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Understanding
Asymmetrical Interrupting Current

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REV .1

INTRODUCTION:

During SC event, a transient response may produce currents in excess of those encountered either before the fault occurred c after the steady-state condition is achieved. These high currents must be taken into consideration when specifying power syst equipment particularly for circuit breakers when calculated fault levels lie very close to circuit breaker interrupting ratings, a thorough evaluation of the asymmetrical currents involved may become the deciding factor between the right breakers for the .

PURPOSE:

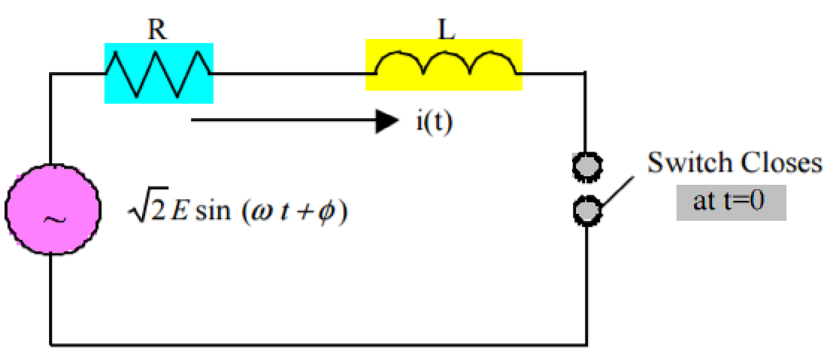
Provide a visualization of the first few cycles of a SC event to understand the phenomenum and hopefully to correlate with the circuit breaker interrupting rating such as: 1) Symmetrical, 2) Asymmetrical, 3) close & Latching.

If the switch is closed at time zero to simulate initiation of the fault and if current values are per-unitized according to the peak symmetrical current (I_o) then the current plot is a function of three independent variables (θ, X/R, and time).

The calculation of the precise magnitude of a short-circuit current at a given time after the inception of a fault is a rather complex computation. Consequently, simplified methods have been developed that yield conservative calculated short-circuit currents that may be compared with the assigned (tested) fault current ratings of various system overcurrentprotective devices.

Equation (1) results from using Kirchhoffs voltage law to sum the voltages around the circuit of Fig. 2 and then solving the resulting nonhomogeneous first order differential equation for current.

$$R \cdot i(t) + L \cdot \left(\frac{d}{dt} i(t)\right) = \sqrt{2} \cdot E(t) \cdot \sin(\omega \cdot t + \phi) \qquad (1)$$



Circuit model for asymmetry

where:

- E *is the rms magnitude of the sinusoidal voltage source*
- i(t) *is the instantaneous current in the circuit at any time after the switch is closed*
- R *is the circuit resistance in ohms*
- L *is the circuit inductance in Henries (= circuit reactance divided by ω)*
- t *is time in seconds*
- φ *is the angle of the applied voltage in radians when the fault occurs*
- ω *is the 2π* f *where* f *is the system frequency in hertz (Hz)*

SOLUTION : Assuming the pre-fault current through the circuit to be zero (i.e., load current $i(0) = 0$), then the instantaneous current solution to above differential Equation is:

$$i = -\frac{\sqrt{2}E}{Z}\sin(\alpha-\phi)e^{-\frac{\omega t R}{X}} + \frac{\sqrt{2}E}{Z}\sin(\omega t+\alpha-\phi) \qquad (2.3)$$

$$i = -i_{dc}\sin(\alpha-\phi)e^{-\frac{\omega R t}{X}} + \sqrt{2}\,I_{ac,\,rms}\sin(\omega t+\alpha-\phi) \qquad (2.4)$$

if time t is expressed in cycles, Equation (2.4) becomes

$$i = -i_{dc}\sin(\alpha-\phi)e^{-\frac{2\pi R t}{X}} + \sqrt{2}\,I_{ac,\,rms}\sin(2\pi t+\alpha-\phi) \qquad (2.5)$$

where

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right) = \tan^{-1}\left(\frac{X}{R}\right)$$

$$X = \omega L \qquad Z = \sqrt{R^2+X^2}$$

Z (~ X if R<<X) is the Thevenin equivalent system impedance (or reactance) from the fault point back to and including the source or sources of short-circuit currents for the electric system

dc component : The first term in Equation (2.3) represents the transient dc component of the solution. The initial magnitude E/Z × sin ($\alpha - \phi$) decays in accordance with the exponentialexpression.

