by DC power or 24 hours by load-shedding and switching to 125V SWBD #6 power supplies. In this period, backup power and air can be established by strategies in Chinshan URG to execute the rescue actions. The reactor core cooling can be maintained in a long period, and the cliff edge effects of loss of power and reactor core make-up will not be happened.

The following is the SBO simulation results by MAAP5 code (Completed by June 30, 2011):

- (1) Assume that RCIC system can be operated for 8 hours, reactor water level will decrease from normal water level to the fuel uncovered level in 11.1 hours after the accident. The fuel temperature will exceed 2200°F in 12.4 hours after the accident. The core starts

degradation.

- (2) Assume that RCIC can be operated for 24 hours after SBO, reactor water level will decrease from normal water level to TAF in 27.94 hours after the accident. The fuel temperature will exceed 2200°F in 29.5 hours after the accident. The core starts degradation.

After occurrence of fuel damage in the reactor pressure vessel

Based on SBO sequence under the assumption of RCIC system operated for 8 hours predicted by MAAP5 code, the reactor water level will decrease from normal water level to fuel uncover in 11.1 hours after the accident. The fuel temperature will exceed 2200°F in 12.4 hours after the accident. The core starts degradation.

For the most conservative situation, if emergency core cooling systems like RCIC and HPCI systems are inoperable because of a large-scale compound disaster, reactor water level will decrease from normal water level to fuel uncover in 0.7 hours after the accident. The fuel temperature will exceed 2200°F in 1.3 hours after the accident.

[Kuosheng NPP](#)

Before occurrence of fuel damage in the reactor pressure vessel

Reactor water level can be maintained via RCIC which is designed with 8 hours DC power supply (24 hours DC power supply in case of unnecessary loads isolated) in case that the station lost all on-site and off-site AC power and reactor water makeup. During this period, the station normal power supply and alternative power supply including the 5th Diesel Generator, GTG, and mobile power can be set up to provide RCIC long term required power in accordance with the URG. Furthermore, emergency water via the alternative water injection measure as described in the URG can be injected to reactor to ensure that core fuel is covered with water in order that the above-mentioned cliff edge effects won't occur.

The risks of cliff edge effects and timing have been assessed with MAAPs. Under the conservative assumption, it is supposed that RCIC is failed after 8 hours & 24 hours so as to result in loss of core water makeup and cooling. In case of RCIC operating for 8 hr, the core water level maybe below TAF (top of active fuel) at 2.2 hr. In case of RCIC operating for 24 hr, the core water level may below TAF at 3.2 hr.

After Fukushima accident, Kuosheng NPP has established Ultimate Response Guideline after reviewing equipment status of the plant. For the above mentioned scenario, e.g., earthquake, tsunami, beyond design basis combined natural disaster, or lost of ECW system as well as loss of off-site power, the staff of the plant can follow URG to establish normal or alternate AC power (including 5th DG, Gas Turbine Generators, or movable diesel generator) and supply long term operation power needed by RCIC. Depending on plant's condition, alternative makeup water can be set up. When reactor is depressurized, alternative makeup water can be injected into reactor to cover fuel in reactor, cliff-edge effect would not occur.

After occurrence of fuel damage in the reactor pressure vessel

In case of RCIC operating for 8 hr, the RPV may fail at 9.7 hr. In case of RCIC operating for 24 hr, the RPV may fail at 13.4 hr.

[Maanshan NPP](#)

Primary circuit closed

The first case is covered by the full power operation state of the unit. Following the complete loss of electrical power, only the TDAFWP remains available to feed water into the steam

generators for 8 hours. The decay heat is removed by opening PORVs.

This case is simulated by MAAP5 code. The first cliff edge effect may appear at 15.2 hour after S/Gs dry out and be followed by core uncover at 16.9 hour. The core is damaged (fuel temperature over 2200 deg-F) at 18.7 hours. The RPV integrity is lost at 22 hours.

If TDAFWP is assumed to feed water into the steam generators for 24 hours, all cliff edge timings would be delayed: steam generators dry out at 41.7 hours; core uncover at 44.6 hours; core damaged at 47.1 hours; RPV failure at 55.7 hours.

Primary circuit open

During outage phase, the significant risk is from RCS operations at mid-loop situation. The water inventory is only 180,000 lb and water level is under the top of hot leg. After the complete loss of electrical power, the primary circuit water heats to boiling point at 18 min and the core is uncovered at 1.8 hours when the mid-loop configuration appears 2 days after the beginning of the shutdown operations.

Lungmen NPP

Reactor water level can be maintained via RCIC which is designed with 8 hours DC power supply (24 hours DC power supply in case of unnecessary loads isolated) in case that the station lost all on-site and off-site AC powers and reactor water makeup. During the time of this period, the station shall follow URG appendix LM.2-04~07 & LM.2-11~14 to set up normal power supply and alternative power supply including the Seventh Diesel Generator, GTG, and backup mobile power which is set aside on high elevation to provide long term RCIC required power. Furthermore, depending on the station condition, emergency water can be injected into reactor by means of the backup alternative water makeup measure as described in the URG attachment 02 "Long term water source plan" and via backup alternative water sources as well as flooding path after reactor emergency pressure relief (URG appendix LM.1-06) in order to insure that core fuel is long term covered with water and the above-mentioned cliff edge effects will not occur..

The risks of cliff edge effects and timing have been assessed with MAAPs. Under the conservative assumption, it is assumed that RCIC is failed after 8 hours & 24 hours respectively so as to result in loss of core water makeup and cooling. The calculation result is described as follows:

Before occurrence of fuel damage in the reactor pressure vessel

- RCIC keeps operation for 8 hours:

The time of core water level drops to TAF (top of active fuel) is 1.6 hrs.

- RCIC keeps operation for 24 hours:

The time of core water level drops to TAF (top of active fuel) is 4.3 hrs.

After occurrence of fuel damage in the reactor pressure vessel

- RCIC keeps operation for 8 hours:

The time of core water level drops to TAF (top of active fuel) is 1.6 hrs.

The time RPV failed: 9.7 hrs.

- RCIC keeps operation for 24 hours:

The time of core water level drops to TAF (top of active fuel) is 4.3 hrs.

The time RPV failed: 15.1 hrs.

6.2.4 Adequacy of current accident management measures

Chinshan NPP

Before occurrence of fuel damage in the reactor pressure vessel

In response to the situation of compound disaster, URG has planned the arrangement of on-duty crew and three stages check sheet that details the tasks that need to be accomplished by crew inside the plant in short period (within one hour). The on-duty operator will integrate manpower in the plant, use existing resources, and implement URG procedure (1415) rapidly. The lineup of raw water injection in accordance with the URG CS.1-01 can be accomplished within one hour. It can inject water into reactor through raw water system/ fire protection system / temporary pipes to prevent reactor core from uncover. It is aimed to mitigate the consequence of the event effectively for 24 hours without the support from outside. When the emergency response teams arrive, they will carry out the emergency response operations. Therefore, plant's URG can provide the guidance to line up the water sources and inject water into reactor to prevent fuel damage before the cliff edge effects can happen.

After occurrence of fuel damage in the reactor pressure vessel

After fuel is damaged and depending on the accident conditions (RC/F-1~RC/F-6), Chinshan NPP will follow the SAP-1 in SAMG to implement (1) the makeup of RPV and primary containment and (2) the control strategies of containment pressure, hydrogen, and residual heat removal based on radioactive material release control procedure (SAP-2). Through these implementations, the target of termination of fuel degradation can be accomplished.

Additionally, the plant can restore core water level in time and reduce the probability of core damage based on URG. Combined with TSC AMT and follow SAP, the plant is implementing the evaluation of various mitigation strategies and suggested action to achieve termination of fuel degradation for different accidents. URG and SAP both include the control strategies of containment pressure, hydrogen, and residual heat removal for maintaining the integrity of containment and reducing the probability of radioactive materials release.

[Kuosheng NPP](#)

Before occurrence of fuel damage in the reactor pressure vessel

The Kuosheng NPP has already reviewed all the response facilities, procedures, equipment, mechanisms used for coping with design basis accidents and beyond design basis conditions, so as to enhance the station response capability.

Compound disaster often has multidimensional impact which is not limited to the threat of the containment integrity. The management of compound disaster condition is very urgent. The reciprocating judgment and treatment process of EOP or SAMG may not be able to cope with the rapid degradation of accident. In order to cope with the compound disaster condition, TPC has established the ultimate response guidelines (URG). The Kuosheng URG is detailed in Section 6.1.4.

In case that all water makeup systems are lost, three assumed scenarios were analyzed: RCIC is failed after 1hr, 4hr, and 8hr operation. The analyses were performed by REAP5-3D to avoid the fuel cladding temperature exceeding 1500 deg-F, in which the hydrogen is generated. The minimum required water injection rate to the reactor is calculated to be 645 gpm (1 hr), 530 gpm (4 hr), and 475 gpm (8 hr), respectively.

A field test was performed in the fire hydrant located in the inlet of fire water pipe at the entrance of building to measure the water injection flow rate via gravity from fire raw water on the hill side. The flow is calculated with 4" fire pipe cross section area in consideration of reactor back pressure and friction loss. The calculation result shows that the flow can reach 808 gpm that is bigger than the most severe required flow rate of 645gpm in the RCIC 1hr operation scenario.

In order for the station to response to compound disaster condition, the station has established

the shift personnel arrangements and three phase check lists as shown in the URG. The related items including reactor pressure relief, alternative water injection, and the required power supply for essential systems and instrumentation control via mobile power source in the first phase shall be accomplished within one hour based on the station's own capability, so that the accident deteriorating condition can be avoided in the first place and be effectively controlled. Therefore, the station URG measures can be ready before the cliff-edge effect of fuel damage occur and various water sources are prepared to inject water to reactor to ensure that fuel is covered with water and the cliff-edge effect of fuel damage will not occur. The RPV integrity can be guaranteed and containment failure and emergency public evacuation are thus avoided.

