Electrical Association

2020 NEC

Overcurrent Protection

Part 1

Presented by

Electrical Association

Acknowledgements

This educational offering is recognized by the MN Department of Labor & Industry as satisfying 2 hours of Code credit toward electrical continuing education requirements.

Please see the 2020 NEC® (NFPA 70) for complete review of code articles.

Comments in green text are interpretations by the Electrical Association.

Overcurrent Protection

Part One

2 hours

3

Art. 100 – Definitions

Overcurrent Protective Device, Branch-Circuit:

A device capable of providing protection for service, feeder, and branch circuits and equipment over the full range of overcurrents between its rated current and its interrupting rating.

Branch-circuit overcurrent protective devices are provided with interrupting ratings appropriate for the intended use but no less than 5,000 amperes.

4

Art. 100 – Definitions

Interrupting Rating:

The highest current at rated voltage that a device is intended to interrupt under standard test conditions.

IN: Equipment that is intended to interrupt current at other than faults levels may have the rating implied; such as horsepower of locked current ratings

5

Interrupting Rating

6

Electrical Association

If possible:

Show video of effects of non- current limiting and current limiting fuses on loose wire

Show video of misapplied IC rating

7

Art. 100 – Definitions

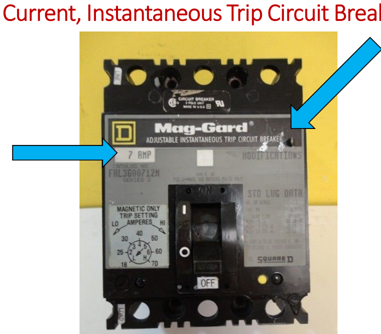
Circuit Breaker:
A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating. (won't be destroyed)

Circuit Breaker - Adjustable (as applied to CB): A qualifying term indicating that the circuit breaker can be set to trip at various values of current, time, or both, within a predetermined range.

Instantaneous Trip (as applied to CB): A qualifying term indicating that no delay is purposely introduced in the tripping action of the circuit breaker.

8

Adjustable Current, Instantaneous Trip Circuit Breaker



9

Art. 100 – Definitions

Inverse Time (as applied to circuit breakers): A qualifying term indicating that there is purposely introduced a delay in the tripping action of the circuit breaker, which delay decreases as the magnitude of the current increases. Higher current = shorter time to trip

Nonadjustable (as applied to circuit breakers): A qualifying term indicating that the circuit breaker does not have any adjustment to alter the value of current at which it will trip or the time required for its operation.

Setting (of circuit breakers): The value of current, time, or both, at which an adjustable circuit breaker is set to trip. Actual value of time and current to trip

10

Art. 100 – Definitions

Coordination (Selective):

Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings.

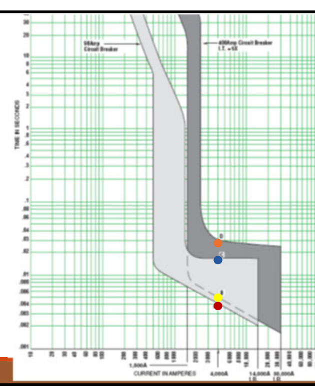
These apply to the full range of overcurrents from overload to full fault current, and the full range of opening times.

11

Selective Coordination

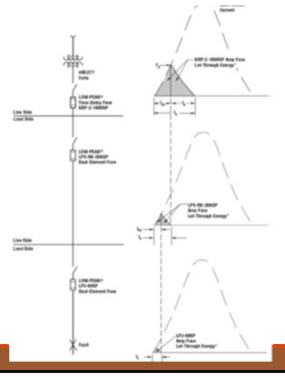
90-Amp Breaker downstream from a 400-Amp Breaker

- Point A – 90A starts to open
- Point B – 400A starts to open
- Point C – 90A breaks the circuit
- Point D – 400A breaks the circuit



12

Series Protection



Art. 100 – Definitions

Ground-Fault Protection of Equipment (GFPE):

A system intended to provide protection (to) of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit.

This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

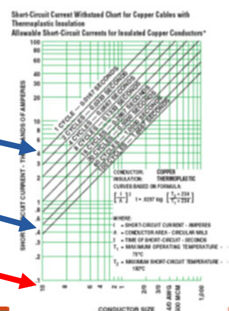
(Protects the equipment but not necessarily people)

Insulated Cable Engineers Association – Table

4000A 1 Cycle

400A 100 Cy

#10 Conductor

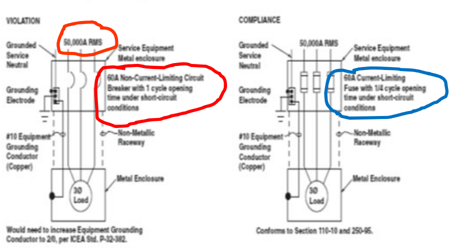


ICEA Table

Copper, 75° Thermoplastic Insulated Cable Damage Table (Based on 60 HZ)						
Copper Wire Size 75°C Thermoplastic	Maximum Short-Circuit Withstand Current in Amperes					
	1/8 Cycles*	1/4 Cycles*	1/2 Cycles*	1 Cycle	2 Cycles	3 Cycles
#14*	4,800	3,400	2,400	1,700	1,200	1,000
#12*	7,600	5,400	3,800	2,700	1,900	1,550
#10	12,000	8,500	6,020	4,300	3,000	2,450
#8	19,200	13,500	9,600	6,800	4,800	3,900
#6	30,400	21,500	16,200	10,800	7,600	6,200
#4	48,400	34,200	24,200	17,100	12,100	9,900

*Extrapolated data

Take the example below. The EGC must be protected from damage. It can withstand 4,300 amperes of current for 1 cycle. The 1 cycle opening time of the circuit breaker will cause damage to the #10 EGC. However, a current-limiting fuse will limit the current to within the withstand rating of the EGC. An LPS-RK60SP will limit the line to ground current to approximately 3300 amperes, providing protection.



Art. 100 – Definitions

Overcurrent Protective Device, Supplementary:

A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires and appliances.

This limited protection is in addition to the protection provided in the required branch circuit by the branch circuit overcurrent protective device.

(Not a substitution for branch circuit protection)

Over 1000 Volts, Nominal

Electronically Actuated Fuse:

An overcurrent protective device that generally consists of a control module that provides current sensing, electronically derived time–current characteristics, energy to initiate tripping, and an interrupting module that interrupts current when an overcurrent occurs.

Electronically actuated fuses may, or may not, operate in a current-limiting fashion, depending on the type of control selected.

19

Over 1000 Volts, Nominal

Fuse: An overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

Controlled Vented Power Fuse: A fuse with provision for controlling discharge circuit interruption such that no solid material may be exhausted into the surrounding atmosphere.

Expulsion Fuse Unit (Expulsion Fuse): A vented fuse unit in which the expulsion effect of gases produced by the arc and lining of the fuseholder, either alone or aided by a spring, extinguishes the arc.

20

Art. 240 Part IX Over 1000 Volts, Nominal

Non-vented Power Fuse:

A fuse **without** intentional provision for the escape of arc gases, liquids, or solid particles to the atmosphere during circuit interruption.

Vented Power Fuse:

A fuse **with** provision for the escape of arc gases, liquids, or solid particles to the surrounding atmosphere during circuit interruption.

21

Power Fuse Unit:

A vented, non-vented, or controlled vented fuse unit in which the arc is extinguished by being drawn through solid material, granular material, or liquid, either alone or aided by a spring.

22

Over 1000 Volts, Nominal

Multiple Fuse:

An assembly of two or more single-pole fuses.

23

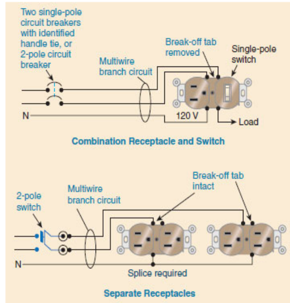
Wiring & Overcurrent Protection and the NEC®

24

210.4 Multiwire Branch circuit

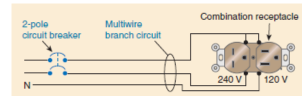
(A) General. A multiwire circuit shall be permitted to be considered as multiple circuits. All conductors of a multiwire branch circuit shall originate from the same panelboard or similar distribution equipment.

(B) Disconnecting Means. Each multiwire branch circuit shall be provided with a means that will simultaneously disconnect all ungrounded conductors at the point where the branch circuit originates.



210.4

(C) Line-to-Neutral Loads. Multiwire branch circuits shall supply only line-to-neutral loads.



The most commonly used multiwire branch circuit consists of two ungrounded conductors and one grounded conductor supplied from a 120/240-V, single-phase, 3-wire system.

Such multiwire circuits supply appliances that have both line-to-line and line-to-neutral connected loads, such as electric ranges and clothes dryers, or supply loads that are line-to-neutral connected only, such as the split-wired combination device shown in Exhibit 210.1 (shown above). A multiwire branch circuit is also permitted to supply a device with a 250-V receptacle (line-to-line) and a 125-V receptacle (line-to-neutral), as shown in Exhibit 210.2, provided the branch-circuit overcurrent device simultaneously opens both of the ungrounded conductors.

210.4

(D) Grouping. The ungrounded and grounded circuit conductors of each multiwire branch circuit shall be grouped as per Art 200.4 (by cable ties or similar means in at least one location within an enclosure)

Exception:
The requirement for grouping shall not apply if the circuit enters from a cable or raceway unique to the circuit that makes the grouping obvious or if the conductors pass through a box or conduit body without a loop, or without a splice or termination.

NEC® Article 240

240.2 Definitions

Supervised Industrial Installation. For the purposes of Part VIII, the industrial portions of a facility where all of the following conditions are met:

(1) Conditions of maintenance and engineering supervision ensure that only qualified persons monitor and service the system.

(2) The premises wiring system has 2500 kVA or greater of load used in industrial process(es), manufacturing activities, or both, as calculated in accordance with Article 220.

(3) The premises has at least one service or feeder that is more than 150 volts to ground and more than 300 volts phase-to-phase.

This definition excludes installations in buildings used by the industrial facility for offices, warehouses, garages, machine shops, and recreational facilities that are not an integral part of the industrial plant, substation, or control center.

240.4 (B) Overcurrent Devices Rated 800 Amps or Less (generally)

The next higher standard overcurrent device rating (above the ampacity of the conductors being protected) shall be permitted, provided all of the following conditions are met:

(1) (IF) The conductors being protected are not part of a branch circuit supplying more than one receptacle for cord-and-plug-connected portable loads. (Multi-receptacle branch circuits are not eligible for up sized OC protection)

AND

(2) (IF) The ampacity of the conductors does not correspond with the standard ampere rating of a fuse or a circuit breaker without overload trip adjustments above its rating. See Table 240.6 (but that shall be permitted to have other trip or rating adjustments). (lower trip adjustments)

AND

(3) The next higher standard rating selected does not exceed 800 amperes.

