

Why is a DC component generated during a short circuit?

1.0 Two fundamental concepts in electrical engineering explain this clearly:

- a) Current through inductor (L) cannot change instantly, i.e., $L \frac{di}{dt}$ cannot be infinite. $I_{L(t0-)} = I_{L(t0+)}$. $I_{L(t0-)}$ is the current just before an instant of switching like fault and $I_{L(t0+)}$ is the current just after an instant of switching like fault.

In practical power systems, the X/R ratio is much greater than 1, meaning the system is predominantly inductive.

Typical X/R values:

- Transformer: 8 to 10
- Generator: 60 to 100
- Overhead line: 4 to 8

Therefore, when a fault occurs, the resulting fault current is largely reactive.

If a fault occurs at time t_0 , the fault current immediately after the fault must be equal to the pre-fault current to satisfy the inductor current continuity condition.

- b) In a reactive circuit, current lags the voltage by 90° . This is a fundamental principle taught in the first year of engineering.

2.0 Typical short circuit wave form is shown in Fig 1. Assume the pre-fault load current is zero, which does not affect final calculations as explained in fault calculation module. Hence, just after fault inception, the fault current must start from O in figure to satisfy criterion (a) above.

The theoretical Voltage – current relationship for pure inductive circuit is shown as dotted lines before time $t = 0$. Assume that fault occurs exactly when voltage is passing through 0. The AC current must lag the voltage by 90° to satisfy criterion (b) above and start from A in figure.

To satisfy both criteria (a) and (b), DC current OB is induced whose magnitude is equal to OA and of opposite polarity so that net current I_{TOT} is zero. Initial DC current is OB and decay of I_{DC} is shown in green curve in figure. Total current $I_{TOT} = I_{AC} + I_{DC}$. DC component decays exponentially with time.

DC Decay Time Constant:

$$\tau_{DC} = \frac{L}{R} = \frac{X/R}{2\pi f}$$

Example 1: $X / R = 8$.

$$\tau_{DC} = \frac{8}{2\pi f} \approx 25 \text{ ms}$$

The DC component decays to 37% of its initial value within 25 ms.

Example 2: At the generator terminal, $X / R = 60$.

$$\tau_{DC} = \frac{60}{2\pi f} \approx 190 \text{ ms}$$

Here, the DC decay is much slower. It takes about 190 ms to fall to 37% of its initial value.

If the fault occurs when the voltage is at its maximum value:

- The lagging AC current is naturally zero at that instant.
- No additional DC component is required (practically zero).
- The fault current becomes symmetrical.

Thus, the magnitude of the DC component depends on the point-on-wave at which the fault occurs.

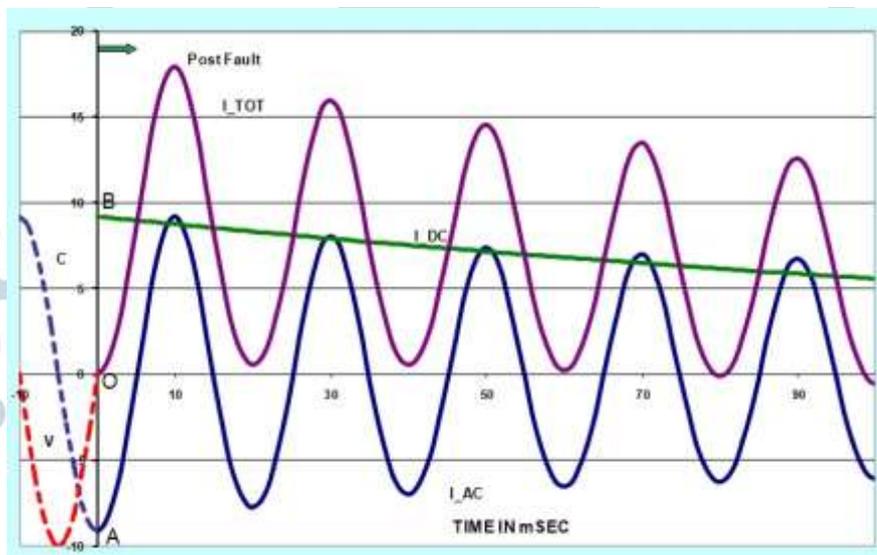


Figure 1

3.0 The expanded view for the first few cycles is shown in Fig 2. At approximately 10 msec (half cycle) after fault inception, the total fault current I_{TOT} is maximum. The Circuit Breaker must be able to dynamically withstand this current and is called Make Duty of Circuit Breaker.