After occurrence of fuel damage in the reactor pressure vessel

The required DC power for RCIC operation to relieve reactor pressure and water makeup can be maintained for 24 hours after isolation of partial unnecessary loads per station's procedure (If necessary, it can also be manually operated). Besides, water can be continuously injected to reactor by various water sources in the short time to ensure that core is covered with water and possibility of fuel damage is reduced.

The station shall follow the URG to perform the first phase water injection to ensure that core is covered by water and the possibility of fuel damage is reduced. Moreover, the station shall complete the second phase measures including the setup of the required system DC & AC power supply within 8 hours. Activation and preparation shall be completed within the time as in each phase check list so as to ensure the integrity of RPV.

Because the containment is designed that the dissoluble radioactive substances can be scrubbed in the suppression pool and fission product can be confined in the containment by the containment enclosure capability, the station shall re-setup the function of Standby Gas Treatment System (SGTS) to mitigate the release of radioactive substances via URG power restoration measures in case that the radioactive substances may be released from damaged fuel. Furthermore, if insufficient cooling condition occurred, hydrogen can be generated by Zirconium water reaction. Hydrogen control will be described in the following section.

Maanshan NPP

Before occurrence of fuel damage in the reactor pressure vessel

For the extreme situation, the first cliff-edge stage is core uncovered and may appear in a short time. It's possible to fail setting up the equipment and means following EOPs and SAMG before core uncover. Therefore, the Maanshan NPP developed the ultimate response guideline (URG), including alternative injection paths, electrical powers, and water sources. While the plant fitting the entry conditions of URG, all available water resources will be set ready for injections in the shortest time. If the original safety injections and cooling functions are unable to be restored in a short time, the URG measures for decay heat removal and preventing fuel damage would be decided. The alternative water will be injected into steam generators and the PORVs of steam generators will be opened.

The URG measures for decay heat removal are established as follows:

- (1) Manual operation of TDAFWP or diesel-driven AFWP (MS.1-01 in URG) for water injection in one hour in case of DC power being unavailable
- (2) Raw (hydrant extinguishing) water injection into S/Gs (MS.1-03 in URG)

Inject the inventory of 50,000/2,000/5,000 tons in raw water reservoir via TDAFWPs or diesel-driven AFWPs, or to implement water injection via outdoor fire hydrant or fire engines into S/Gs. At the same time, manual opening of S/G PORVs is required for increasing the injection capability.

- (3) Connections of 480V mobile diesel generators (MS.2-03 in URG) for long-term TDAFWP operation
- (4) Water inventory for S/G injection (a guideline in URG)
 - Raw water, fire extinguishing water, sea water, and water inventory of Ongluan Lake and Mudan reservoir could be used as water inventory for long term cooling of S/Gs.
- (5) Manually open S/G PORVs without electrical power and instrumental air (a guideline in URG)
- (6) RCS depressurization (a guideline in URG)

In order to prevent the RCS failure at high pressure, a guideline in URG is established to depressurize the RCS via opening PZR PORVs or venting by relief valves on the vessel top. In order to guarantee the RCS depressurization, the other guideline in URG is established to charge the batteries (DC power) by mobile diesel generators. In case of RCS depressurization, the containment vent is required to avoid the overpressure of containment.

The strategies in the first level of URG are required to be completed in one hour. It's believed that the water can be injected into S/Gs in 2.1 hours and the cliff-edge effect of the fuel damage can thus be prevented.

For RCS running at half water level during outage, the procedures have been updated to reserve the inventory in two accumulators. Once the loss of heat sink occurs, operators can inject the water of these two accumulators into RCS in one hour and the time of core uncovering being extended from 1.5 hours to 4.1 hours is believed. With the alternative water injections, alternative powers and water sources arranged in URG, the prevention of fuel damage may be guaranteed.

After occurrence of fuel damage in the reactor pressure vessel

The cliff-edge effect of RPV failure is identified at 22 hours. The results of reviewing present procedures and equipment in plant, it's possible to fail to start rescuing operations in 22 hours. The following strategies in URG are established to overcome the weakness:

- (1) Alternative containment injection (a guideline in URG)
 - Inject water into reactor pit at the bottom of reactor vessel. The pathways are listed: RWST gravity injection into recirculation pump, water injection via fire hydrant system into containment, and water injection via fire engines into containment spray lines.
- (2) Containment depressurization (a guideline in URG)
- (3) Injection of fire extinguishing (raw) water into S/Gs (MS.1-03 in URG)
- (4) S/G depressurization (a guideline in URG)
 - Manually open S/G PORVs without electrical power and instrumental air.
- (5) RCS depressurization

These strategies can be completed in 22 hours and the cliff-edge effect of RPV failure could thus be prevented.

Lungmen NPP

Before occurrence of fuel damage in the reactor pressure vessel

Under the condition similar to Japan, Fukushima 311 nuclear compound disaster accident resulted from earthquake accompanying tsunami attack, the facilities designed for mitigation of severe accident may be inoperable at the same time or inoperable gradually; The station had already reviewed all the response procedures, facilities, and mechanisms used for coping

with design basis accident so as to concretely enhance the station response capability.

Compound disaster is a kind of aspect impact and it is not limited to the threat of the containment integrity. The management of compound disaster condition is very urgent in the time limit and the reciprocating judging process and treatment process of EOP or SAMG can't cope with the worsen extent of accident. In order to cope with the compound disaster condition, TPC had already prepared the "Ultimate Response Guidelines (URG)" for station to follow and its initiation opportunity and action basis shall follow this guideline based on the site-specific basis because each kind of defense equipment or water facilities may simultaneously lose its function when compound disaster accident happens. Therefore, TPC had programmed to incorporate all site and off-site available resources and measures into enhance strategies to program mobile power, water, and air sources based on the redundant, diversity and independent defense-in-depth strategy and emphasize their mobility to shorten their management timing in order to response to each kind of compound disaster condition.

According to the analysis results via Three Dimensional Two-Phase Thermal-Hydraulic Model(RELAP5-3D) and considering the station URG reasonable operation process, it is analyzed that after reactor emergency pressure relief, URG water injection to reactor by ways of fire water piping, the minimum required individual flows, that keep fuel cladding temperature below 1500°F (hydrogen producing point), are 1974gpm(1hr), 1483gpm (4hr), and 1335gpm (8hr) respectively, in case that all water makeup system are lost and RCIC continuously control reactor pressure as well as the three conditions of water injection failed after 1 hr, 4hrs, 8hrs respectively (the former assumption is very conservative because RCIC actually operate exceed 24 hrs as per Fukushima experience).

In order for the station to response compound disaster condition, the station had already mapped out the shift personnel arrangement and three phase check list as shown in the URG attachment 05 & 06. Its relevant items including reactor pressure relief, alternative water injection, and the required power for essential systems and instrumentation control via mobile power source in phase-1 shall be independently completed by the station manpower itself within 1 hr so that the accident worsen condition can be avoid at first time and effectively controlled. Therefore, the station URG measures can be ready before the cliff-edge effect of fuel damage occur and each kind of water sources is prepared to inject water into reactor to insure that core fuel is covered with water and the cliff-edge effect of fuel damage will not occur.

After occurrence of fuel damage in the reactor pressure vessel

The station containment is designed that by way of suppression pool scrubbing, fission products can be limited in the containment by the containment enclosure capability and the station shall re-setup the system function of Standby Gas Treatment System (SGTS) to mitigate the release of radioactive substances via URG power restoration measures. Furthermore, Zirconium and water reaction to produce hydrogen whenever loss of adequate cooling will be described in the section 6.2.3.1 "The risk of hydrogen control".

In response to the fuel damage condition, the station shall continuously carry out the URG rescue actions and initiate severe accident management (SAG) as per EOP. The On-site Accident Management Team (AMT) shall carry out each kind of the optimize rescue actions in view of each kind of accident conditions (RCF/F-1~6) in order to achieve the goal of termination of fuel degradation.

6.3 Accident management measures to maintain the containment integrity after core damage

6.3.1 Management of hydrogen risks inside the containment

Chinshan NPP

The Hydrogen/Oxygen Monitoring System (HOMS) installed inside containment can monitor the content of hydrogen. The purge of the containment nitrogen system and the operation of the Standby Gas Treatment System (SBGT) can ensure the dilution and release of hydrogen.

Secondary containment is the only space that can accumulate hydrogen in Chinshan NPP. In order to reduce the accumulation of hydrogen, in current stage, a portable generator can be used to supply power to SBGT. Additionally, a DCR has been established to add a manual/remote opening blowout plate on the roof of 5th floor of reactor building. When compound disaster happens, blowout plates can be opened in advance to avoid hydrogen accumulation in reactor building. (Completed after June 2011)

After reactor vessel damage, Chinshan NPP will follow hydrogen control strategy (PC/G) in the corresponding guideline of SAP-2 to exhaust and purge containment to reduce hydrogen concentration in primary containment. Considering the possibility of the decrease of instrument reliability in a beyond design basis accident, Chinshan NPP will open the truck double doors of secondary containment and release plates on the roof of secondary containment to reduce the accumulation of hydrogen and primary containment overpressurization according to procedure 1451 (URG) regardless the radiation release rate in the emergency depressurization.

Kuosheng NPP

The EOP & SAG are designed for containment hydrogen concentration control (PC/G). Hydrogen igniter and recombiner shall be started to reduce containment hydrogen concentration. In addition, containment venting (if necessary, it is allowed to exceed radiation release rate) or containment core spray shall be started to reduce containment pressure and hydrogen concentration depending on the station condition so as to secure the containment integrity.