240.4(C)

(C) Overcurrent Devices Rated over 800 Amperes.
Where the overcurrent device is rated over 800 amperes, the ampacity of the conductors it protects shall be equal to or greater than the rating of the overcurrent device defined in 240.6.

(conductor-rated ampacity must meet or exceed the OC protection rating)

31

240.4(D) Small Conductors

Unless specifically permitted in 240.4(E) (tap conductors) or (G) (See Specific conductors: Table 240.4(G), the overcurrent protection shall not exceed that required by (D)(1)–(D)(7) (see NEC) **after any correction factors for ambient temperature and number of conductors have been applied.**

(Apply correction factors to the conductors, and then pick OC protection.)

32

240.4(D) Small Conductors

(1) **18 AWG** (7 amperes with restrictions)

(2) **16 AWG** (10 amperes with restrictions)

(3) **14 AWG Copper** (15 amperes)

(4) **12 AWG Aluminum** and **Copper-Clad Aluminum** (15 amperes)

(5) **12 AWG Copper** (20 amperes)

(6) **10 AWG Aluminum** and **Copper-Clad Aluminum** (25 amperes)

(7) **10 AWG Copper** (30 amperes)

33

240.5 Protection of Flexible Cords and Cables, and Fixture Wires

These wire shall be protected from overcurrent as in Art. 400.5(A) or (B)

(A) Ampacities for flexible cords and cables as per Table 400.4 (1) and (A)(2)
Ampacities for fixture wire as per Table 402.5
Supplemental protection as per 240.10

(B) Branch circuit overcurrent device - shall protect the branch circuit as in (B)(1-4) below.

1. Listed appliance or luminaire – use approved supply wires
2. Fixture wire: 20A – #18 for 50 ft; #16 for 100 ft, etc.
3. Extension cords – as listed
4. Field assembled extension cords: 20A – #16 or larger

34

240.6 Standard Ampere Ratings for Fuses and Inverse Time Circuit Breakers

Standard Ampere Ratings

15	20	25	30	35
40	45	50	60	70
80	90	100	110	125
150	175	200	225	250
300	350	400	450	500
600	700	800	1000	1200
1600	2000	2500	3000	4000
5000	6000	—	—	—

35

240.6 Standard Ampere Ratings

(B) Adjustable-Trip Circuit Breakers.

The rating of adjustable trip circuit breakers having external means for adjusting the current setting (long-time pickup setting), not meeting the requirements of 240.6(C), shall be the maximum setting possible.

36

240.8 Fuses or Circuit Breakers in Parallel

Fuses and circuit breakers shall be permitted to be connected in **parallel where they are factory assembled in parallel** and listed as a unit.

Individual fuses, circuit breakers, or combinations thereof shall not otherwise be connected in parallel.

37

240.9 Thermal Devices

Thermal relays and other **devices not designed to open short** circuits or ground faults **shall not be used for the protection of conductors against overcurrent due to short circuits** or ground faults, but the use of such devices shall be permitted to protect motor branch-circuit conductors from **overload** if protected in accordance with 430.40.

(motor overload relays)

38

240.10 Supplementary Overcurrent Protection

Where supplementary overcurrent protection is used for luminaires, appliances, and other equipment or for internal circuits and components of equipment, it shall not be used as a substitute for required branch-circuit overcurrent devices or in place of the required branch-circuit protection.

Supplementary overcurrent devices shall not be required to be readily accessible.

39

240.12 Electrical System Coordination

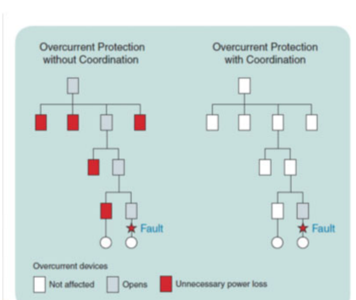
Where an orderly shutdown is required to minimize the hazard(s), a system of coordination based on the following two conditions shall be permitted:

(1) Coordinated short-circuit protection

(2) Overload indication based on monitoring systems or devices

40

Example of System Without & With Coordinated Protection



41

240.13 Ground-Fault Protection of Equipment

Ground-fault protection of equipment (GFPE)shall be provided for solidly grounded wye systems of **more than 150 V to ground but not exceeding 1000V phase-to-phase** for each device used as a building disconnecting means rated 1000 amps or more.

This section shall not apply to the disconnecting means for:

(1) Continuous industrial processes where a non-orderly shutdown will introduce additional hazards

(2) Installations where GFP is provided by other requirements for services or feeders

(3) Fire pumps

42

240.15 Ungrounded Conductors

(A) Overcurrent Device Required.
A fuse or an overcurrent trip unit of a circuit breaker shall be connected in series with each ungrounded conductor.
You may use a CT and an overcurrent trip relay in lieu of a fuse.

(B) Circuit Breaker as Overcurrent Device.
Circuit breakers shall open all ungrounded conductors of the circuit both manually and automatically. (See 1-4 following)

43

240.15(B) Circuit Breaker as Overcurrent Device

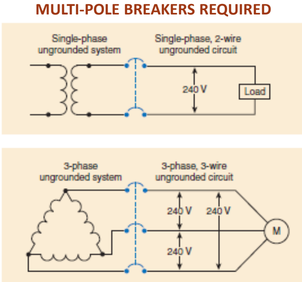
(1) Multiwire Branch Circuit.
Individual single-pole circuit breakers, with identified handle ties, shall be permitted as the protection for each ungrounded conductor of multiwire branch circuits that serve only single-phase line-to-neutral loads.
(Typically 120V loads)

(2) Grounded Single-Phase AC Circuits.
In grounded systems, individual single-pole circuit breakers rated 120/240 AC with identified handle ties shall be permitted as the protection for each ungrounded conductor for line-to-line connected loads for single-phase circuits. (Typically 240V loads)

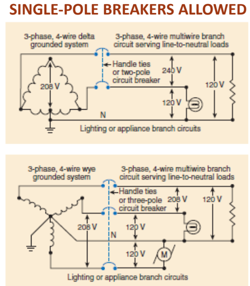
44

240.15(B)

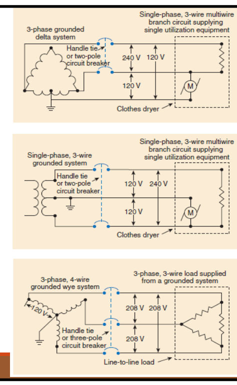
MULTI-POLE BREAKERS REQUIRED



SINGLE-POLE BREAKERS ALLOWED



45



HANDLE TIES REQUIRED

MULTI-POLE OR HANDLE TIES PERMITTED

46

240.15 Ungrounded Conductors

(3) 3-Phase and 2-Phase Systems:
In 4-wire, 3-phase, and 5-wire, 2-phase systems, individual breakers rated 120/240 with identified handle ties are permitted if the systems have a grounded neutral point and the voltage to ground does not exceed 120V. (Typically 120/208 V wye systems)

(4) 3-Wire DC Circuits:
Individual circuit breakers rated 125/250VDC with identified handle ties are permitted for 3-wire circuits to protect the line to line connected loads if there is a grounded neutral and the voltage to ground does not exceed 125V

47

Part II — 240.21 Location in Circuit

Overcurrent protection shall be provided in each ungrounded circuit conductor and shall be located at the point where the conductors receive their supply conductors receive their supply except as specified in 240.21(A)–(H).

Conductors supplied under the provisions of 240.21(A)–(H) shall not supply another conductor except through an overcurrent protective device meeting the requirements of 240.4. (Subsequent conductors protected by OC protection)

48

Part II — 240.21(A) Location of OC Protection

Branch-Circuit Conductors.
Branch-circuit tap conductors meeting the requirements specified in 210.19 (not less than maximum load after adjustment and correction factors are applied)

shall be permitted to have overcurrent protection as specified in 210.20. (125% for continuous loads)

49

240.21(B) Feeder Taps

Conductors are permitted to be tapped without O.C. protection at the tap if to a feeder as specified in (B)(1)—(B)(5). The tap shall be permitted at any point on the load side of the feeder OCP device.

240.4(B) shall not be permitted.

(O.C. – next higher size - not over 800 A) rule are not permitted for tap conductors

50

(B)(1) Taps Not over 10 ft Long

(1) Where the length of the tap conductors does not exceed **10 ft** and the tap conductors comply with all of the following:

(1) The ampacity of the tap conductors is:

a. Not less than the combined calculated loads on the circuits supplied by the tap conductors, and

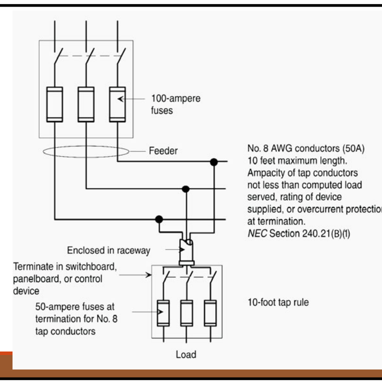
b. Not less than the rating of the **equipment** containing an overcurrent device(s) supplied by the tap conductors,

or

not less than the rating of the overcurrent protective device at the termination of the tap conductors.

51

10-foot Tap Rule



52

(1) Taps Not Over 10 feet Long

(2) The tap conductors do not extend beyond the switchboard, panelboard, disconnecting means, or control devices they supply.

(3) Except at the point of connection to the feeder, the tap conductors are enclosed in a raceway, which shall extend from the tap to the enclosure of an enclosed switchboard, panelboard, or control devices, or to the back of an open switchboard.

(4) For field installations if the tap conductors leave the enclosure or vault in which the tap is made, the ampacity of the tap conductors is not less the 1/10 the rating of the OC device protecting the feeder.

53

25-foot Tap Rule
(B)(2) Taps Not over 25 feet Long

Where the length of the tap conductors does not exceed (25 ft) and the tap conductors comply with all the following:

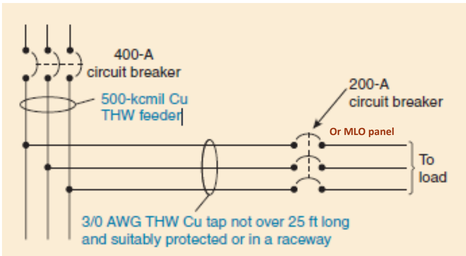
(1) The ampacity of the tap conductors is not less than **one-third** of the rating of the overcurrent device protecting the feeder conductors.

(2) The tap conductors terminate in a single circuit breaker or a single set of fuses that limit the load to the ampacity of the tap conductors. This device shall be permitted to supply any number of additional overcurrent devices on its load side.

(3) The tap conductors are protected from physical damage by being enclosed in an approved raceway or by other approved means.

54

240.21(B) 25' Tap Rule



55

240.21(B)(3) Taps Supplying a Transformer Pri + Sec Not Over 25 Feet Long

Taps that supply a transformer where the primary plus the secondary are not over 25 ft. All of the conditions of 1-5 are met:

(1) The tap for the primary is at least 1/3 the ampacity of the feeder conductors

(2) The secondary conductor ampacity is at least 1/3 of the feeder OC after the transformer ratio is used.

