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# Short Circuit Calculations: Circuit Breaker Asymmetric Switching Duty

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# Short Circuit Calculations

- Short circuit calculations are governed by various well-known standards
  - IEC 60909 (Sometimes called IEC 909)
  - ENA G74 (UK only)
  - ANSI C37
- Most engineers are familiar with the basic concept of short circuit calculations, but sometimes do not fully appreciate some of the important subtleties.
  - Peak short circuit current
  - DC offset and asymmetry
  - Delayed current zeroes

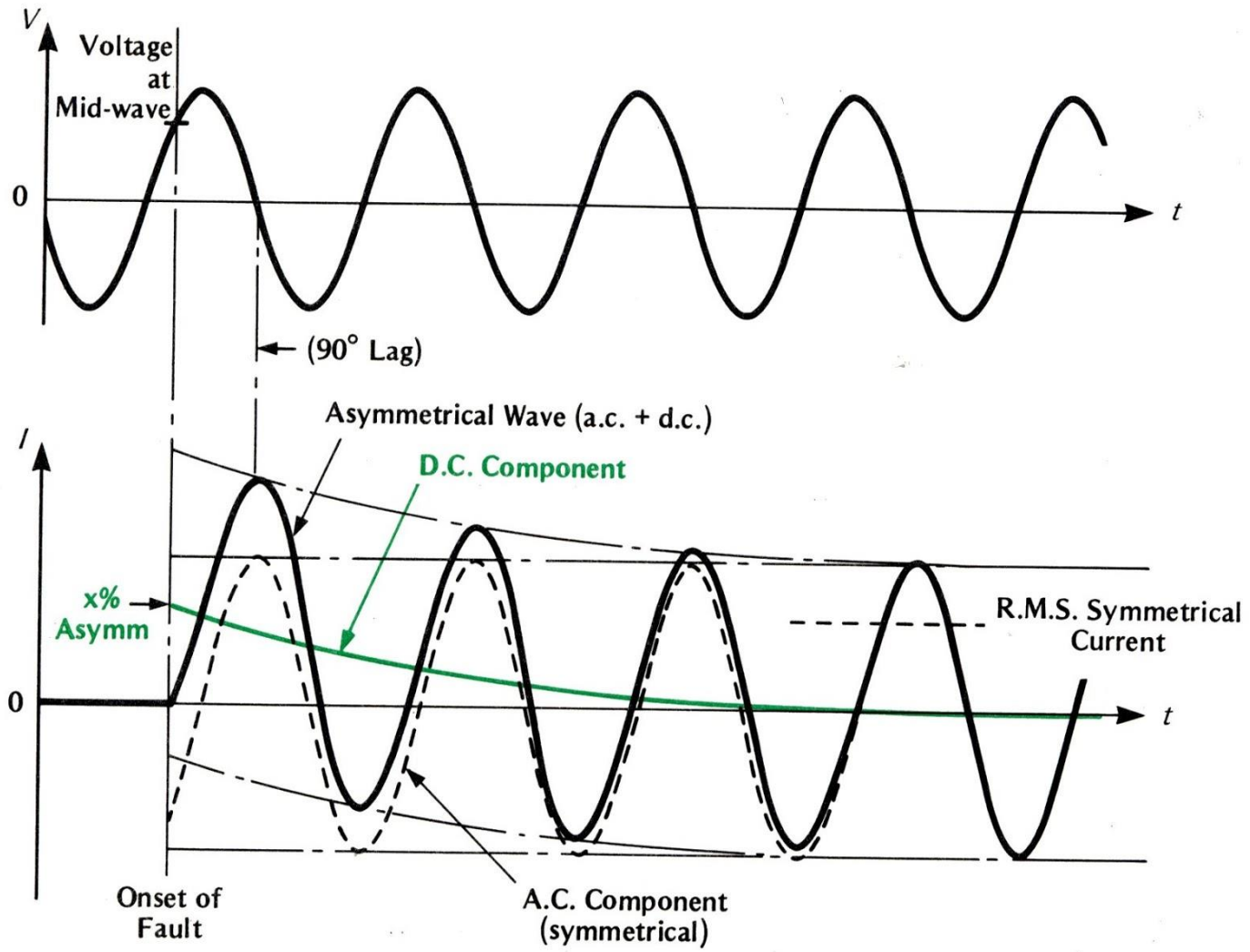
# Network X/R ratio & DC Component

- X/R is a simple comparison of reactance / resistance, but has a profound affect on the system behaviour for short circuits.
- High X/R ratios can lead to fault current exceeding switchgear capability!
- Most short circuit calculations do not adequately consider the X/R ratio of the network.
- In simple distribution networks the X/R ratio is normally small >10, but for larger networks, or systems that include generators it can be much higher.
- Standard IEC designed CBs' only consider X/R ratios below 17 (20%)

# Network X/R ratio & DC Component - II

- The DC component in fault current is caused by a high X/R ratio, which effectively offsets the normal fault current making it appear larger.
- The DC component usually decays within a few cycles ($\tau$ = 45ms).
- Lack of consideration of DC component can circuit breakers chopping current, leading to restrikes, damage to equipment and risk to system and personnel.
- What causes high X/R ratio and DC Component?
  - Switchboards with a large percentage of motor load
  - Switchboards with generators connected to them

# Short Circuit Current Waveform

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# Peak Short Circuit Current

- Circuit breakers are usually defined / specified on the ‘break’ (Ib) rating. HV circuit breakers peak (Ip) short circuit rating is a multiple of its ‘break’ rating:
  - 2.5x Ib (50Hz) i.e. 25kA break & 62.5kA peak
  - 2.6x Ib (60Hz) i.e. 40kA break & 104kA
- In cases of large motor load or closely coupled generators, the network X/R ratio and %DC component increases, which increase the peak fault level.
- In these scenarios it is possible for a circuit breaker to achieve a satisfactory ‘break’ rating, but exceed the circuit breaker peak rating.
- Peak short circuit levels is best checked using a computer package such as ETAP.