In case that a beyond design basis accident occurs, it is anticipated the unit will lose its off-site and on-site AC power. The station shall follow URG "Containment pressure control" to open containment exhaust system related isolation valves (to open the motor operated valve in the containment in advance and then to open the air operated valve outside the containment). The containment will be connected to the atmosphere once the isolation valves are opened. As a result, hydrogen concentration is reduced and hydrogen explosion can be prevented by way of containment pressure relief and containment exhaust.

Besides, in order to avoid hydrogen accumulated in the secondary containment, the long shape door located in Auxiliary Building 7F and air intake shutters in Auxiliary Building shall be opened to release hydrogen to outside the building in order to prevent hydrogen accumulated in the secondary containment to result in hydrogen explosion condition.

During the station emergency rescue, except for reactor water makeup as per URG to avoid hydrogen generation, power recovery for hydrogen control system is one of the first priority strategies in URG. Once the electric power is restored, hydrogen igniters and recombiners shall be started to reduce hydrogen concentration so that hydrogen explosion can be avoided.

Maanshan NPP

For controlling hydrogen concentration below 4%

In SAMG, the SAG-7 “Hydrogen Management inside Containment” is designed to prevent a detonation which could threaten the containment integrity. In addition to the hydrogen recombiners equipped in the containment, it is possible to reduce the hydrogen concentration inside containment by the following measures: burn the hydrogen with a spark, dilute the hydrogen via steam released into containment.

For hydrogen concentration over 6%

In SAMG, the SCG-3 “Hydrogen Control inside Containment” is designed to implement containment venting through the low volume purging system and post-accident hydrogen purge system (PAHPS) to mitigate the impacts of hydrogen burning on containment integrity.

Lungmen NPP

Both EOP & SAG for the station are programmed with hydrogen concentration control (PC/G) measures inside containment. Except that hydrogen igniter and hydrogen recombine shall be started to reduce containment hydrogen concentration, containment exhaust (if necessary, it is allowed to exceed radiation release rate) or containment spray shall be started to reduce containment pressure and hydrogen concentration depending on the station condition so as to secure the containment integrity.

In case that design basis accident occurred, the unit lost its off-site and on-site AC power, the station shall immediately follow URG appendix LM.1-07 “ Primary Containment Exhaust Operation procedure” to open Containment Atmosphere Control System (ACS) relevant isolation valves in order for containment be connected to atmosphere so that containment hydrogen concentration can be reduced and occurrence of hydrogen explosion condition can be avoided by way of containment pressure relief and containment exhaust.

Besides, in order to avoid hydrogen accumulated in the Secondary Containment, the station shall immediately follow URG appendix LM.2-02”Secondary Containment Exhaust operating procedure” to open 4 sets of blasting windows located on Reactor building 7F (1 set on North side, 3 sets on south side) to release hydrogen to outside of containment by natural convection in order to prevent hydrogen accumulated in the Secondary Containment to result in hydrogen explosive condition.

During the station emergency rescue process, except for reactor water makeup as per URG to avoid hydrogen to continuously produce, the station shall cooperate with containment exhaust measure to start hydrogen recombination to reduce hydrogen concentration in order to avoid hydrogen explosive condition once the required power for hydrogen control system is restored.

6.3.2 Prevention of overpressure of the containment

Chinshan NPP

In the situation of loss of power and core cooling water makeup, RPV depressurization and water makeup can be conducted by RCIC system. DC power supply can be maintained for RCIC system for 24 hours by proper load-shedding and the mechanism of switching 125VDC SWBD #6 to DC SWBD #2. In this period, according to the first stage strategy of URG CS.1-01 of Ultimate Response Guideline Procedure (1415), raw water (fire water) must be injected into the reactor vessel. The pipes for raw water (fire water) injection can be established within one hour after action order. The emergency operation of raw water injection into RPV can effectively protect the core by recovering core water level and prevent the fuel from further damage.

According to Chinshan SAP-2 "Containment and radioactive materials release control" PC/P, the primary containment pressure can be reduced by containment venting and containment spray systems. The pressure can also be released directly by containment pressure release system "Direct Torus Venting System" to avoid containment overpressurization failure.

Kuosheng NPP

Kuosheng's containment is designed to have suppression function that the exhaust steam from SRV / RCIC is condensed by suppression pool to mitigate containment pressure rising condition. Besides, containment pressure can be effectively reduced by means of containment core spray and containment exhaust (if necessary, it is allowed to exceed radiation release rate) as per the station's EOP and SAG "Containment pressure control measures."

In case that a beyond design basis accident occurs and it is anticipated the unit will lose its off-site and on-site AC power, the station shall follow URG "Containment pressure control" to open containment exhaust system related isolation valves in order for containment to be connected to atmosphere to exhaust containment and reduce containment pressure to prevent containment overpressure so as not to lose its enclosure capability.

During the station emergency rescue, the power recovery for SGTS is one of the first priority strategies in URG. Once the electric power is restored, SGTS shall be started.

Maanshan NPP

In SAMG, the SAG-6 "Containment P/T Control" is designed to utilize the containment spray system and fan coolers for P/T control to prevent the overpressure of containment.

In SAMG, the SCG-2 "Containment Depressurization" is applicable for containment pressure over 110 psig. The containment spray system, fan coolers, low volume purging system, and post-accident hydrogen purge system (PAHPS) are utilized to reduce the pressure.

For the accidents beyond design basis, the MS.2-03, MS.2-08, MS.3-01, and MS.3-02 strategies in Maanshan URG are developed for preventing overpressure of containment.

Lungmen NPP

The station's containment is designed to have suppression function that the exhaust steam from SRV / RCIC is condensed by suppression pool to mitigate containment pressure rising condition. Besides, both EOP & SAG for the station are programmed with containment pressure control (PC/P) strategy to effectively reduce containment pressure by means of containment spray and containment vent. As per the station emergency operating procedure EOP-582, it is permitted that primary containment can vent air to atmosphere via COPS in case COPS was opened no matter radiation release rate. Containment vent can't be isolated until post accident recovery.

The station Containment design pressure is 310kPaG; Containment Overpressure Protection System (COPS) passive destructive pressure is 620.5kPaG; containment structure destructive pressure is 1025.3kPaA so that the integrity of containment can be long term maintained.

During the station emergency rescue process, the required power for SGTS is programmed with the first priority item in URG. Once the station power is restored, SGTS shall be restarted to exhaust containment air to effectively reduce containment pressure and radioactive substance release and further secure the integrity of containment.

6.3.3 Prevention of re-criticality

Chinshan NPP

When implementing SAP-1 reactor power control (RC/Q), the operators will make sure that the switch position of reactor mode is at "SHUTDOWN", the RRCS ARI has been actuated, the SBLC boron solution injection is implemented to RPV until boron tank water level decrease to 0%, and finally the reactor is shutdown. During the RHR shutdown cooling, the operators should closely monitor WRNM to ensure that the injected boron solution is not diluted so that the reactor would not re-critical.

If SBLC system is unavailable in an accident, the emergency measures of boron injection are:

- (1) If the power is available, methods of boron injection are: (1) Inject the boron liquid to reactor core through reactor water cleanup (RWCU) system from the storage tank of standby boron liquid control system. (2) Inject borax/boric acid to reactor core through reactor water cleanup (RWCU) system. (3) Inject the boron liquid to reactor core from demineralized water storage tank through control rod drive system.
- (2) In a SBO accident, first make boron solution by spare boron acid and borax in warehouse, and transport the solution to fire water tankers by sump pump, and then inject the solution in fire water tankers to reactor core through RHR system.
- (3) Besides considering the existing warehouse space, NPP has purchased sufficient amount of spare boron acid and borax to satisfy the required boron liquid concentration, which is comparable to that for RPV safe shutdown, for containment flooding to TAF.

Kuosheng NPP

One of the most important actions of EOP is to confirm the reactor has already scrammed. If the reactor is still under criticality condition, the operator shall follow procedure to insert the alternative control rod. In addition, boric acid liquid shall be injected into reactor via Standby Boric Liquid Control (SBLC) or via alternative boron injection measure to maintain the reactor in sub-critical condition. Boric acid shall be immediately injected into reactor unconditionally in case that SAG conditions are reached.

In case that a beyond design basis accident occurs as well as the unit lost its off-site and on-site AC power that resulted in the above-mentioned boron injection failure, procedure provides emergency boron injection measure to inject boric acid into reactor via RHR-B by way of fire water piping to prevent reactor re-criticality.

Procurement of standby boric acid, borax for each nuclear power plant is according to the quantity required for containment flooding to TAF and the boron concentration comparable to that for RPV safe shutdown and the consideration of each station's storage capacity.

Maanshan NPP

The NIS starting rate will be monitored while implementing RCS injection in SAMG or URG. If the NIS starting rate is greater than zero, the amount of boric acid in the coolant would be changed or injection would be stopped so that void fraction is increased to impede the reaction.

Lungmen NPP

The station EOP first priority action is to confirm if reactor was already scrammed (RC/Q). Once reactor is at critical, the station shall follow procedure 590.13 to insert the alternative control rod and depending on the condition that power oscillation or Suppression Pool

exceeding boron injection initiative temperature, Boric acid shall be injected into reactor via Standby Liquid Control (SLC) or via alternative boron injection measure (proc. 590.14) to maintain the reactor at sub-critical condition. In case that SAG condition entered, Boric acid in SLC tank shall be absolutely immediately injected to reactor.

In case that design basis accident occurred, the unit lost its off-site and on-site AC power that resulted in the above -mentioned boron injection failure, Boric liquid will be extracted by fire water truck and then inject to reactor core via Residual Heat Removal System to prevent reactor re-critical.

The procurement of standby boric acid, borax for the station is according to the required quantity comparing with the required born concentration for containment water injection to TAF and for RPV safe shutdown and consideration of station's storage capacity. The quantities procured for standby boric acid, borax are 72 tons each.