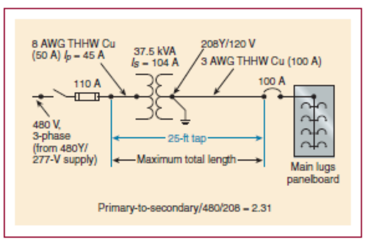
(3) The primary plus the secondary conductors are not over 25 feet in length

(4) Conductors are physically protected

(5) The secondary terminates in OC protection

56

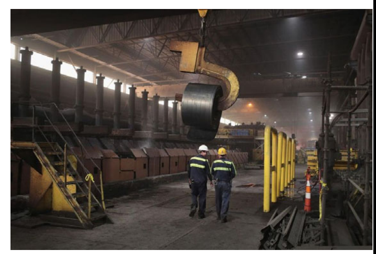
Transformer Pri + Sec: Not over 25 Feet



57

240.21(B)(4) Taps Over 25 Feet Long
240.21(5) Outside Taps Unlimited Length

- See 240.21(4) for high bay manufacturing buildings (over 35 feet high)
- See 240.21(5) for tap conductors that are outdoors with unlimited length



58

240.21(C) Transformer Secondary Conductors

A set of conductors feeding a single load, or each set of conductors feeding separate loads, shall be permitted to be connected to a transformer secondary, without overcurrent protection at the secondary, (in the transformer) as specified in 240.21(C)(1)–(C)(6).

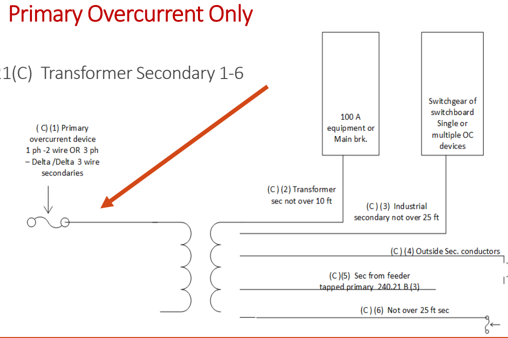
The provisions of 240.4(B) shall not be permitted for transformer secondary conductors. (Cannot go to the next larger size of OC above the conductor ampacity)

Informational Note:
For overcurrent protection requirements for transformers, see 450.3.

59

C(1) Primary Overcurrent Only

240.21(C) Transformer Secondary 1-6



60

240.21(C)(1) Transformer Secondary Conductors

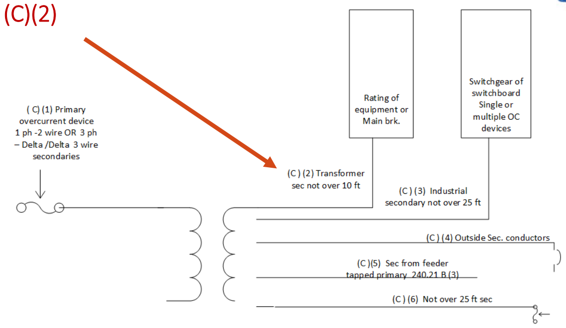
(1) Protection by Primary Overcurrent Device.

Conductors supplied by the secondary side of a single-phase transformer having a 2-wire secondary, --- or a three-phase, delta-delta connected transformer having a 3-wire secondary, shall be permitted to be protected by OCP provided on the primary side of the transformer, *provided this protection is in accordance with 450.3 and does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.*

E.g., 2:1 step down xfmr –
E.g., 30A sec. conductor × (1 sec voltage : pri. voltage) (1/2) = 15A Primary Fuse

Single-phase (other than 2-wire) and multiphase (other than delta-delta, 3-wire) transformer secondary conductors are not considered to be protected by the primary overcurrent protective device. Only these two configurations are protected by primary only protection.

(C)(2)



240.21(C)(2) Transformer Secondary Conductors not over 10 Feet Long

Where the length of secondary conductor does not exceed 10 ft and complies with all of the following:

(1) The ampacity of the secondary conductors is :

a. Not less than the combined calculated loads on the circuits supplied by the secondary conductors,

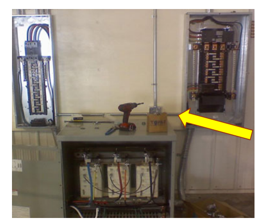
AND

b. Not less than the rating of the equipment containing overcurrent devices --- or not less than the rating of the OCP device at the termination of the secondary conductors

240.21(C)(2)(2 & 3) 10 Ft Transformer Secondary Conductors

(2) The secondary conductors do not extend beyond the switchboard, switchgear, panelboard, disconnecting means, or control devices they supply.

(3) The secondary conductors are enclosed in a raceway, which shall extend from the transformer to the enclosure of an enclosed switchboard, panelboard, or control devices or to the back of an open switchboard.



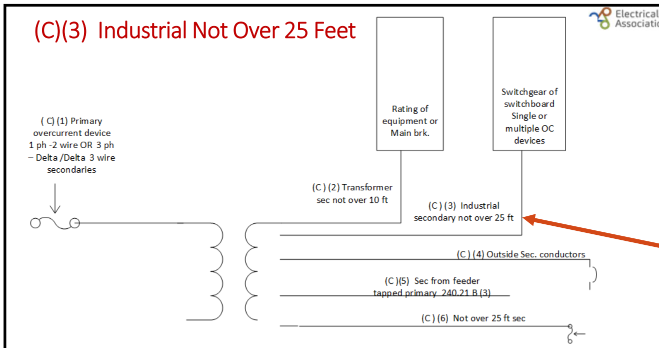
240.21(C)(2) (4) Transformer Secondary Conductors

For field installations where the secondary conductors leave the enclosure or vault in which the supply connection is made, the rating of the overcurrent device protecting the primary of the transformer, multiplied by the primary to secondary transformer voltage ratio, shall not exceed 10 times the ampacity of the secondary conductor

This requirement applies to transformer secondary conductors that leave an enclosure or transformer vault.

EG: 20A primary OC × 2:1 voltage ratio = 40A sec × 10: means the secondary conductors must be at least 1/10 of 400A, so the secondary ampacity is 40A or more.

(C)(3) Industrial Not Over 25 Feet



240.21(C)(3) Industrial Insulation Transformer Secondary Conductors Not Over 25 ft

3) For the supply of switchboards or switchgear in Industrial Installation
For industrial installations only, where the length of the secondary conductors does not exceed 25 ft and complies with all of the following:

(1) Conditions of maintenance and supervision ensure that only qualified persons service the systems.

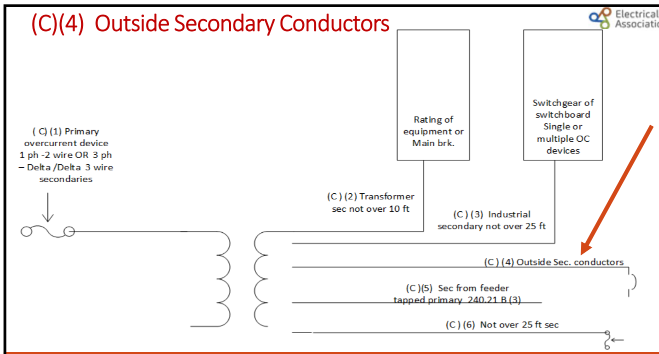
(2) The ampacity of the secondary conductors is not less than the secondary current rating of the transformer, **and the sum of the ratings** of the overcurrent devices does not exceed the ampacity of the secondary conductors.

(3) All overcurrent devices are grouped.

(4) The secondary conductors are protected from physical damage by being enclosed in an approved raceway or by other approved means.

67

(C)(4) Outside Secondary Conductors



68

240.21(C)(4) Outside Secondary Conductors

Where the conductors are located outdoors of a building or structure, except at the point of load termination, and comply with all of the following conditions:

(1) The conductors are protected from physical damage in an approved manner.

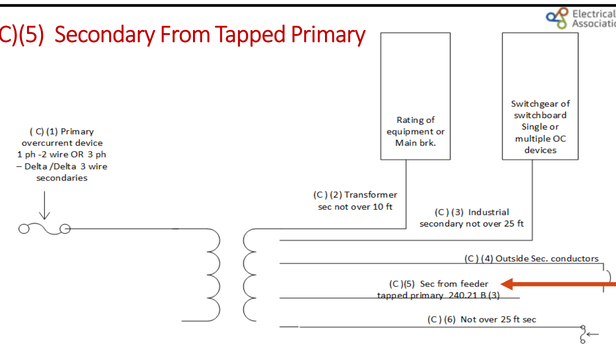
(2) The conductors terminate at a single circuit breaker or a single set of fuses that limit the load to the ampacity of the conductors. This single overcurrent device shall be permitted to supply any number of additional overcurrent devices on its load side.

(3) The overcurrent device for the conductors is an integral part of a disconnecting means or shall be located immediately adjacent thereto.

(4) The disconnecting means for the conductors is installed at a readily accessible location complying with one of the following:
   a. Outside of a building or structure
   b. Inside, nearest the point of entrance of the conductors
   c. Where installed in accordance with 230.6, nearest the point of entrance of the conductors

69

(C)(5) Secondary From Tapped Primary



70

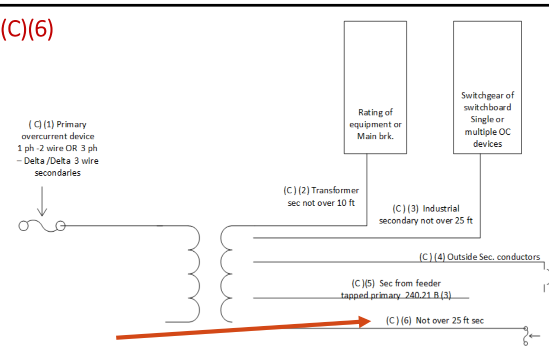
240.21(C)(5) Secondary Conductors from a Feeder Tapped Transformer

Follow 240.21(B)(3) if the transformer is supplied by feeder taps

Taps supplying a transformer within 25 feet or less.

71

(C)(6)



72

240.21(C)(6) Transformer Secondary Conductors

Secondary Conductors Not over 25 ft Long. Where the length of secondary conductor does not exceed 25 ft and complies with **all** of the following:

(1) The secondary conductors shall have an ampacity that is not less than the value of the primary-to-secondary voltage ratio multiplied by one-third of the rating of the overcurrent device protecting the primary of the transformer.

EG: 240:120 voltage ratio × 1/3 the Pri OC 300A = 2 × 100 = 200A sec ampacity

(2) The secondary conductors terminate in a single circuit breaker or set of fuses that limit the load current to not more than the conductor ampacity that is permitted by 310.15.

(3) The secondary conductors are protected from physical damage by being enclosed in an approved raceway or by other approved means.