# Asymmetric Breaking Current

- The concept of asymmetric breaking is similar to the previous case – a high X/R ratio, leads to a high to a high DC component which offsets the fault current.
- The offset fault current appears higher and increases the breaker duty.
- This could exceed the breaker safe operating value leading and result in the breaker failing to clear the fault and possibly a catastrophic failure (explosion).
- The faster the circuit breaker operates the higher the DC component it ‘sees’ – i.e. a breaker with fast operating time and high speed differential protection can be at risk

# Delayed Current Zeroes

- Delayed current zeroes are an extreme occurrence when the system X/R ratio and %DC component is very high.
- The DC offset is so high that the first few cycles of the fault current do not pass through any current zeroes.
- It is relatively uncommon, but can happen with large generating stations.
- If current zeroes are delayed and the circuit breaker tries to operate it will fail to clear the fault and possibly lead to a catastrophic failure (explosion).
- Delayed current zeroes can have a significant impact on power system stability due to reduced fault clearance time.

# Solutions

- A simple approximation is that if the circuit breakers asymmetrical duty is exceeded, the next standard (R10) series fault rating should be selected. (IEC 62271-100, Annex I)
  - I.e. at 11kV 28kA fault current at 30% DC should use a 40kA circuit breaker instead of 31.5kA
- Switchgear manufacturer guidance should be sought for large %DC component and proved through synthetic testing.
- Current zero passing can be determined graphically using computer software and the IEC 61363 method.
- Be careful – not all manufacturers understand the issue!!

# Summary

- Industrial plants with large quantities of motors, or generating plants, can have a high X/R ratio.
- High X/R ratios can lead to a high peak fault currents and a high %DC component, which means that circuit breakers may not operate as desired – leading to dangerous conditions for operators and risk to plant and continuity.
- Delayed current zeroes can sometimes occur on large generation plants with very high X/R ratios – they can pose a significant risk to system operation and power system stability
- SPE used the software package ETAP which allows detailed analysis including asymmetric duty and identification of delayed current zeroes.

# What Next?

- All questions welcome!
- SPE's website has a lot of further information, or contacts us to discuss your issue.
  - www.sp-eng.co.uk
  - info@sp-eng.co.uk
- How can SPE help you with your design?