6.3.4 Prevention of basemat melt through

[Chinshan NPP](#)

The procedure SAP-1 "RPV and the primary containment flooding accident management procedure" includes the drywell spray/flooding guidelines. These procedures ensure that the vessel bottom surroundings will be covered with water as vessel fails. The core debris can be quenched fully to avoid the containment basemat melt through.

According to the newly established procedure of ultimate response guideline (1451), NPP has also established back up power supplies and air sources which can support the secure operations.

[Kuosheng NPP](#)

In Mark III containment, core debris will not immediately challenge containment integrity because the skirt of drywell is enclosed by the weir wall of wet well. The station's major response measure for mitigating the debris falling down to core cavity is still to utilize water to mitigate the Molten Core-Concrete Interaction (MCCI) for preventing containment base mat melt through.

[Maanshan NPP](#)

In order to prevent the basemat melt through after the rupture of reactor vessel, the strategies of Containment Injection (SAG-4) and Containment Flooding (SAG-8) will be implemented to ensure the vessel bottom surrounding will be covered with water while vessel perforated. Once the core debris falls into water, it could be easily cooled and the MCCI would be avoided.

For accidents beyond design basis, three strategies in a guideline of Maanshan URG are developed as alternative measures for flooding the reactor cavity. These three strategies include RWST gravity injection, injection of firewater system via KC-XV111, and injection through containment spray lines. The prevention of basemat melt through may be secured.

[Lungmen NPP](#)

The station's major response measures for mitigation of core molten residue falling down to core cavity are AC-Independent Water Addition (ACIWA), and Lower Drywell Flooder (LDF) to utilize flooding water to cover molten liquid to mitigate the reaction between molten residue and concrete to prevent containment base mat melt through condition. It is described as follows:

- 1.ACIWA: In case that all on-site and off-site power is lost, the station shall start diesel-driven fire pump or utilize fire water reservoir truck to carry water and carry out lower drywell flooding via ACIWA piping and spray spargers in containment. If diesel-driven fire pump failed to start, water of 4.8 metric ton raw water pool, located at 116 M above sea level, would flow through the check valve by gravity to flood drywell via ACIWA piping and spray spargers in containment.
- 2.Lower Drywell Flooding (LDF) System: Lower Drywell Flooding System, a passive system, is used as an alternative flooding system whenever ACIWA failed. After RPV bottom head is molten through, the molten core will drop down upon the drywell basemat, Suppression Pool water would flood into Lower Drywell to form a pool of 1.55 M depth when its high temperature fusible plug acts. As per BWROG EPG / SAG Rev. 2 Appendix B 17.18, drywell liner would avoid to be molten through, the reaction between molten core and concrete would be limited, and the temperature of core debris bed would be effectively reduced when water floods 1.22M above drywell bottom. There is no active equipment or instrumentation in this system and it can also operate its intended function under high radiation condition.

6.3.5 Need for and supply of electrical AC and DC power and compressed air to equipment used for protecting containment integrity

[Chinshan NPP](#)

The Chinshan EOP's response of containment venting to the accident is controlled by the systems listed in EOP-PC 540.3 "Primary Containment Control". These systems include SGTS, normal purge supply/exhaust system, post LOCA purge supply/exhaust system, drywell to primary containment exhaust valves and drywell emergency vacuum relief valves. If necessary, the isolation interlock can be removed. The strategy has included the CTMT ventilation/dilution execution programs after station blackout (SBO).

When the beyond design basis accident occurs and the related power is lost, plant operators can use the backup power according to the URG procedure. These backup powers include the 5th D/G, gas turbine generator, and portable diesel generators.

To ensure that the essential emergency equipment can be powered in a short time as the beyond design basis accident occurs, the plant has established the following enhancement measures to make 4.16kV/480V AC power available: (Completed by June 2011)

- (1) Modified the procedures to make the 5th D/G to supply power to two units simultaneously in emergency.
- (2) Prepared power cables and related operating procedures to connect the two black-start 4.16kV/1100kW diesel generators associated with gas turbine generator to the 4kV essential power BUS.
- (3) Purchased twelve 480V portable diesel generators and issued a DCR to install power supplying adapters and circuits.
- (4) TPC headquarters is purchasing six 4.16kV/1500kW D/G power supply vehicles. Chinshan NPP will receive one of these.

[Kuosheng NPP](#)

The uses of containment sprays and vents are the primary protections during the accident response as per the station's EOP/SAMG. Containment vent is performed by the systems listed in EOP 500.14 "Venting Primary Containment", including SGTS, normal purge supply/exhaust system, post LOCA purge supply/exhaust system, drywell to primary

containment exhaust valve and drywell emergency vacuum relief valve. If necessary, the isolation interlock could be defeated. The containment spray is one of RHR designed functions which is powered by safety-related power.

When the beyond design basis accident occurs and the related power is lost, the station shall follow the Power Recovery Guideline in Kuosheng URG to setup the normal and alternative power sources, including 5th D/G, GTG, and mobile powers to restore the availability of various rescue facilities. In case of all power unavailable, the station shall follow the Guideline of Containment Pressure Control in Kuosheng URG to open the isolation valves of containment exhaust system for containment venting and depressurization.

Maanshan NPP

All severe accident management measures to maintain the containment integrity need the AC and DC power. For the accidents beyond design basis, the MS.2-03 and MS.2-08 strategies in Maanshan URG are developed for restoring AC/DC power.

Lungmen NPP

The primary containment protections during EOP/SAMG are containment spray and containment vent. The containment vent mode is by ways of COPS which includes two sets of normal open pneumatic control valves, rupture disks and vent piping connected to Secondary Containment. Those pneumatic control valves would keep open when loss of its pneumatic power happens. Therefore, it would function without power and Primary Containment overpressure can be avoided. Moreover, Containment Spray which is designed with safety related ESF power is one of the RHR designed functions.

In case that Beyond Design Basis Accident occurred and lost all of its related powers, the station shall follow the measures in URG attachments LM.2-04~07& LM.2-11~14 to setup the normal and alternative power including startup of the Seventh D/G, GTGs, or mobile diesel generators etc as described in this chapter 5 in order to restore the availability of each kind of rescue facilities.

6.3.6 Cliff-edge effects and timing

Chinshan NPP

Department of Nuclear Safety of TPC headquarters had contracted to Institute of Nuclear Energy Research to assess the cliff edge effects using MAAP5 code. The calculation is based on a conservative assumption that the RCIC system is failed at 8 or 24 hours after reactor scram caused by earthquake, resulted in loss of core cooling and makeup. The calculated results are (time period is counted from the RCIC system failure):

RCIC system operates for 8 hours

The containment overpressurization (not considering the RPV depressurization and containment venting) may occur at 19.2 hr.

RCIC system operates for 24 hours

The containment overpressurization (not considering the RPV depressurization and containment venting) may occur at 33.7 hr.

Kuosheng NPP

The Institute of Nuclear Energy Research (INER) contracted by TPC Safety Department to assesses the risks of cliff edge effects with MAAPs. With conservative assumptions, it is

assumed that RCIC is failed after 8 and 24 hours, respectively, so as to result in loss of core water makeup and cooling. The calculation result is described as follows:

RCIC system operates for 8 hours

The hydrogen combustion may occur at 9.8 hr and the RPV overpressure (in case of no reactor pressure relief and no containment exhaust gas) may occur at 9.7 hr.

RCIC system operates for 24 hours

The hydrogen combustion may occur at 13.4 hr and the RPV overpressure (in case of no reactor pressure relief and no containment exhaust gas) may occur at 13.4 hr.

The station shall handle the accident in accordance with the existing symptom bases EOP / SAG as well as in accordance with the URG planning strategy for a compound disaster accident. Water injection measures in the first phase are prepared item by item per checklist and the second phase measures including the setup of the DC & AC power supply is required to be completed within 8 hours. The first phase water injection measures shall be continuously performed via hydrogen control, pressure control, and power restoration as well as other response actions mentioned above to ensure containment integrity before the cliff-edge effect occurs.

Maanshan NPP

In Maanshan NPP, the medium (A_m) value of containment overpressure failure is 182 psig, the uncertainty (β_M) of the simulation model is 0.20, and the uncertainty of structure strength is 2.15. The HCLPF of 101 psig is thus calculated as the containment overpressure limit. The MAAP5 code was used to estimate the cliff-edge effects and timing of an extended SBO accident.

If the TDAFWP operating for 8 hours is assumed, local hydrogen burning inside containment would occur at 19.5 hours. RPV would fail at 22 hours and the containment failure due to overpressure may follow at 60.2 hours. If the TDAFWP operating for 24 hours is assumed, RPV would fail at 55.7 hours. Local hydrogen burning inside containment would occur at 57.4 hours and the containment failure due to overpressure may follow at 101.9 hours. The cliff-edge timing of containment failure is viewed as 60.2 hr in case of TDAFWP operating for 8 hr.

Lungmen NPP

The Institute of Nuclear Energy Research (INER) committed by TPC Nuclear Safety Department assesses the risks of cliff edge effects with MAAP5. Under the conservative assumption, it is assumed that RCIC is failed after 8 hours & 24 hours respectively so as to result in loss of core water makeup and cooling. The calculation result is described as follows (calculated from the time of RCIC inoperable):

- RCIC continuous operation for 8 hours:

The time of containment overpressure (in case of no reactor pressure relief and no containment venting): 9.73 Hrs.

- RCIC continuous operation for 24 hours:

The time of containment overpressure (in case of no reactor pressure relief and no containment venting): 3.57 Hrs.

Except that the station shall follow the existing EOP/SAMG to consider how to manage the overall accident response strategies in symptom base, the station shall simultaneously follow the advanced programming measures in URG in response to compound disaster accident to complete all mobilizations and preparations of each phase checks as described in the check

list within time limits, including the phase-2 measures to setup of the required system DC & AC power supply within 8 hours so that the integrity of containment can be ensured before the cliff-edge effect occurs.