240.21(D), (E), (F), (G)

(D) Service conductors: Follow 230.91

(E) Busway taps: Follow 368.17

(F) Motor circuit taps: Follow 430.28 and 430.53

(G) Conductors from generator terminals: Follow 445.12 and 445.13

240.21(G) Generator conductors

240.21(H) Battery Conductors

Overcurrent protection shall be permitted to be installed as close as practicable to the storage battery terminals in an **unclassified** location. Art 480 for storage batteries

Installation of the overcurrent protection within a hazardous (**classified**) location shall also be permitted.

240.21(H) Battery Conductors

240.22 OCP in Grounded Conductor

No overcurrent device shall be connected in series with any conductor that is <u>intentionally grounded</u>, unless one of the following two conditions is met:

(1) The overcurrent device opens all conductors of the circuit, including the grounded conductor, and is designed so that no pole can operate independently.

(2) Where required by 430.36 or 430.37 for motor overload protection.

240.24(A) Location In, or On, Premises

Accessibility.
Switches containing fuses and circuit breakers shall be readily accessible and installed so the center of the operating handle of the switch or circuit breaker, when in its highest position, is **not more than 6 ft 7 in.** above the floor unless one of the following applies:

(1) For busways, as provided in 368.17(C).
(2) For supplementary OCP as in 240.10
(3) For overcurrent devices as described in 225.40 and 230.92.
(4) For overcurrent devices adjacent to utilization equipment that they supply, access shall be permitted to be by portable means.

79

240.24(B) Occupancy

Each occupant shall have ready access to all overcurrent devices protecting the conductors supplying that occupancy, unless otherwise permitted in 240.24(B)(1) and (B)(2) below

(1) Service and Feeder Overcurrent Devices. Where electric service and electrical maintenance are provided by the building management and where these are under continuous building management supervision, the service overcurrent devices and feeder overcurrent devices supplying more than one occupancy shall be permitted to be accessible only to authorized management personnel in the following:
(1) Multiple-occupancy buildings
(2) Guest rooms or guest suites

80

240.24(B) Occupancy

(2) Branch-Circuit Overcurrent Devices

Where electric service and electrical maintenance are provided by the building management and where these are under continuous building management supervision, the branch-circuit overcurrent devices supplying any guest rooms or guest suites without permanent provisions for cooking shall be permitted to be accessible only to authorized management personnel.

81

240.24 Location

(C) Not Exposed to Physical Damage. Overcurrent devices shall be located where they will not be exposed to physical damage.

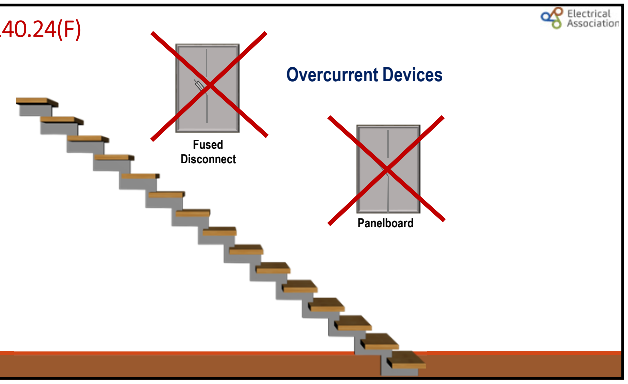
(D) Not in Vicinity of Easily Ignitible Material. Overcurrent devices shall not be located in the vicinity of easily ignitible material, such as in clothes closets.

(E) Not Located in Bathrooms. In dwelling units, dormitory units, and guest rooms or guest suites; overcurrent devices, other than supplementary overcurrent protection, shall not be located in bathrooms.

(F) Not Located over Steps. Overcurrent devices shall not be located over steps of a stairway.

82

240.24(F)



83

Part III
Enclosures

84

240.30 General

(A) Protection from physical damage

(1) As when in cabinets or boxes

(2) Mounting on open-type switchboards, panelboards, or control boards that are in rooms or enclosures free from dampness and easily ignitible material and are accessible only to qualified personnel

(B) Operating Handle

The operating handle of a circuit breaker shall be permitted to be accessible without opening a door or cover.

85

240.33 Vertical Position

Enclosures for overcurrent devices shall be mounted in a vertical position. Circuit breaker enclosure are permitted to be installed horizontally when the circuit breaker is install as per 240.81 (Indicating **ON** or **OFF**)

Listed busway plus are allowed to be installed to meet the busway orientation.

86

Part IV Disconnecting & Guarding

87

240.40 Disconnecting Means for Fuses

Partial:

Cartridge fuses in circuits of any voltage where accessible to other than qualified persons, and all fuses in circuits over 150 volts to ground, shall be provided with a disconnecting means on their supply side so that each circuit containing fuses can be independently disconnected from the source of power.

88

240.41(A-B) Arcing or Suddenly Moving Parts

(A) Fuses and circuit breakers shall be located or shielded so that persons will not be burned or otherwise injured by their operation.

(B) Moving handles of ckt breakers must not cause injury when moved suddenly

89

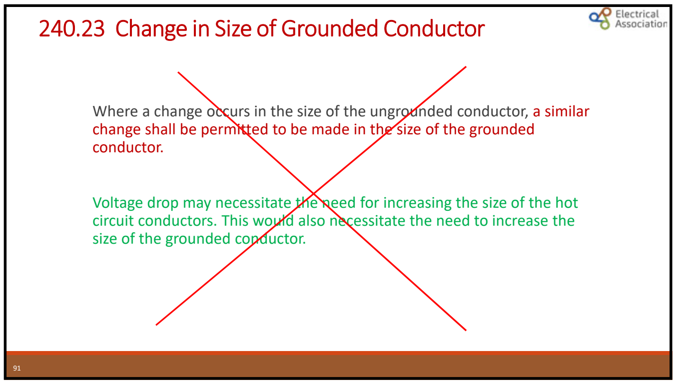
2020 NEC
Overcurrent Protection
Part 1

The End — Thank You for Attending!

QUESTIONS?

Electrical Association

90


Electrical Association
240.23 Change in Size of Grounded Conductor
Where a change occurs in the size of the ungrounded conductor, a similar change shall be permitted to be made in the size of the grounded conductor.
Voltage drop may necessitate the need for increasing the size of the hot circuit conductors. This would also necessitate the need to increase the size of the grounded conductor.
91

Electrical Association

2020 NEC
Overcurrent Protection
Part 2

Presented by

Electrical Association

1

Acknowledgements

Disclaimer: Through the presentation of this course and or these materials, no representation actual or implied, is made that the trainer or the Electrical Association is setting or enforcing specific standards or is providing peer review, certification, accreditation, or product endorsement or testing. The Electrical Association has no proprietary interest in the materials or products used in this presentation.

This educational offering is recognized by the MN Department of Labor & Industry as satisfying 2 hours of Code credit toward electrical continuing education requirements.

Please see the 2020 NEC® (NFPA 70) for complete review of code articles.

Comments in green text are interpretations by the Electrical Association.

2

Part V

PLUG FUSES, FUSEHOLDERS AND ADAPTERS

3

240.50 General

(A) Maximum voltage for plug fuses for circuits not exceeding 125 volts between conductors and for circuits with a grounded neutral where the line to neutral voltage does not exceed 150V

(B) Each fuse shall be marked with the ampere rating

(C) Plug fuses 15A and lower will have a hexagonal window design

(D) When installed they have no energized parts exposed

(E) The screw shell of the plug fuse is connected to the LOAD side of the circuit

4 4

240.51 Edison-Base Fuses

(A) Classification. Plug fuses of the Edison-base type shall be classified at not over 125 volts and 30 amperes and below.

(B) Replacement Only. Plug fuses of the Edison-base type shall be used only for replacements in existing installations where there is no evidence of over fusing or tampering.

5

Plug Fuses

W Series Fast Acting
Ampere Ratings: 1/8 - 30 Amps
Voltage Rating: 125V AC
Element is a simple fusible, metal link. For general purpose circuit protection. Quickly opens when short-circuit or overload occurs. Use for lighting and other non-motor circuits. Edison base.

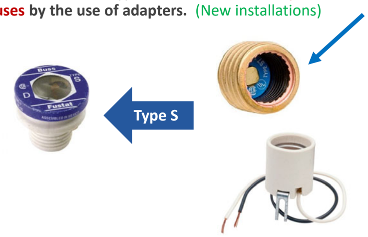
SL and TL Series Time-Delay, Loaded Link
Ampere Ratings: 15 - 30 Amps **Voltage Rating:** 125V AC
Heat absorbing metal bead on element link for time-delay. Passes motor overload starting currents without needlessly opening. Edison base (TL), Rejection base (SL).

S and T Series Time-Delay, Dual-Element
Ampere Ratings: Type S:1/4A - 30 Amps
Type T: 3/10 - 30 Amps **Voltage Rating:** 125V AC

6

240.52 Edison-Base Fuseholders

Fuseholders of the Edison-base type shall be installed only where they are made to accept Type S fuses by the use of adapters. (New installations)



7

240.53 Type S Fuses

Type S fuses shall be of the plug type and shall comply with 240.53(A)-(B):

(A) Classification.
Type S fuses shall be classified at not over 125 V and 0–15 amps, 16–20 amps, and 21–30 amps.

(B) Non-interchangeable.
Type S fuses of an ampere classification as specified in 240.53(A) shall not be interchangeable with a lower ampere classification. They shall be designed so that they cannot be used in any fuseholder other than a Type S fuseholder or a fuseholder with a Type S adapter inserted.

8

Type S Fuses – continued

(C) Non-removable
Type S adapters shall be designed so that once inserted in a fuseholder, they cannot be removed.

(D) Non-tamperable
Type S fuses, fuseholders, and adapters shall be designed so that tampering or shunting (bridging) would be difficult.

(E) Interchangeability
Dimensions of Type S fuses, fuseholders, and adapters shall be standardized to permit interchangeability regardless of the manufacturer.

9

Part VI

CARTRIDGE FUSES & FUSEHOLDERS

10

240.60 General

(A) Maximum Voltage 300-Volt Type.
Cartridge fuses and holders of the 300 V type shall be permitted to be used in:

(1) Circuits not exceeding 300 V between conductors

(2) Single-phase line-to-neutral circuits supplied from a 3-phase, 4-wire, solidly grounded neutral source where the line-to-neutral voltage does not exceed 300 V

Eg: 120/208 for 300V fuses

(B) Noninterchangeable 0–6000-Ampere Cartridge Fuseholders.
Fuseholders shall be so that it will be difficult to put a fuse of any given class into a fuseholder that is designed for a current lower, or voltage higher, than that of the class to which the fuse belongs. Fuseholders for current-limiting fuses shall not permit insertion of fuses that are not current-limiting.