Typical breaker operating time is 2 to 3 cycles (50 to 75 msec). The current at the time of breaking, called Break Duty, depends on the magnitude DC component at the time of breaking. DC component at the time of breaking is usually given

by Circuit Breaker manufacturer and is of the order of 25% to 35%. For GCB it can be much higher.

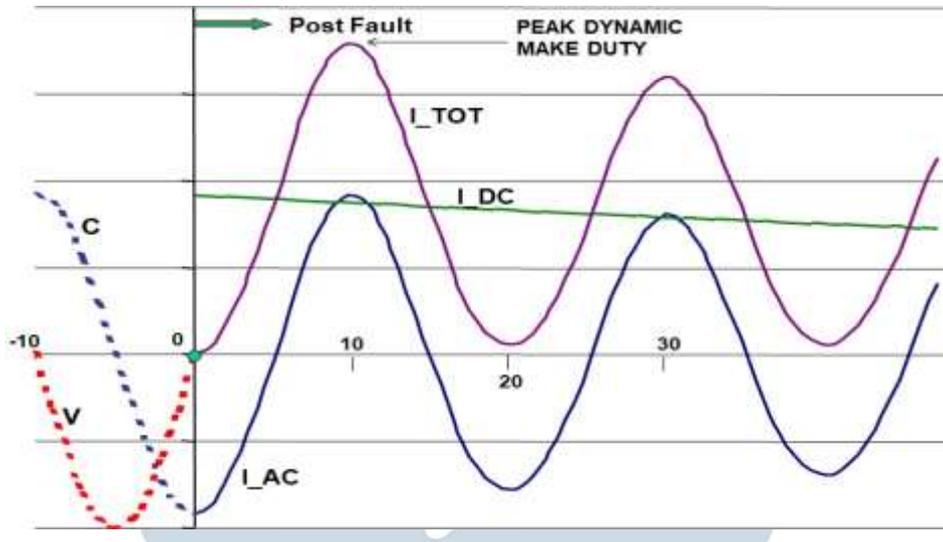


Figure 2

4.0 The advantage of having numerical relay is that the fault current waveforms can be captured and later used for post mortem analysis. One such waveform is shown in Fig 3. Prenc of DC component introduces asymmetry (positive and negative half cycles are not symmetric with respect to time axis) and it is more pronounced on R phase.

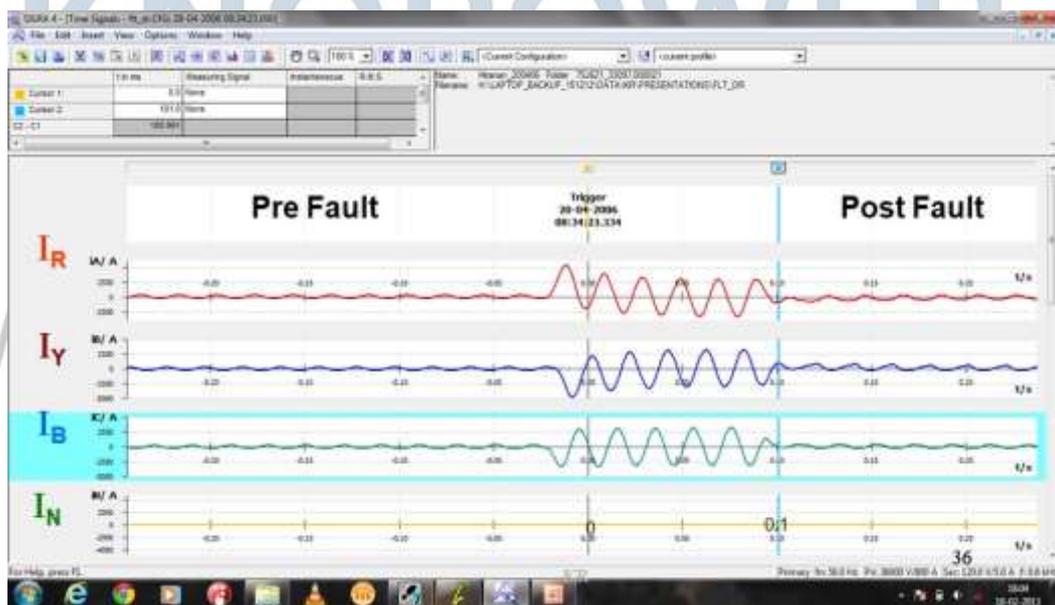


Figure 3

5.0 In conclusion, The DC component during faults is not an anomaly. it is a natural consequence of Inductor current continuity, current lagging voltage by 90° in inductive circuit and Point-on-wave switching. If fault occurs at voltage zero, the DC component is maximum and If fault occurs at voltage maximum, the DC component is practically nil. Decay of DC component depends on X/R ratio.



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