6.4 Accident management measures to restrict the radioactive releases

Chinshan NPP

Once a severe accident occurs, the management and confinement of radioactive releases of Chinshan NPP could be divided into two portions, radioactive gas and liquid releases.

Radioactive gas release

- (1) Under normal condition, primary containment may enclose the radioactive substance within containment by automatic isolation function, and it can prevent fission product release during the accident period, and guarantee that the off-site dose will not exceed the regulation of 10CFR 100.
- (2) When emergency accidents occur and site boundary dose of the plant reaches 5 Ci/sec, all releases must be isolated according to the EOP 540.4. If the situation deteriorates and the SAP is required, according to the procedure of 540.6, HVAC isolation must be confirmed and SBGTS must be started to effectively filter the radioactive materials when the secondary containment HVAC radiation is over 100 mR/hr.
- (3) During EOP/SAMG phase, the containment at high pressure or high hydrogen concentration may be possibly failed to suppress the pressure induced from RPV energy blowdown. Procedure 540.3 requires to vent the primary containment to assure the integrity and avoid the large radioactive gas release.
- (4) If compound disasters like Fukushima accident occur; the containment blowdown/vent system may out of order due to the loss of power. Chinshan plant will proceed the operation according to the strategy URG CS.1-03.

Radioactive liquid release

- (1) The possible release route of the radioactive fluids

The radioactive materials could be drained into the plant sumps and then overflow. The first and second floors of the plant buildings could be flooded and the liquid overflows the buildings into the sewer. The liquid could permeate into the service water conduits with cracks of the bottom level. All of them finally flow into the ocean through the exit of cooling service water of the plant.

According to the procedure 912, the release of the waste water should be stopped immediately while earthquakes and commands received. The release can only be proceeded again if the waste system and waste water release routes are checked to be normal and guaranteed to be safe without any concerns.

- (2) Response plan

The evaluation of the impacts of the radioactive material release resulted from the accidents shows that the maximum storage for the waste fluids in Chinshan plant is 51,400 m³ for units #1 and #2. The EAT and NNERC are immediately notified. If necessary, NNERC coordinate radiation survey center to send professionals to the shore of the station for radiation monitor.

Kuosheng NPP

Once a severe accident occurs, the management and limitation of radioactive releases of Kuosheng NPP could be divided into two portions, radioactive gas release and the radioactive liquid release, which are described as follows:

Radioactive gas release

- (1) Under normal condition, primary containment may enclose the radioactive substance by automatic isolation function. It can prevent fission product release during the accident period and guarantee that the off-site dose will not exceed the regulation of 10CFR 100.
- (2) According to EOP, the primary system shall be isolated if plant boundary radiation rate over 0.02 mSv/hr in an accident. During the SAG phase, the HVAC must be confirmed isolated and SBGTS must be started to effectively filter the radioactive materials per SAG-2 “secondary containment / radiation release” if the HVAC radiation intensity of secondary containment over 0.15 mSv/hr (corresponding to Noble Gas channel: When 5.87×10^5 CPM).
- (3) During the EOP/SAMG phase, the containment at high pressure or high hydrogen concentration may be possibly failed to suppress the pressure induced from RPV energy blowdown. The EOP/SAMG requires to vent the primary containment to assure the integrity and avoid the large radioactive gas release.
- (4) In case of the multiple-disaster accident similar to the Fukushima event, the vent system of containment is anticipated to be possibly failure due to loss of power. Based on the planned URG “containment control (including off-gas, heat removal, and hydrogen control)”, Kuosheng NPP will prior open the motor-driven isolation valve inside primary containment and turn off the power when power is still available. The isolation valve outside containment is a pneumatic valve and it is actuated by backup nitrogen gas or manual operation for containment venting. The integrity of primary containment could be ensured and the large radioactive gas release would be avoided. Also, Kuosheng NPP has included the SGTS power source supply into the restore-items at the first priority. The venting and filter functions of containment can be recovered as soon as possible.

Radioactive liquid release

- (1) A leakage from the damaged ACST on the ground. Its full-water level volume is approximately 1,325 m³. The activity concentration is approximately 2.2×10^5 Bq/m³.
- (2) Spent fuel pool is located at the ground floor in the independent fuel building. The water leaks are only spread within the first and second floors of the fuel building. The activity concentration of fuel pool water is approximately 1.0×10^7 Bq/m³.
- (3) For the worst case, loss of core water and the integrity of primary containment (cracked, piping penetrations worn-out or damaged, or pipe break), the core water flows to the first to second floors of auxiliary building. The activity concentration and volume of drainage water may be reasonably assessed by means of observing the leakage of pipeline, the increase of radiation level, and the rising of sump water level.

Maanshan NPP

Current situation

- (1) For the releases from the containment

In Maanshan SAMG, for mitigating radioactive release, FP Release Mitigation (SCG-1), FP Release Reduction (SAG-5), Containment P/T Control (SAG-6), and Containment Flooding (SAG-8) are identified. For prevention of large radioactive release from containment failed at overpressurization, Containment Depressurization (SCG-2), Hydrogen Control inside Containment (SCG-3), and Containment Vacuum Control (SCG-4), Containment P/T Control (SAG-6), and Hydrogen Management inside Containment (SAG-7) are identified. The corresponding equipment installed include containment fan cooler, containment spray, low volume purging system, post-accident hydrogen purge system (PAHPS), and hydrogen recombiner. The measures for hydrogen

management are to dilute the hydrogen inside containment by steam release from PZR PORVs or vent valves on the vessel top, to ignite the hydrogen with a spark, and to vent the containment through low volume purging system and/or PAHPS. The measures for containment vacuum control are to open PZR PORVs and/or vent valves on the vessel top.

(2) For the releases from the steam generators

In Maanshan SAMG, for mitigating radioactive release, FP Release Mitigation (SCG-1), S/G Injection (SAG-1), and FP Release Reduction (SAG-5) are identified. The strategies are trying to fill the steam generators with water, isolate the affected steam generator and release the steam from the affected steam generator to the condenser, atmosphere instead.

(3) For the releases from auxiliary building

In Maanshan SAMG, for mitigating radioactive release, FP Release Mitigation (SCG-1) and FP Release Reduction (SAG-5) are identified.

The improvements after Fukushima accident

In case of multi-event accidents occur in Maanshan NPP, the on-site electrical AC and DC power are possibly unavailable and all the aforementioned measures for reducing FP releases are thus not functional. Therefore, Maanshan is establishing the URG and a draft have been issued. The corresponding URG strategies are as follows:

(1) Containment depressurization (a guideline in URG)

(2) Containment injection (a guideline in URG)

In order to ensure the vessel bottom covering with water while vessel experiences failure, a guideline in URG is established to inject water into containment to flood the reactor pit. In addition, the falling debris can be immediately cooled and the fission products can be scrubbed by water.

(3) AC power recovery (guidelines in URG)

The URG strategies can be carried out in 60.2 hours so that cliff-edge effect of radioactive releases can be avoided.

Lungmen NPP

Once a severe accident occurs, the management and limitation for gas and liquid radioactive releases in Lungmen NPP are respectively described as the following:

1. Radioactive gas release

Under normal condition, primary containment may enclose the radioactive substance within containment by designed automatic isolation function to prevent from fission product release during an accident, and assure that the off-site radiation dose will not exceed the regulation limit of 10CFR100.

If plant boundary radiation dose rate achieved 0.1 mSv/hr after the accident occurred, the station shall carry out all relevant isolations to isolate all leakages according to EOP procedure 584 “ Radiation release control”. If the accident conditions worsen to the extent for the need of entering SAG and Secondary Containment RBSCHV Exhaust radiation intensity or Refueling Floor radiation intensity exceeded 0.21mSv/hr, the station shall confirm if RBSCHV is isolated or not and start SGT to effectively filtrate radioactive material.

If containment is subject to high pressure and high hydrogen concentration or containment is unable to withstand the RPV energy-blowdown so that containment might be failed

(containment pressure suppression capability)during the executing process of EOP/SAMG rescue actions, the station shall force to carry out containment exhaust (its operation process please refer to URG attachment LM.1-07 Primary Containment Exhaust operating procedure) according to EOP/SAMG in order to assure the integrity of primary containment and thus avoid uncontrollable radioactive gas release to the environment.

In case of the multiple disaster similar to the Fukushima accident occurs and it is anticipated the containment inerting/ exhaust system may loss its intended function due to power loss, the programmed URG phase-1 strategy LM.1-07 “Primary Containment Exhaust Operation Procedure” and phase-2 strategy LM.2-02 “Secondary Containment Exhaust Operation Procedure” shall be implemented. The station has already incorporated SGTS power supply into priority restore item in order to rapidly restore containment exhaust and filtration operability.

2. Radioactive liquid release

In an accident, the possible radioactive liquid release will first flow into plant building sump and then overflow, or the worst case is that the liquid release submerges into the first and the second floors in the building and then further overflows outside the building and flow into station district rain-water sewers or sink into the bottom layer sea-water draining tunnel which has crack. Above-mentioned release will flow into the sea via the station cooling sea-water outlets

As per procedure 913, the release of the waste water should be stopped immediately while earthquakes and commands received. The release can only be proceeded again if the waste system and waste water release routes are checked to be normal and guaranteed to be safe without any concerns. It is assessed that the largest waste liquid storage space of the station is 17,968 m³

TPC Nuclear Emergency Planning Executive Committee and Central Disaster Response Center shall be immediately reported. If necessary, Central Disaster Response Center shall coordinate with Radiation Detection Center to dispatch the specialists to the monitoring station on the coast to enhance the detection.

Lungmen plant has completed specifications in the procedures for entering the plant, radiation protection and control, and supporting manpower in the emergency repairs. Some special professionals may be needed in the compound disasters. To the extent possible, these professionals are enrolled in the working team in advance and the repair operations are performed according to the existing procedures.