11

240.60(C) General

(C) Marking
Fuses shall be plainly marked, either by printing on the fuse barrel or by a label attached to the barrel showing:

(1) Ampere rating

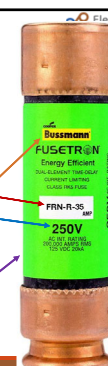
(2) Voltage rating

(3) Interrupting rating where other than 10,000 amperes

(4) Current limiting where applicable

(5) The name or trademark of the manufacturer

The interrupting rating shall **not** be required to be marked on fuses used for supplementary protection.



12

240.60(D)

Renewable link fuses:

Class H fuses with renewable links, shall be permitted to be used for replacement only in existing installations where there is no evidence of over-fusing or tampering

13

240.61 Classification

Cartridge fuses and fuseholders shall be classified according to voltage and amperage ranges.

- Fuses rated 1000 volts, nominal, or less shall be permitted to be used for voltages at or below their ratings.
- Higher voltage rated fuses can be used at lower utilization voltages, but not lower rated fuses at higher utilization voltages.

14

Class G Fuses – Various Voltages

Two fuses rated 300 V with Class G markings.

15

Fuse Bases for Bolt in Fuses (Blocks)

For bolt-in cartridge fuses, various base mountings are available.

Connector Type

Stud Type

Fixed Center Base Style

16

TRON Clip-Clamps

17

Fuse Reducers for Class J Dimension Fuses

18

240.62 Reconditioned Equipment

Low-voltage (under 1000V) fuse holders, and non-renewable fuses, shall not be reconditioned.

19

Fuse Dimensions

250V fuses 1/10 0- 30A ferrule end 2” long with ferrule 9/16” diameter

250V fuses 31-60A ferrule end 3” long with ferrule 13/16” diameter

600V fuses 1/0 = 10-30A ferrule are 5” long ferrule 13/16” diameter

600V fuses 31-60A are 5-1/2” long with ferrule 1-1/16” diameter

Fuses over 60 A – 600 A are knife blade ends

20

Classes of Fuses

The industry has developed basic physical specifications and electrical performance requirements for fuses with voltage ratings of 600 V or less. These are standards.

If a type of fuse meets the requirements of a standard, it can fall into that class.

Typical classes include:

- K
- RK1
- RK5
- G
- L
- H
- T
- CC
- J

21

Class R (Rejection) current Limiting
RK1- RK-5

Rejection Feature

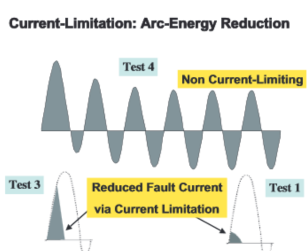
Class H Fuse

Non current Limiting

10kA IC

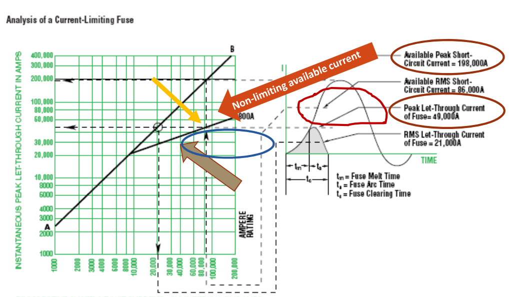
22

Non-Current Limiting vs. Current Limiting



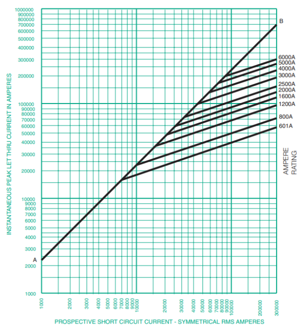
23

800A Fuse



24

Low-Peak Class L Time-Delay Fuses
KRP-C_SP



KRP-C_SP Fuse – RMS Let-Through Currents (kA)

Prosp. Short C.C.	Fuse Size									
	601	800	1200	1600	2000	2500	3000	4000	5000	6000
	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}	I_{RMS}
5,000	5	5	5	5	5	5	5	5	5	5
10,000	8	10	10	10	10	10	10	10	10	10
15,000	9	12	15	15	15	15	15	15	15	15
20,000	10	13	17	20	20	20	20	20	20	20
25,000	11	14	19	22	25	25	25	25	25	25
30,000	11	14	20	24	27	30	30	30	30	30
35,000	12	15	21	25	29	35	35	35	35	35
40,000	13	16	22	26	30	35	40	40	40	40
50,000	14	17	23	28	32	37	50	50	50	50
60,000	15	18	25	30	34	40	49	60	60	60
70,000	15	19	26	32	36	42	52	62	70	70
80,000	16	20	27	33	38	44	54	65	76	80
90,000	17	21	29	34	39	45	56	67	79	90
100,000	17	22	30	36	41	47	58	70	81	100
150,000	20	25	34	41	47	54	67	80	93	104
200,000	22	27	37	45	51	59	73	87	102	114
250,000	24	29	40	49	55	64	79	94	110	123
300,000	25	31	43	52	59	68	84	100	117	30

Note: For I_{RMS} value at 300,000 amperes, consult Factory.

Class CC Rejection-Type Fuses

XXX-R is rejection fuses. Type CC are current limiting fuses –R is a rejection fuse meaning the fuse holder will not accept or "reject" any non-current limiting CC fuse

FNQ-R Time-Delay, Rejection Type
Branch Circuit Fuse
Class CC
Physical Size: 13/32 × 11/2"
Construction: Melamine Tube
Ampere Ratings: 1/4 - 30 Amps.
Voltage Rating: 600V AC or less
Interrupting Rating: 200,000A RMS Sym.

LP-CC Low-Peak® Fuse
Time-Delay Current Limiting,
Class CC - Rejection Type
Physical Size: 13/32 × 1-1/2"
Construction: Melamine Tube
Ampere Ratings: 1/4 - 30 Amps.
Voltage Rating:
600 Volts AC (or less), (300V DC & 20-30A), 150V DC (3-15A)
Interrupting Rating: 200,000A RMS Sym; 20,000A DC

26

Quick Acting, Class J Fuses

Quick Acting
Ampere Ratings: 1-600 Amps.
Voltage Rating: 600 V AC (or less)
Current Limiting
Interrupting Rating: 200,000A RMS Sym.

27

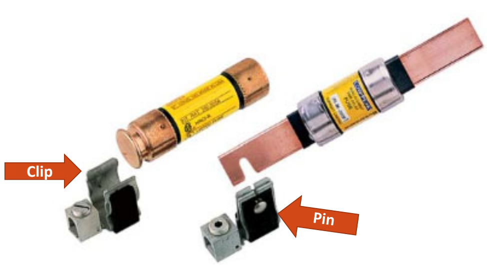
Dual Element -- Time Delay Fuses

FRS-R 600V Knife blade

FRN-R 250V ferrule end

28

Rejection Fuseholders



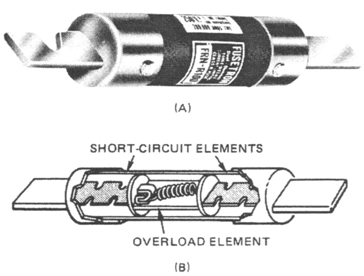
29

Time-Delay Class G Fuses

SC
Fast Acting (1/2-6A), Class G
Time-Delay (7-60A), Class G
Construction: Melamine Tube
Ampere Ratings: ½ - 60A
Voltage Rating: ½ - 20A: 600V AC/170V DC or less
25-60A: 480V AC/300V DC or less
Interrupting Rating: 100,000A RMS Sym., 10,000A DC

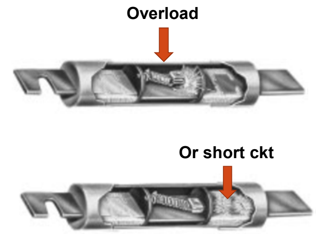
30

Dual Element Time Delay Fuses



31

Dual-Element, Time-Delay Fuses



32

One-Time General Purpose Fuses - NON and NOS

General Purpose Application

Non-Current Limiting

Ampere Ratings: 1/8-600 Amps

Voltage Rating:
NON: 250 Volts AC, 125 Volts DC (0-100A);
NOS: 600 Volts AC

Interrupting Rating:
50,000A RMS Sym. (1-60A)

10,000A RMS Sym. (65-600A)

10,000A @ 125V DC (NON 0-100A)

33

E-Rated Medium Volt for Potential & Small Power Transformers

JCD, JCW, JCE, JCQ, JCI & JCT

Current Limiting

Indicating/Non-Indicating

Plated Ferrules

Voltage Rating:
(Max. Design) 2475, 2750, 5500, 8300, 15,500

Current Ratings: 1/4E through 10E

34

240.67 Arc Energy Reduction

Effective on Jan. 1, 2020, where fuses are 1200 A or more - follow (A) and (B) below:

(A) Documentation needs to be available as to the methods used to reduce clearing time. The documentation shall be available to all who are concerned.

(B) Either the fuse must clear the overcurrent in 0.07 seconds or other one of the methods as referenced in 240.67(B)(1-4) (below) shall be used.

1. Differential relaying
2. Energy reduction maintenance switching
3. Active arc mitigation system
4. Current limiting electronic fuses
5. An approved equivalent means

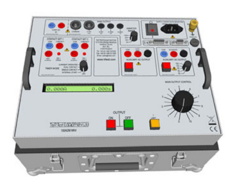
35

240.67 Arc Energy Reduction

(C) Performance testing

The arc energy reduction protection system shall be tested by – primary current injection or by other approved means – when first installed. A written record shall be provided to the AHJ by a qualified tester according to the manufacturer's instructions.

By **injecting** a predetermined current into the circuit breaker, it is possible to determine whether the relay will trip at this current and, if so, how long the current needs to flow before the trip is initiated.



36

Part VII

CIRCUIT BREAKERS

37

240.80 Method of Operation

- Circuit breakers shall be trip free and capable of being closed and opened by manual operation.
- Normal method of operation by other than manual means, such as electrical or pneumatic, shall be permitted if means for manual operation are also provided.

38

39

240.81 Indicating

- Circuit breakers shall clearly indicate whether they are in the open "off" or closed "on" position.
- Where circuit breaker handles are operated vertically rather than rotationally or horizontally, the **UP** position of the handle shall be the **ON** position.

40

240.83 Marking

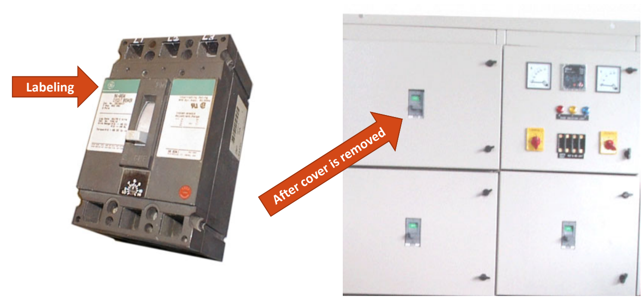
(A) Durable and Visible. Circuit breakers shall be marked with the ampere rating that will be visible after installation. Such marking shall be permitted to be made visible by removal of a trim or cover.

(B) Location. Circuit breakers rated 100 amperes or less and 1000 volts or less shall have the ampere rating molded, stamped, etched, into their handles or escutcheon areas.

(C) Interrupting Rating. Every circuit breaker having an interrupting rating **other than 5000 amperes shall have its interrupting rating shown** on the circuit breaker.

(D) and (E) continued on next slides.

41



42

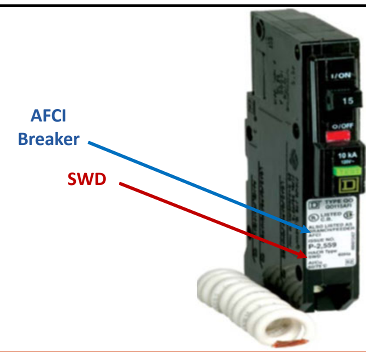
240.83 Marking

(D) Used as Switches

- CB used as switches in 120 V and 277 V fluorescent lighting circuits shall be listed and shall be marked SWD or HID.
- Circuit breakers used as switches in high-intensity discharge lighting circuits shall be listed and shall be marked as HID.

(E) Voltage Marking
Circuit breakers shall be marked with a voltage rating not less than the nominal system voltage that is indicative of their capability to interrupt fault currents between phases or phase to ground.

43



44

GFCI 1-Pole and 2-Pole

45

GFCI 2-Pole 120/240V with Shared Neutral

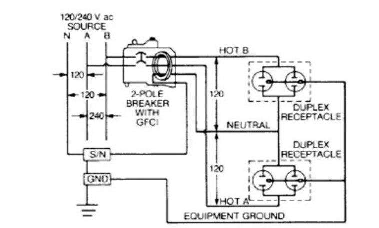
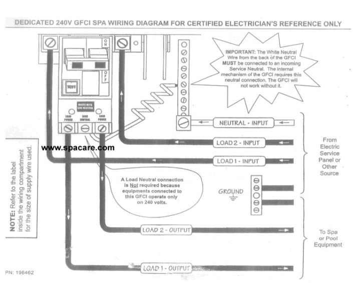


Figure 3. In a two-pole GFCI circuit breaker, if single-phase (120 V) loads are to be served, both of the hot conductors, and the neutral conductor, must pass through the CT; therefore, the load neutral conductor must be connected to the circuit breaker.

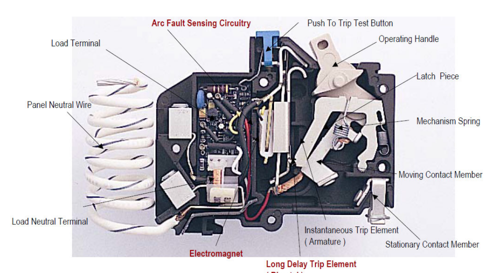
46

GFCI 2-Pole / 240V – Without Neutral



47

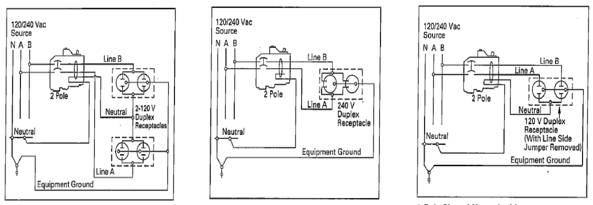
A Look Inside an AFC Breaker



48

CH 2-Pole AFCI

Combination 2 Pole Arc Fault Configurations



2-Pole Shared Neutral with Multi-Duplex Receptacle Application

2-Pole 240 Volt Load Application Sourced by 120/240 Vac

2-Pole Shared Neutral with Duplex Receptacle Application

49

CH Trip Codes on AFCI BKR

Standard Features and Benefits:

- Enhanced electronics to reduce unwanted tripping from non-compliant devices
- Standard LED indicates one of seven trip codes to simplify circuit diagnostics
- Trip codes are stored permanently into the breaker's memory, to help identify "trip" history
- Meets areas requiring AFCI protection under the 2008 and 2011 NEC®
- Exclusive "Trip to OFF" and simple 1-Step breaker reset
- Branch overvoltage protection for sensitive electronics
- Limited lifetime warranty

Optional Plug-on Neutral Features and Benefits:

- Time savings up to 25% per AFCI and GFCI installation
- Eliminates unwanted tripping due to loose pigtail connections
- Improved wireway access
- Easier troubleshooting due to less wiring

Next Generation Trip Codes

- **Thermal trip/manual disconnect** - The breaker has detected an overload, short circuit or was manually turned off
- **Series arc** - A low current arc has been detected within one of the current pathways
- **Parallel arc** - A high current arc has been detected between two conductors
- **Short delay** - An electronic backup to the short-circuit mechanism
- **Overvoltage** - Voltage of 160V rms or greater
- **Ground fault** - Current has found an alternate path to ground
- **Self test failure** - The breaker continually tests the internal electronics and software to ensure that the arc fault detection technology is working properly

50

Dual Function AFCI/GFCI

Breakers can be both Class A GFCI and "Combination" – (series and parallel faults) – AFCI breakers as well as inverse time overcurrent protection

51

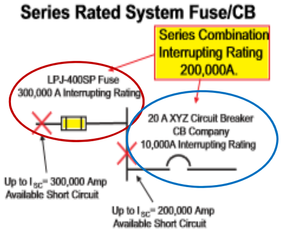
240.86 Series Ratings

Where a circuit breaker is used on a circuit having an available fault current higher than the marked interrupting rating by being connected on the load side of an acceptable overcurrent protective device having a higher rating, the circuit breaker shall meet the requirements specified in (A) or (B), and (C).

52

***CAUTION:** A series rated combination allows a load side (protected) circuit breaker to be applied where the available short circuit current exceeds the interrupting rating marked on that circuit breaker.*

Series Rated System Fuse/CB



53

240.86 Series Ratings

(A) Selected Under Engineering Supervision in Existing Installations.

The series rated combination devices shall be selected by a licensed professional engineer engaged in the design or maintenance of electrical installations. The selection shall be documented and stamped by the professional engineer. This series combination rating, including identification of the upstream device, shall be field marked on the end use equipment.

For calculated applications, the engineer shall ensure that the downstream circuit breaker(s) that are part of the series combination remain passive during the interruption period of the line side fully rated, current-limiting device.

54

240.86 Series Ratings

(B) Tested combinations
The combination of line side OCP and load side ckt breakers is to be tested and marked on the equipment.
(Must be available to any qualified uses of the OCP.)

(C) Motor contribution: Series rated equipment shall not be used…
(1) Where motors are connected between the up stream and down stream rated combination.
(2) Where the sum of the motor full load currents exceeds 1% of the IR rating of the lower rated circuit breaker

55

240.87 Arc Energy Reduction

Where the highest continuous current trip setting for which the actual overcurrent device installed in a circuit breaker is rated or can be adjusted is 1200 A or higher, 240.87(A) and (B) shall apply. (below)

(A) Documentation. Documentation shall be available to those authorized to design, install, operate, or inspect the installation as to the location of the circuit breaker(s), and what method of calculation was used.

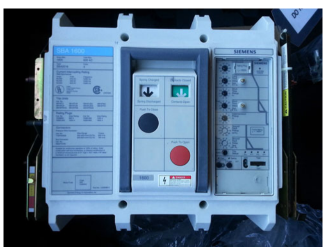
(B) Method to Reduce Clearing Time. One of the following shall be set to operate at less than the available arcing current.
(1) Zone-selective interlocking
(2) Differential relaying
(3) Energy-reducing maintenance switching with local status indicator
(4) Energy-reducing active arc flash
(5) An instantaneous trip setting at less than fault current. No temporary overrides are permitted
(6) An instantaneous override that is less than fault current
(7) An approved equivalent means

56

Long Time, Short Time, Instantaneous (LSI) Pick up

LSI breaker with energy reducing maintenance switch - Used to reduce arc fault energy when working downstream- by using "no intentional delay" mode.

When using "an energy reducing active arc mitigation system," no change in the circuit breaker setting is required.



57

240.88 Reconditioned Equipment

Reconditioned equipment shall be listed as re-conditioned and marked as such.

The original listing must be removed and new listing applied.

(A) Circuit breakers (See P. 107 in 2020 NEC)

(B) Components (see P. 107 In 2020 NEC)

58

Part VIII

SUPERVISED INDUSTRIAL INSTALLATIONS

59

240.90 General

Overcurrent protection in areas of supervised industrial installations shall comply with all of the other applicable provisions of this article, except as provided in Part VIII.

The provisions of Part VIII shall be permitted only to apply to those portions of the electrical system in the supervised industrial installation used exclusively for manufacturing or process control activities.

60

240.91 Protection of Conductors

Conductors shall be protected in accordance with 240.91(A) or (B). Below

(A) General. Conductors shall be protected in accordance with 240.4.

(B) Devices Rated Over 800 Amperes. Where the overcurrent device is rated over 800 amperes, the ampacity of the conductors it protects shall be equal to- or greater than- 95 percent of the rating of the overcurrent device specified in 240.6 in accordance with (B)(1) and (2).

(1) The conductors are protected within recognized time vs. current limits for short-circuit currents

(2) All equipment in which the conductors terminate is listed and marked for the application

61

240.92 Location in Circuit

An OCP shall be install in each ungrounded conductor as per (A)-(E):

(A) Feeder and branch circuits are protected at their origin as allowed in 240.21

(B) Feeder taps may follow 240.21 (B) (2) – (4)

(C) Transformer secondary taps for separately derived systems follow 240.92(C) (1)–(3) See this section in NEC.

(D) Outside feeder taps See this section in NEC.

(E) Protection by primary OCP for transformers.

62

Part IX

OVERCURRENT PROTECTION OVER 1000V, NOMINAL

63

240.100 Feeders and Branch Circuits

(A) Location and Type of Protection.
Feeder and branch circuit conductors shall have overcurrent protection in each ungrounded conductor located at the point where the conductor receives its supply, or at an alternative location in the circuit when designed under engineering supervision that includes, but is not limited to, considering the appropriate fault studies and time–current coordination analysis of the protective devices, and the conductor damage curves.

The overcurrent protection shall be permitted to be provided by either 240.100(A)(1) or (A)(2). (following)

64

Cable Limiters

Interrupting Rating:
200,000 Amps.,
600 Volts AC

RMS Symmetrical

UL Listing:
KDM, KDR, KDP
and KFM

65

240.100(A)(1) & (2)

(1) Overcurrent Relays and Current Transformers. Circuit breakers used for overcurrent protection of 3-ph circuits shall have a minimum of 3 overcurrent relay elements operated from three current transformers. The separate overcurrent relay elements (or protective functions) shall be permitted to be part of a single electronic protective relay unit.