Considering the emergency conditions of the timing effectiveness of the rescue, those who are not enrolled in advance, will be instructed by HPC staff for 5~10minutes before performing their tasks. The contents provided by the HPC staff include the safety of repairing under radiation, the regulation stipulations of emergency exposure, the risks of receiving radiation, the status of on site radiation condition, and the alarming values of radiation does. They will perform their work after signing the permission of receiving the does. They are accompanied by HPC staff to the site and are notified the caution notes of the corresponding radiation protection.

Before the rescue staff entering the radiation quarantine, every rescue worker is issued a badge and an auxiliary dose alarming meter from HPC staff, and is instructed for how to wear the radioactive protection clothes, how to utilize the radiation protective equipment, etc. After rescue, they are helped by health physics staff, and go to the specified temporary controlled stop for whole body contamination detection and removal. According to their received does, implement necessary dose inspection and medical care to assure the radioactive safety of the rescue staff.

6.5 Accident management measures for loss of cooling of spent fuel pools

6.5.1 Lost of adequate shielding against radiation

Chinshan NPP

In CSNPP, adequate shielding against radiation is defined as 10 ft. water level remained above top of active fuel (TAF).

1. Before losing adequate shielding against radiation

The spent fuel located on the 5th floor of reactor building is accessible. The new spent fuel pool cooling system with a 480V mobile generator could be used to recover spent fuel pool cooling function. In addition, the spent fuel pool water could be made up by the following approaches:

- (1) Backup Containment Spray System (BCSS) through RHR system piping using water reservoir car engine or mobile fire pump.
- (2) Fire hose from fire hydrants (normal capacity is 3,600 MT, can be connected to two 3,000 MT tanks backed up by a 100,000 MT water pool) on the 5th floor of reactor building.
- (3) Raw water can be provided to DST through make-up demineralizer branch piping by gravity. The power supply of DST pump can be connected to a 480V mobile generator to MCC 1A-2 or 2A-2. The water can be pumped to the spent fuel pool overflow buffer tank or directly to spent fuel pool by using temporary hose through Service Box.
- (4) One seismic grade standby hard type firefighting make-up piping and one spray piping are installed to provide 500gpm make-up water and 200gpm spray water to spent fuel pool, respectively, using reservoir car engine or mobile fire pump.

2. After losing adequate shielding against radiation

Since the spent fuel pool couldn't be accessed under this situation, "using fire hose from fire hydrants" (Approach (2)) and "using temporary hose through Service Box" (Approach (3)) cannot be conducted. But the rest approaches can still be used to provide water makeup.

Kuosheng NPP

1. Before loss of adequate shielding against radiation:

Judging from the condition of power supply and water supply availability, the spent fuel pool cooling or water makeup will be used in accordance with case 1 described in the Ultimate Response Guideline attachment 13.

2. After loss of adequate shielding against radiation:

In case of inaccessibility of the spent fuel pool floor with power supply available, the spent fuel pool cooling or water makeup in accordance with cases 1~4 as described in the Ultimate Response Guideline attachment 13 should be carried out. Otherwise, the spent fuel pool cooling or water makeup by means of the new added injection or spray piping located in Fuel Building in accordance with cases 5~6 as described in the Ultimate Response Guideline attachment 13 should be performed.

Maanshan NPP

In Maanshan plant's certificate, the appropriate radioactive shield of the spent fuel pool is defined as 10 feet's above TAF.

1. Before loss of adequate shielding against radiation:

Procedure 597.1 “The procedure of recovering the spent fuel pool's cooling capability” decides the appropriate strategy of evacuating the staff according to the dose rate of measured radiation under loss of cooling capability of the spent fuel pool

According to the procedure 597.1, it is required by the procedure 366.1 “The water replenishing, draining and filtering of the spent fuel pool” to seek the water sources and routes to replenish water to spent fuel pool to the normal level (EC-LI109 > 34.88%, > 142'10"). The available replenishing routes are:

- (1) Replenish water from Demineralizer Water Storage Tank (DST). The storage capacity is 100,000 gallons, water replenishing flow rate is 215gpm. If there are requirements of replenishing the boric acid water, the water will be replenished by the fuels' Replacement Water Storage Tank (RWST) via water cleaning system. The boron density of the boric acid water of RWST is 2400~2500ppm, the storage capacity is 460,000 gallons, water replenishing flow rate is 100gpm.
- (2) Replenish water by Condensate Storage Tank (CST) (It is a seismic category I tank with storage capacity 750,000 gallons). There are two independent seismic category I CST transporting pumps (210gpm each).

All the actions described in procedure 597.1 required power supplies. If all the AC power and water heat sink are lost, the plant will lose its rescue capability of cooling the spent fuel pool.

2. After the loss of appropriate radioactive shields

If appropriate radioactive shields are lost, the spent fuel pool floor or fuel building will be inaccessible. This condition is beyond current procedure 597.1. Possible additional provision will be described in section 6.5.5.

Lungmen NPP

1. before loss of adequate shielding against radiation:

Judging from the condition of power supply and water supply availability, the station shall follow measures described in URG appendix LM.SFP.1-04 & LM.SFP.2-01 to carry out the spent fuel pool cooling or water makeup.

2. After loss of adequate shielding against radiation:

In case that personnel can't access the spent fuel pool after loss of adequate shielding against radiation, the station shall follow operation processes described in URG appendix LM.SFP.1-01~03 to carry out the spent fuel pool water makeup or spray by ways of its dedicated water makeup or spray piping.

6.5.2 Uncover of the top of fuel in the fuel pool

Chinshan NPP

1. Before uncovering of the top of fuel in the SFP

Same approaches as described in “Loss of adequate shielding” item 1 will be executed if the spent fuel pool is accessible. Otherwise, the approaches described in “Loss of adequate shielding” item 2 will be executed. In addition, if the water level is expected to

be lower than the top of fuel in the SFP, the seismic grade standby hard type firefighting make-up piping and the spray piping (as mentioned in “Loss of adequate shielding”, Item 1 approach (4)) will be set up immediately.

2. After uncovering of the top of fuel in the SFP

In addition to the implementation of the same action as described in “Loss of adequate shielding” item 2, the seismic grade standby hard type firefighting make-up piping and the spray piping (as mentioned in “Loss of adequate shielding” Item 1 approach (4)) will be setup immediately.

Kuosheng NPP

1. Before the water level of the spent fuel pool drop to the top of fuel element:

- (1) If the spent fuel pool floor is accessible, the management measure is the same as “Loss of adequate shielding” item 1.
- (2) If the radiation dose is too high to access the spent fuel pool floor, the management measure is the same as “Loss of adequate shielding” item 2.

2. After the water level of the spent fuel pool drop to the top of fuel element:

If the radiation dose is too high to access the spent fuel pool floor, the management measure is same as “Loss of adequate shielding” item 2.

Maanshan NPP

The management measure is the same as 6.5.1.

Lungmen NPP

1. Before the water level of the spent fuel pool drop to the top of fuel assemblies:

If the change of radiation condition is not too much and the personnel can still access the fuel pool, the management measure is the same as 6.5.1 item 1 “Before loss of adequate shielding against radiation”.

2. After the water level of the spent fuel pool drop to the top of fuel assemblies:

If the radiation dose is too high and the personnel can’t access to the fuel pool, the management measure is same as 6.3.1.1 item 2 “After loss of adequate shielding against radiation”.

6.5.3 Occurrence of fuel degradation in the fuel storage facility

Chinshan NPP

The same actions as described in “Uncover of the top of fuel” item 2 will be performed. In addition to that the hydrogen concentration will be monitored to avoid large scale hydrogen combustion or explosion. CSNPP has implemented an additional URG procedure (1451) to setup backup power supply, water and air sources to protect the fuel assembly.

Kuosheng NPP

1. Before severe damage of the fuel in the spent fuel pool:

If the spent fuel pool floor is accessible, the management measure is the same as “Loss of adequate shielding” item 1.

2. After severe damage of the fuel in the spent fuel pool:

If the radiation dose is too high to access the spent fuel pool floor, the management measure is same as “Loss of adequate shielding” item 2.

Maanshan NPP

Since the chemical reaction of zirconium and water or zirconium's oxidation will produce large quantity of heat and hydrogen, the temperature of spent fuel will be raised up aggravatingly and the risk of hydrogen explosion could not be ignored under this situation (the explosion is likely to happen as the hydrogen concentration reach to $>4\%$).

If the spent fuel pool floor or fuel buildings are inaccessible and procedure 597.1 couldn't cope with these circumstances, possible additional provisions are described in section 6.5.5.

Lungmen NPP

1. before severe damage of the fuel in the spent fuel pool:

If the change of radiation condition is not too much such that the personnel can still access the fuel pool, the management measure is the same as 6.3.1.1 item 1 “Before loss of adequate shielding against radiation”.

2. after severe damage of the fuel in the spent fuel pool:

If the radiation dose rate is too high for personnel to access the fuel pool, the management measure is the same as 6.3.1.1 item 2 “After loss of adequate shielding against radiation”.

6.5.4 Risks of cliff edge effects and deadlines

Chinshan NPP

According to the result of analysis, which assumes that all core fuel is discharged to SFP on the 7th day of outage and the initial temperature of SFP is 30°C , SFP will boil after 11.2 hours, the water level will drop below “10 ft. Above TAF” after 2 days, and the water level will drop below TAF after 3.3 days.

Kuosheng NPP

Taking unit 1 EOC-21 outage maintenance as an example, which assumes the decay heat of the full spent fuel (624 pieces) removed from core to SFP on the tenth day of outage, the total decay heat of 160 pieces of spent fuels is estimated approximately to be 6.6MW. SFP will boil after 20.4 hours, the water level will drop below “8ft. above TAF” after 99 hours, and the water level will drop below TAF after 132.4 hour. Moreover, the initiate degradation time of the fuel is 147.4hr.