On 3-phase, 3-wire circuits, an overcurrent relay element in the residual circuit of the current transformers shall be permitted to replace one of the phase relay elements. An overcurrent relay element, operated from a current transformer that links all phases of a 3-ph, 3-wire circuit, shall be permitted to replace the residual relay element and one of the phase-conductor current transformers. Where the neutral conductor is not re-grounded on the load side of the circuit as permitted in 250.184(B), the current transformer shall be permitted to link all 3-ph conductors and the grounded circuit conductor (neutral).

(2) Fuses. A fuse shall be connected in series with each ungrounded conductor.

66

240.100 (B) & (C) Branch Circuits and Feeders

(B) Protective Devices.
The protective device(s) shall be capable of detecting and interrupting all values of current that can occur at their location in excess of their trip-setting or melting point.

(C) Conductor Protection.
The operating time of the protective device, the available short-circuit current, and the conductor used shall be coordinated to prevent damage or dangerous temperatures in conductors or conductor insulation under short circuit conditions.

67

Medium-Voltage Fuse Links

68

Dummy Fuse "Neutrals" These are not fuses, Listed Product

69

Fault Current Calculations

70

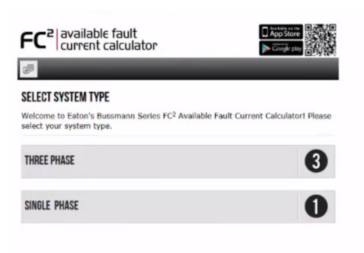
Procedure

To determine the fault current at any point in the system, first draw a one line diagram showing all of the sources, as well as the impedances of the circuit components. To begin, all system components including the utility should be shown.

Eaton.com/Bussmannseries/FC2

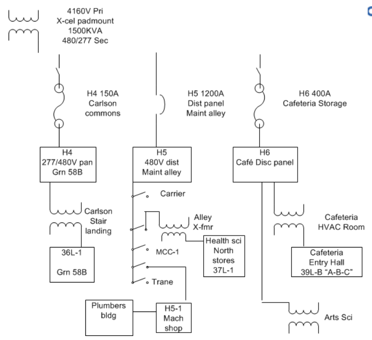
71

Web-Based Calculator

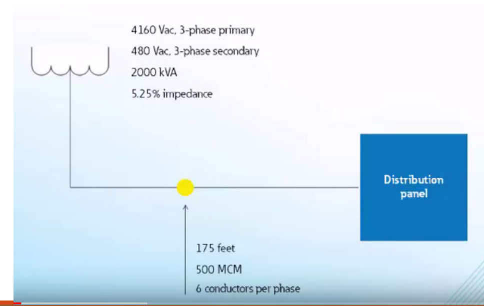


72

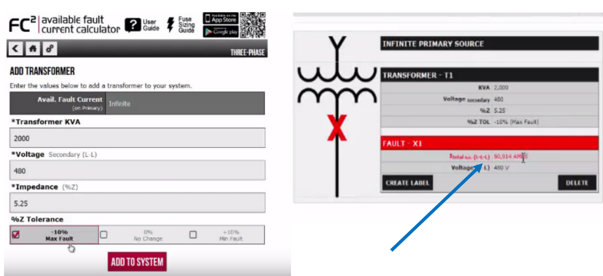
One-Line Diagram



Sample from FC²



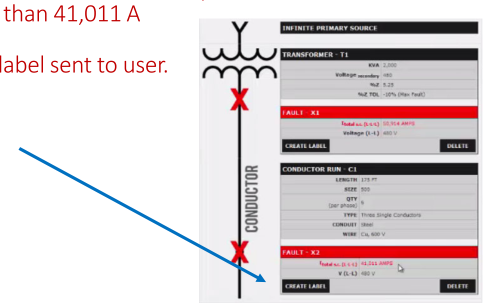
50,914A Fault at Transformer Sec.



Fault occurs 150 ft from secondary = 41,011 A

SCCR greater than 41,011 A

Can create a label sent to user.



Manual Procedure = Ugly's

It must be understood that the short circuit calculations are done without considering current limiting devices in the system.

Short circuit at the transformer secondary terminals:

$$I\ sc = \frac{\text{Rated transformer current – full load at secondary}}{\%\ impedance\ (decimal)}$$

3-phase

Fault Current

Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amperes from either the nameplate or the following formulas:

3Ø Transformer $I_{L.L.} = \frac{KVA \times 1000}{E_{L-L} \times 1.732}$

1Ø Transformer $I_{L.L.} = \frac{KVA \times 1000}{E_{L-L}}$

Step 2. Find the transformer multiplier.

$$\text{Multiplier} = \frac{100}{^{*}\%Z_{trans}}$$

***Note.** Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary. Transformer impedance is determined as follows: The transformer secondary is short circuited. Voltage is applied to the primary which causes full load current to flow in the secondary. This applied voltage divided by the rated primary voltage is the impedance of the transformer.

Example: For a 480 volt rated primary, if 9.6 volts causes secondary full load current to flow through the shorted secondary, the transformer impedance is 9.6/480 = .02 = 2%Z.

In addition, U.L. listed transformer 25KVA and larger have a ± 10% impedance tolerance. Short circuit amperes can be affected by this tolerance.

Electrical Association

Step 3. Determine the transformer let-through short-circuit current**.

$I_{S.C.} = I_{L.L.} \times$ Multiplier

*Note. Motor short-circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4. Values of 4 to 6 are commonly accepted.

Step 4. Calculate the "f" factor.

3Ø Faults

$$f = \frac{1.732 \times L \times I_{3Ø}}{C \times E_{L\text{-}L}}$$

1Ø Line-to-Line (L-L) Faults on 1Ø Center Tapped Transformer

$$f = \frac{2 \times L \times I_{L\text{-}L}}{C \times E_{L\text{-}L}}$$

1Ø Line-to-Neutral (L-N) Faults on 1Ø Center Tapped Transformer

$$f = \frac{2 \times L \times I_{L\text{-}N}^{\dagger}}{C \times E_{L\text{-}N}}$$

Where:
L = length (feet) of conductor to the fault.
C = constant from Table of "C" values for conductors and busway. For parallel runs, multiply C values by the number of conductors per phase.
I = available short-circuit current in amperes at beginning of circuit.

†**Note.** The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L\text{-}N} = 1.5 \times I_{L\text{-}L}$ **at Transformer Terminals.**

79

Electrical Association

"C" Values for Conductors and Busway

Copper AWS or kcmil	Three Single Conductors, Conduit, Steel 600V	5KV	15KV	Nonmagnetic 600V	5KV	15KV	Three-Conductor Cable, Conduit, Steel 600V	5KV	15KV	Nonmagnetic 600V	5KV	15KV
14	389	389	389	389	389	389	389	389	389	389	389	389
12	617	617	617	617	617	617	617	617	617	617	617	617
10	981	981	981	981	981	981	981	981	981	981	981	981
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note: These values are equal to one over the impedance per foot for impedances found in IEEE std. 241-1990, IEEE Recommended Practice for Commercial Building Power Systems.

80

Electrical Association

Step 5. Calculate "M" (multiplier).

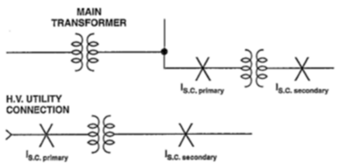
$$M = \frac{1}{1 + f}$$

Step 6. Calculate the available short-circuit symmetrical RMS current at the point of fault.

$$I_{S.C.\ sym\ RMS} = I_{S.C.} \times M$$

Calculation of Short-Circuit Currents at Second Transformer in System

Use the following procedure to calculate the level of fault current at the secondary of a second, downstream transformer in a system when the level of fault current at the transformer primary is known.



81

Electrical Association

Procedure for Second Transformer in System

Step A. Calculate the "f" factor ($I_{S.C.\ primary}$ known)

3Ø Transformer
($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 3Ø fault values)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times 1.73\ (\%Z)}{100{,}000 \times KVA_{trans}}$$

1Ø Transformer
($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 1Ø fault values: $I_{S.C.\ secondary}$ is L-L)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times (\%Z)}{100{,}000 \times KVA_{trans}}$$

Step B. Calculate "M" (multiplier).

$$M = \frac{1}{1 + f}$$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\ secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\ primary}$$

82

Electrical Association

System A

Available Utility Infinite Assumption

1500 KVA Transformer, 480V, 3Ø, 3.5%Z, 3.45%X, 56%R

$I_{L.L.}$ = 1804A

25' - 500kcmil 6 Per Phase Service Entrance Conductors in Steel Conduit

2000A Switch

KRP-C-2000SP Fuse

Fault X_1

400A Switch

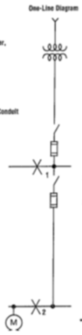
LPS-RK-400SP Fuse

50' - 500 kcmil Feeder Cable in Steel Conduit

Fault X_2

Motor Contribution

One-Line Diagram



Fault X_1

Step 1. $I_{L.L.} = \frac{1500 \times 1000}{480 \times 1.732} = 1804A$

Step 2. Multiplier $= \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1804 \times 28.57 = 51{,}540A$

$I_{S.C.\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS} = 51{,}504 + 7{,}216 = 58{,}720A$

Step 4. $f = \frac{1.732 \times 25 \times 51{,}540}{6 \times 22{,}185 \times 480} = 0.0349$

Step 5. $M = \frac{1}{1 + .0349} = .9663$

Step 6. $I_{S.C.\ sym\ RMS} = 51{,}540 \times .9663 = 49{,}803A$

$I_{S.C.\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS\ (fault\ X_1)} = 49{,}803 + 7{,}216 = 57{,}019A$

Fault X_2

Step 4. Use $I_{S.C.\ sym\ RMS}$ @ Fault X_1 to calculate "f"

$f = \frac{1.732 \times 50 \times 49{,}803}{22{,}185 \times 480} = .4050$

Step 5. $M = \frac{1}{1 + .4050} = .7117$

Step 6. $I_{S.C.\ sym\ RMS} = 49{,}803 \times .7117 = 35{,}445A$

$I_{sym\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS\ (fault\ X_2)} = 35{,}445 + 7{,}216 = 42{,}661A$

Example:

3-Phase Fault Current Calculation

*Assumes 100% motor load. If 50% of this load was from motors, $I_{S.C.}$ motor contrib. = 4 x 1,804 x .5 = 3608A

83

Electrical Association

System B

Available Utility Infinite Assumption

1000 KVA Transformer, 480V, 3Ø, 3.5%Z

$I_{L.L.}$ = 1203A

30' - 500 kcmil 4 Per Phase Copper in PVC Conduit

1600A Switch

KRP-C-1500SP Fuse

Fault X_1

400A Switch

LPS-RK-350SP Fuse

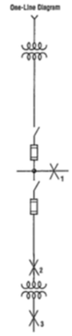
20' - 2/0 2 Per Phase Copper in PVC Conduit

Fault X_2

225 KVA transformer, 208V, 3Ø 1.2%Z

Fault X_3

One-Line Diagram



Fault X_1

Step 1. $I_{L.L.} = \frac{1000 \times 1000}{480 \times 1.732} = 1203A$

Step 2. Multiplier $= \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1203 \times 28.57 = 34{,}370A$

Step 4. $f = \frac{1.732 \times 30 \times 34{,}370}{4 \times 26{,}706 \times 480} = .0348$

Step 5. $M = \frac{1}{1 + .0348} = .9664$

Step 6. $I_{S.C.\ sym\ RMS} = 34{,}370 \times .9664 = 33{,}215A$

Fault X_2

Step 4. $f = \frac{1.732 \times 20 \times 33{,}215}{2 \times 11{,}423 \times 480} = .1049$

Step 5. $M = \frac{1}{1 + .1049} = .905$

Step 6. $I_{S.C.\ sym\ RMS} = 33{,}215 \times .905 = 30{,}059A$

Fault X_3

Step A. $f = \frac{30{,}059 \times 480 \times 1.732 \times 1.2}{100{,}000 \times 225} = 1.333$

Step B. $M = \frac{1}{1 + 1.333} = .4286$

Step C. $I_{S.C.\ sym\ RMS} = \frac{480 \times .4286 \times 30{,}059}{208} = 29{,}731A$

Example:

3-Phase Fault Current Calculation

84

1-Phase Fault Current Calculation

1. It is necessary that the proper impedance be used to represent the primary system. For 3Ø fault calculations, a single primary conductor impedance is only considered from the source to the transformer connection. This is compensated for in the 3Ø short-circuit formula by multiplying the single conductor or single-phase impedance by 1.73.