Maanshan NPP

According to the result of analysis, which assumes that all core fuel is discharged to SFP on the 7th day of outage, the water will boil after 11.23 hours, the water level will drop below “10 feet's above TAF” after 56 hours, reach the TAF after 84.4 hours. The fuel will be heated to 600°C at 8.5 hours after fuel starts to be uncovered, and if situation continues (no replenishing water), the fuels will reach 1200°C at 18.6 hours after fuel starts to be uncovered.

Lungmen NPP

The decay heat of the spent fuel decreases as the unit shutdown time increases. During the

specific fuel cycle, the decay heat in the spent fuel pool is the maximum if all core fuel is transferred to the spent fuel pool in the shortest time after unit shutdown. The station is under construction and has no spent fuels yet. The decay heat of the spent fuel is calculated based on the assumptions that spent fuels are discharged into the pool from last 9 cycles and all core fuels are discharged after 7 days of unit shutdown. The total decay heat at this moment is 12.88MW and the temperature of fuel pool water is 49°C.

1. Cliff-edge time under the conditions of loss of spent fuel pool cooling and water makeup:
 - The time to boiling: 9.5 hrs
 - Time of water level drop to the level (8 feet above TAF) which cannot maintain adequate shielding against radiation: 52 hrs
 - Time of water level drop to the top of active fuel elements: 91 hrs
 - Time of beginning of the fuel degradation (1200°C): 98.3hrs [note]

Note: The spent fuel pool is arranged in a tight sequence.

2. Effectiveness of the existing management measures

Based on the above-mentioned analysis under the most severe condition (all spent fuels are discharged in the spent fuel pool at the seventh days of outage after unit shutdown), fuels will not start to degrade till 98.37 hrs (about 4 days) after loss of spent fuel pool cooling and water makeup. Therefore, the station has enough time to restore the power supply or to prepare the alternative power supply to provide the power for restoring spent fuel pool cooling or water makeup. In case adequate radiation shielding is lost or high temperature is encountered at site, the station will be able to carry out spent fuel pool water makeup or spray through its dedicated water makeup or spray piping from various alternative water sources (fire water, CST water sources etc.) outside the building so as to effectively avoid the cliff-edge effect of fuel damage.

6.5.5 Adequacy of the existing management measures and possible additional provisions

Chinshan NPP

SFP water can be made up by Condensate Storage Tank (CST) or Demineralizer Water Storage Tank (DST) in an emergency. During outage, the SFP is open to reactor cavity, SFP water can be made up from Backup Containment Spray System (BCSS) through RHR system piping using water reservoir car engine or mobile fire pump, or using fire hose from fire hydrants located on the 5th floor of the reactor building. It can effectively maintain the safe state of SFP.

Hydrogen detectors have not been installed inside reactor building (Secondary containment). In case a small amount of hydrogen accumulated at an area in the building, this hydrogen can be diluted and vented if the Reactor Building Ventilation system or Standby Gas Treatment system (SBGT) are still operable.

Kuosheng NPP

Under the most serious condition as analyzed in section 5.2.3.3 (all spent fuels of 624 pieces are pulled out and stored in the spent fuel pool at the tenth day after outage), fuels will not start to degrade till 147.4 hrs (6 days). Therefore, KSNPP has enough time to restore the power supply or to prepare the alternative power supply to provide the power for restoring spent fuel pool cooling or water makeup capability. Furthermore, because the spent fuel pool

is located on the ground floor in the Fuel Building, KSNPP may dispatch personnel to the site to carry out the spent fuel pool cooling or water makeup by means of fire water, water pump, firefighting engine.

In case adequate radiation shielding is lost or high temperature is encountered at site, KSNPP may proceed spent fuel pool makeup or spray by means of the setup of the fire water pipes located in the northern wall in the Fuel Building and take water from miscellaneous water sources (firefighting water, CST) from outside of Fuel Building, to avoid the risks of cliff edge effects of fuel damage.

Maanshan NPP

The URG procedure 1451 is issued to provide the corresponding procedures to maintain the fuel integrity and arrange the available water source in the shortest time under the loss of cooling capability of spent fuel pool.

Every rescue stage planned by URG according to the water levels of spent fuel pool is explained as follows:

- (1) Before losing appropriate radioactive shield:
Under this circumstances, the adoptable measures can be referred to 5.2.3.3, 5.2.3.4 and 5.2.3.5.
- (2) After losing appropriate radioactive shield:
Under this circumstances, the reserved external water replenishing measures must be adopted:
 - a. Refer to item 8 of 5.2.3.5, utilize the fire engine or outdoors fire hydrant via fire hose connecting to the standby hard replenishing pipe outside the plant to precede the water replenishing of the fuels pool.
 - b. Refer to item 9 of 5.2.3.5, utilize the fire engine or outdoors fire hydrant via fire hose connecting to the standby hard replenishing pipe outside the plant to spray the fuels pool and also replenish water to spent fuel pool.
- (3) Before water level lowered to the top of the fuel bundles:
Adopt the same measure as “Loss of adequate shielding” item 1.
- (4) After water lowered to the top of the fuel bundles:
Under this circumstances the radiation dose rate is too high to access the spent fuel pool floor, the management measures are the same as “Loss of adequate shielding” item 2.
 - a. When the fuels start to be uncovered, the item 8 of 5.2.3.5 strategy is adopted. The water replenishing volume is 500gpm and the water level can be recovered to the original height after 6.8 hours.
 - b. If the water replenishing strategy cannot be carried out or the structure of the spent fuel pool is damaged so that the water level can not be built up, the item 7 of 5.2.3.5 strategy is adopted. The water spraying volume is 200gpm and the water level can be recovered to the original height after 20 hours.
 - c. If the spray strategy can not recover the water level, the water should be sprayed immediately when temperature reaches 600°C according to the INER's heat and flow analysis.
- (5) Before the serious damage of spent fuel pool
Adopt the same measure as “Uncover of the top of fuel” and continuously replenish and spray on the spent fuel pool.

- (6) After the serious damage of spent fuel pool in this circumstance, all means must be done to reduce the fuels temperature and restrain the release of the radioactive materials. At the same time, the hydrogen concentration in the spent fuel pool building must be monitored, and the hydrogen control strategy must be adopted to avoid the over accumulation of hydrogen. According to this, Maanshan plant has provided an improvement project of hydrogen concentration monitor system in the spent fuel pool of fuels factory building (M1-4286/M2-4287).

According to the request from URG, after two hours of Ultimate Response Maanshan plant will complete the arrangement of the strategy 「MS.2-05 urgent water replenishing/spray of the spent fuel pool」 in two hours. Considering the fuel uncovering time 84.4 hours mentioned above, Maanshan has sufficient capability to avoid the situation of cliff-edge effect.

Lungmen NPP

The residual heat removal and water makeup of the Spent Fuel Pool during normal operation is by ways of Fuel Pool Cleanup System (FPCU) and it can also use Residual Heat Removal System as alternative fuel pool cooling system. The Spent Fuel Pool is designed to make up water can also be used from Suppression Pool Cleanup System (SPCU) and Condensate Transfer System (CSTF) and to make up water by ways of RHR system or fire water system in case of emergency. The detailed design of its related power supply is described in the section 2 of chapter 5.

In order to deal with various compound disaster conditions, the station has already programmed the spent fuel pool emergency water makeup processes and the cooling or water makeup methods according to different conditions in the station procedure 510.05 “Loss of Spent Fuel Pool Cooling and Cleanup” and procedure 1451”Ultimate Response Guideline”.

The major response measure for the spent fuel pool is to set up its water makeup measure to avoid loss of pool water. If fuel pool only loses its cooling function and there is no obvious water level drop, it shall have sufficient time to take the relevant rescue action strategies and arrangements as per the analysis results of Computational Fluid Dynamics (CFD), the station shall carry out the relevant measures as per procedure 515.05 “Loss of spent fuel pool cooling and cleanup” and there is no need to take URG.

The spent fuel pool cooling and water makeup in accordance with different conditions is described as follows:

If Fuel Pool water level drops after accident, the station shall carry out Spent Fuel Pool emergency water makeup/spray measures. Depending on the station status the arrangement of the phase-1 strategies shall be completed within 2 hours and those of the phase-2 strategies shall be completed within 8 hours.

The phase-1 Spent Fuel Pool emergency water makeup / spray measures in URG:

- LM.SFP.1-01 RB Spent Fuel Pool water makeup by ways of outdoor fire hydrant
- LM.SFP.1-02 RB Spent Fuel Pool water makeup by ways of fire water tanker operation guideline.
- LM.SFP.1-03 RB Spent Fuel Pool water makeup by ways of engine-driven fire water pump operation guideline.
- LM.SFP.1-04 RB 7F Spent Fuel Pool water makeup by ways of indoor fire hydrant operation guideline.

The phase-2 spent fuel pool emergency water makeup / spray measures in URG:

- LM.SFP.2-01 RB Spent Fuel Pool water makeup by ways of FPCU and CSTF pumps operation guideline.

6.6 Assessment and conclusions of the regulatory body

Procedures, training and exercises

1. AEC required TPC to combine the additional equipment and operations into the procedures or guideline;
2. AEC required TPC to re-evaluate the feasibility of EOPs and SAMGs with the involvement of new procedures/guidelines;
3. AEC required TPC to ensure that the SAMGs are appropriate for multi-unit events and to promote them from guidelines to procedures if required;
4. AEC required TPC to strength SBO mitigation at operating reactors for design basis and beyond design basis external events;
5. AEC required TPC to improve the emergency preparedness staffing and communications per NRC NTTF report.

The establishment of URGs

TPC needs to identify the URG and its implementation timing, the subsequent measures and monitoring strategy after implementing URG, including the monitor of radioactive releases, backup ability of present systems and equipment, etc.

Multi-event accidents

AEC required TPC to estimate the duration of independent response capability for various severe accidents, beyond design accidents, and multi-event accidents. The materials and equipment in contracting the off-site supports should also be identified.

The improvement of main control room in case of a beyond design basis accident

AEC required TPC to:

1. Ensure the capability of DC power for instrumentation and control systems of MCR, TSC, backup TSC, etc. in case of monitoring unit conditions during SBO accidents. The duties, associations, and implementations of these staff should also be identified;
2. improve the seismic level of MCR, TSC, backup TSC, and their equipment;
3. Assess the adequacy of MCR human arrangement in case of multi-unit events.

Design and reliability of containment hardened vent with filters (only for Chinshan NPP)

Per the recommendation item 5.1 in USNRC NTTF report, AEC recommended TPC to add a robust and reliable containment system in Chinshan NPP (Mark-I), in which the hardened vent and filters are involved, for long-term operations in case of extended SBO accidents. The drywell or wetwell hardened vent system shouldn't be shared with the other units. The hardened vent system will be able to operate either with electrical power or manual operation.

Improvements and integration of EOPs, SAMGs and EDMGs

Per the recommendation item 8 in USNRC NTTF report, AEC recommended TPC to:

1. integrate EOPs, SAMGs, and EDMGs;
2. identify the commands and control strategies of implementations;
3. AEC referred the nuclear industry's response to the Fukushima accident and required TPC to finish the regulatory document:

The current procedure is designed for full power condition, which cannot cover the conditions of low power and shutdown. Each nuclear power plant should prepare the response action before revision of current SAMG.

4. Provide appropriate training and qualification to the decision-maker.

AEC also required TPC to involve the URG into the integration of EOPs, SAMGs, and EDMGs if URG is available.

Spent fuel pool

AEC required TPC to enhance the spent fuel pool instrumentation per NRC NTTF report.

Abbreviations

ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
ACB	Access Control Building
ACIWA	AC- Independent Water Addition
ACS	Atmosphere Control System
ACST	Auxiliary Condensate water Storage Tank
ADS	Automatic Depressurization System
ADSL	Asymmetric Digital Subscriber Line
ADST	Auxiliary Demineralizer Water Storage Tank
AEC	Atomic Energy Council
AFB	Auxiliary Fuel Building
AFP	Auxiliary Feedwater Pump
AFPC	Auxiliary Fuel Pool Cooling and Cleanup
AFW	Auxiliary Feedwater
AFWP	Auxiliary Feedwater Pump
AMT	Accident Management Team
AOP	Abnormal Operating Procedure
AOV	Air Operated Valve
ARI	Alternate Rod Insertion
ARM	Area Radiation Monitor
ASME	American Society of Mechanical Engineers
ASP	Alternate Shutdown Panel
ASTS	Automatic Seismic Trip System
ATWS	Anticipated Transient Without Scram
BCSS	Backup Containment Spray System
BDB	Beyond Design Basis
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owner's Group
CB	Control Building
CCP	Component Cooling Pump
CCW	Component Cooling Water
CDF	Core Damage Frequency
CDRC	Central Disaster Response Center
CFD	Computational Fluid Dynamics
CGS	Central Geological Survey
CHT	Chunghwa Telecom
CLB	Current Licensing Basis
COPS	Containment Overpressure Protection System
CSCW	Combination Structure Cooling Water System
CST	Condensate Storage Tank
CSTF	Condensate Storage and Transfer System
CTMT	Containment
CVCF	Constant Voltage. Constant Frequency.
CW	Circulating Water
CWB	Central Weather Bureau
CWP	Circulating Water Pump
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DECT	Digital Enhanced Cordless Telecommunications

DG	Diesel Generator
DST	Demineralized Water Storage Tank
EAT	Emergency Action Team
ECCS	Emergency Core Cooling system
ECHW	Emergency Chilled Water System
ECT	Emergency Control Team
ECW	Emergency Circulating Water System
ECWP	Emergency Circulating Water Pump
ECWS	Emergency Chilled Water System
EDG	Emergency Diesel Generator
EDMG	Extreme Damage Mitigation Guidelines
EEC	Emergency Execution Commission
EHV	Extra High Voltage
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedure
EPD	Environmental Protection Dosimeter
EPIC	Emergency Public Information Center
EPRI	Electric Power Research Institute
ERF	Emergency Response Facility
ESF	Engineered Safety Feature
ESW	Essential Service Water System
FCP	Forward Command Post
FCS	Flammable Gas Control System
FP	Fission Product
FPC	Fuel Pool Cooling Mode
FPCU	Fuel Pool Cooling and Cleanup System
FPH	Fire Pump House
FSAR	Final Safety Analysis Report
FWIV	Feedwater Isolation system
GE	General Electric Company
GTG	Gas Turbine Generator
GV	Governor Valve
HCLPF	High Confidence and Low Probability of Failure
HCU	Hydraulic Control Unit
HIS	Hydrogen Ignition System
HOMS	Hydrogen/Oxygen Monitoring System
HPC	Health Physics Center
HPCF	High Pressure Core Flooder
HPCI	High Pressure Coolant Injection System
HPCS	High Pressure Core Spray
HPME	High Pressure Melt Ejection
HVAC	Heating, Ventilating and Air Conditioning
INER	Institute of Nuclear Energy Research
ISFSI	Independent Spent Fuel Storage Installation
JSCE	Japan Society of Civil Engineers
KK	Kashiwazaki-Kariwa
LC	Load Center
LDF	Lower Drywell Flooder
LERF	Large Early Release Frequency
LFAP	Local Fire Alarm Panel
LMNPP	Lungmen Nuclear Power Plant
LOCA	Loss-of-Coolant Accident
LOOP	Loss of Offsite Power

LOUH	Loss of sea water Ultimate Heat sink
LOV	Loss of Voltage
LPCI	Low Pressure Coolant Injection system
LPCS	Low pressure core spray
LPFL	Low Pressure Flooder
MAAP	Modular Accident Analysis Program
MCC	Motor Control Center
MCCI	Molten Core Concrete Interaction
MCI	Melt-Concrete Interactions
MCR	Main Control Room
MDAFP	Motor Driven Auxiliary Feedwater Pump
MFAP	Main Fire Alarm Panel
MHI	Mitsubishi Heavy Industries
MMCS	Maintenance Management Control System
MMI	Modified Mercalli Intensity
MOV	Motor Operated Valve
MSIV	Main Steam Isolation Valve
NCCW	Nuclear Component Closed Cooling Water System
NCD	Nonconformance Notice Quality Document
NCO	Niigata-ken Chuetsu-Oki
NEI	Nuclear Energy Institute
NEPEC	Nuclear Emergency Planning Executive Committee
NIS	Nuclear. Instrument System
NISA	Nuclear and Industrial Safety Agency
NPB	Non-segregated Phase Bus
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NSC	National Science Council
NSCW	Nuclear service cooling water system
NSSS	Nuclear Steam Supply System
NTTF	Near-Term Task Force
OBE	Operating Basis Earthquake
OSC	Operation Support Center
PA	Peak Acceleration
PAHPS	Post-Accident Hydrogen Purge System
PAT	Parameter Assessment Table
PCACS	Primary Containment Air Control System
PGA	Peak Ground Acceleration
PHS	Personal Handyphone system
PMP	Probable Maximum Precipitation
PORV	Power Operated Relief Valve
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
PZR	Pressurizer
RB	Reactor Building
RBCW	Reactor Building Cooling Water
RBSCHV	Reactor Building Secondary Containment Heating, Ventilation
RBSW	Reactor Building Service Water System
RBSWPH	Reactor Building Service Water Pump House
RCIC	Reactor Core Isolation Cooling
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System

RFP	Reactor Feedwater Pump
RHR	Residual Heat Removal
ROC	Republic of China
ROCAEC	Republic of China Atomic Energy Council
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRCS	Redundant. Reactivity Control System
RWCU	Reactor Water Cleanup System
RWST	Refueling Water Storage Tank
RWT	Refueling Water Tank
SAG	Severe Accident Guideline
SAMG	Severe Accident Management Guideline
SAP	Severe Accident Procedures
SBGT	Standby Gas Treatment
SBGTS	Standby Gas Treatment System
SBLC	Standby Liquids Control System
SBO	Station Black Out
SCG	Severe Challenge Guideline
SEDG	Swing Emergency Diesel Generator
SFP	Spent Fuel Pool
SFPACS	Spent Fuel Pool Additional Cooling System
SFPCS	Spent Fuel Pool Cooling System
SG	Steam Generator
SGT	Standby Gas Treatment
SGTS	Standby Gas Treatment System
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control
SMA	Seismic Margin Assessment
SOER	Significant Operating Experience Report
SOP	Standard Operating Procedure
SPCU	Suppression Pool Cleanup System
SPDS	Safety Parameter Display System
SPRA	Seismic Probabilistic Risk Assessment
SR	Safety Related
SREA	Safety-Related Equipment Area
SRV	Safety Relief Valve
SSC	Structures, Systems and Components
SSE	Safe shutdown Earthquake
SWBD	Switchboard
SWCB	Soil and Water Conservation Bureau
TAF	Top of Active Fuel
TBCW	Turbine Building Cooling Water
TBSW	Turbine Building Service Water
TDAFP	Turbine Driven Auxiliary Feedwater Pump
TPC	Taiwan Power Company
TSC	Technical Support Center
UPS	Uninterruptible Power Supply
URG	Ultimate Response Guideline
US	United States
USNRC	United States Nuclear Regulatory Commission
VSAT	Very Small Aperture Terminal
WANO	The World Association of Nuclear Operators
WOG	Westinghouse Owners Group

WRNM

Wide Range Neutron Monitor