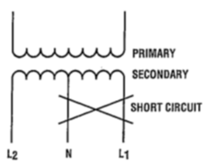
However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the 3Ø primary source impedance by two.

2. The impedance of the center-tapped transformer must be adjusted for the half-winding (generally line-to-neutral) fault condition.

The diagram at the right illustrates that during line-to-neutral faults, the full primary winding is involved but, only the half-winding on the secondary is involved. Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are as follows:

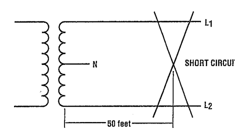
- 1.5 times full winding %R on full winding basis.
- 1.2 times full winding %X on full winding basis.

Note: %R and %X multipliers given in "Impedance Data for Single Phase Transformers" Table may be used, however, calculations must be adjusted to indicate transformer KVA/2.

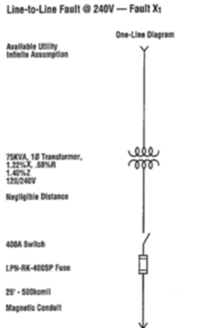


3. The impedance of the cable and two-pole switches on the system must be considered "both-ways" since the current flows to the fault and then returns to the source. For instance, if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation.

The calculations on the following pages illustrate 1Ø fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.



Line-to-Line Fault @ 240V — Fault X_1



Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.} = 312.5 \times 71.43 = 22{,}322A$

Step 4. $f = \frac{2 \times 25 \times 22{,}322}{22{,}185 \times 240} = .2096$

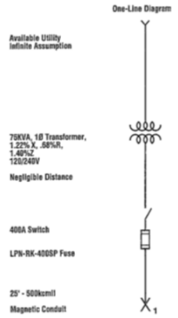
Step 5. $M = \frac{1}{1 + .2096} = .8267$

Step 6. $I_{S.C.\ L\text{-}L\ (X_1)} = 22{,}322 \times .8267 = 18{,}453A$

"C" Values for Conductors and Busway

[illegible]

Line-to-Neutral Fault @ 120V — Fault X_1



Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.\,(L\text{-}L)} = 312.5 \times 71.43 = 22{,}322A$

$I_{S.C.\,(L\text{-}N)} = 22{,}322 \times 1.5 = 33{,}483A$

Step 4. $f = \frac{2^{*} \times 25 \times 22{,}322 \times 1.5}{22{,}185 \times 120} = .6288$

Step 5. $M = \frac{1}{1 + .6288} = .6139$

Step 6. $I_{S.C.\,L\text{-}N\,(X_1)} = 33{,}483 \times .6139 = 20{,}555A$

*Assumes the neutral conductor and the line conductor are the same size.

Transformer Short Circuit Amps

TRANSFORMERS

Short-Circuit Currents Available from Various Size Transformers

Voltage And Phase	KVA	Full Load Amps	% Impedance†† (Nameplate)	Short-Circuit Amps†
120/240 1 ph.*	25	104	1.58	11,574
	37½	156	1.56	17,351
	50	209	1.54	23,122
	75	313	1.6	32,637
	100	417	1.6	42,478
	167	696	1.8	60,255
120/208 3 ph.**	25	69	1.6	4,791
	50	139	1.6	9,652
	75	208	1.11	20,821
	100	278	1.11	27,828
	150	416	1.07	43,198
	225	625	1.12	62,004
	300	833	1.11	83,383
	500	1388	1.24	124,373
	750	2082	3.5	66,095
	1000	2776	3.5	88,167
	1500	4164	3.5	132,190
	2000	5552	5.0	123,377
	2500	6950	5.0	154,444
277/480 3 ph.	112½	135	1.0	15,000
	150	181	1.2	16,759
	225	271	1.2	25,082
	300	361	1.2	33,426
	500	601	1.3	51,362
	750	902	3.5	28,410
	1000	1203	3.5	38,180
	1500	1804	3.5	57,261
	2000	2406	5.0	53,461
	2500	3007	5.0	66,822

*Single-phase values are L-N values at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 KVA primary, zero feet from terminals of transformer, 1.2 (%X) and 1.5 (%R) multipliers for L-N vs. L-L reactance and resistance values and transformer X/R ratio = 3.

**Three-phase short-circuit currents based on "infinite" primary.

†U.L. listed transformers 25 KVA or greater have a ±10% impedance tolerance. Short-circuit amps reflect a "worst case" condition.

Various Types of Short Circuit Currents as a Percent of Three Phase Bolted Faults (Typical).

Three Phase Bolted Fault	100%
Line-to-Line Bolted Fault	87%
Line-to-Ground Bolted Fault	100%*
Three Phase Arcing Fault	89% (480V) 12% (208V)
Line-to-Line Arcing Fault	74% (480V) 2% (208V)
Line-to-Ground Arcing Fault	38% (480V) 0% (208V)

*Typically much lower but can actually exceed the Three Phase Bolted Fault if it is near the transformer terminals.

Impedance Data for Single-Phase Transformers

kVA 1Ø	Suggested X/R Ratio for Calculation	Normal Range of Percent Impedance (%Z)*	Impedance Multipliers** For Line-to-Neutral Faults for %X	for %R
25.0	1.1	1.2–6.0	0.6	0.75
37.5	1.4	1.2–6.5	0.6	0.75
50.0	1.6	1.2–6.4	0.6	0.75
75.0	1.8	1.2–6.6	0.6	0.75
100.0	2.0	1.3–5.7	0.6	0.75
167.0	2.5	1.4–6.1	1.0	0.75
250.0	3.6	1.9–6.8	1.0	0.75
333.0	4.7	2.4–6.0	1.0	0.75
500.0	5.5	2.2–5.4	1.0	0.75

* National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

** Based on rated current of the winding (one–half nameplate kVA divided by secondary line-to-neutral voltage).

Note: U.L. Listed transformers 25 KVA and greater have a ± 10% tolerance on their impedance nameplate.

Impedance Data for Single-Phase and Three-Phase Transformers-Supplement†

kVA 1Ø	kVA 3Ø	%Z	Suggested X/R Ratio for Calculation
10	—	1.2	1.1
15	—	1.3	1.1
	75	1.11	1.5
	150	1.07	1.5
	225	1.12	1.5
	300	1.11	1.5
333	—	1.9	4.7
	500	1.24	1.5
500	—	2.1	5.5

†These represent actual transformer nameplate ratings taken from field installations.

Note: U.L. Listed transformers 25KVA and greater have a ±10% tolerance on their impedance nameplate.

Ampacity	Busway Plug-In Copper	Feeder Aluminum	Feeder Copper	High Impedance Aluminum	High Impedance Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Note: These values are equal to one over the impedance per foot for impedance in a survey of industry.

2020 NEC
Overcurrent Protection
Part 2

Thank You for Attending!

Extra Voltage Drop Material on the following slides.

QUESTIONS?

97

Voltage Drop Extra Material

98

Voltage Drop
Single-Phase

$$VD = \frac{2 \times K \times I \times L}{CM}$$

VD = Voltage drop
K = Ohms per mil foot – copper @75˚C is 12.8
I = Current in amperes
L = Length of wire one direction
CM = Circular mil area of conductor

99

Voltage Drop
Three-Phase

$$VD = \frac{1.732 \times K \times I \times L}{CM}$$

100

Voltage Drop Problem

What size copper conductor is needed to keep voltage drop to 3% or less for a 120V, single-phase circuit that is serving a load of 8 amps and is 140′ in length in one direction? Use K = 12.8

101

Voltage Drop Problem

What size copper conductor is needed to keep voltage drop to 3% or less for a 120V, single-phase circuit that is serving a load of 8 amps and is 140′ in length in one direction? Use K = 12.8

1. 3% = 0.03 × 120V = 3.6V

102

Voltage Drop Problem

What size copper conductor is needed to keep voltage drop to 3% or less for a 120V, single-phase circuit that is serving a load of 8 amps and is 140′ in length in one direction? Use K = 12.8

1. 3% = 0.03 × 120V = 3.6V
2. $3.6VD = \frac{2 \times 12.8 \times 8 \times 140}{CM}$

103

Voltage Drop Problem

What size copper conductor is needed to keep voltage drop to 3% or less for a 120V, single-phase circuit that is serving a load of 8 amps and is 140′ in length in one direction? Use K = 12.8

1. 3% = 0.03 × 120V = 3.6V
2. $3.6VD = \frac{2 \times 12.8 \times 8 \times 140}{CM}$
3. $CM = \frac{2 \times 12.8 \times 8 \times 140}{3.6}$

104

Voltage Drop Problem

What size copper conductor is needed to keep voltage drop to 3% or less for a 120V, single-phase circuit that is serving a load of 8 amps and is 140′ in length in one direction? Use K = 12.8

1. 3% = 0.03 × 120V = 3.6V
2. $3.6VD = \frac{2 \times 12.8 \times 8 \times 140}{CM}$
3. $CM = \frac{2 \times 12.8 \times 8 \times 140}{3.6}$ = **7965**

105

Voltage Drop Problem

What size copper conductor is needed to keep voltage drop to 3% or less for a 120V, single-phase circuit that is serving a load of 8 amps and is 140′ in length in one direction? Use K = 12.8

1. 3% = 0.03 × 120V = 3.6V
2. $3.6VD = \frac{2 \times 12.8 \times 8 \times 140}{CM}$
3. $CM = \frac{2 \times 12.8 \times 8 \times 140}{3.6}$ = **7965**

Answer: 10 AWG

106

End of Voltage Drop Problems

QUESTIONS?

Thank You for Attending!

107