- At time zero ($t := 0$. $i_{dc} = \sqrt{2}\,i_{ac.rms}$) the dc component of fault current is exactly equal in magnitude to the value of the ac fault current component but opposite in sign.
- This condition must exist due to the fact that the initial current in the circuit is zero and the fact that current cannot change instantaneously in the inductive circuit omodel show above.

ac steady-state component is represented by the second term of the solution. Is a sinusoidal function of time

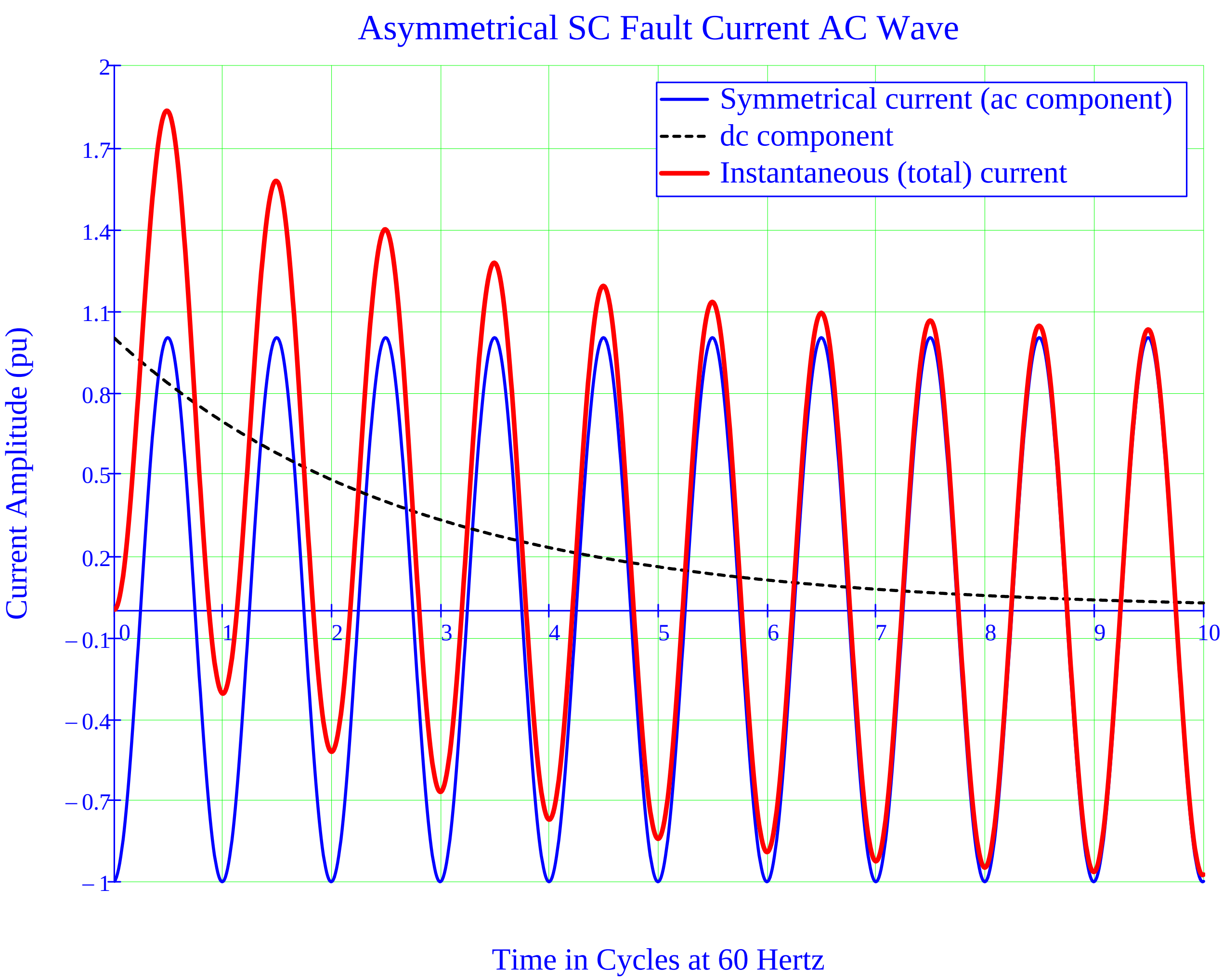
- The ac component crest value is simply the maximum peak value of the supply voltage divided by the magnitude of the Thevenin equivalent system impedance ($\sqrt{2}$ E/Z) as viewed from thefault.
- The difference between the initial fault current magnitude and the final steady-state fault current magnitude depends only on the X/R ratio of the circuit impedance and the phase angle α of the supply voltage when the fault occurs.

Fault Current Evaluation:

1. Symmetrical current (ac component)........ $i_{ac}(t, X/R, \alpha) := 1pu\cdot\sin(2\pi\cdot t + \alpha - \operatorname{atan}(X/R))$
2. dc component.. $i_{dc}(t, X/R, \alpha) := -1pu\cdot\sin(\alpha - \operatorname{atan}(X/R))\cdot e^{-\frac{2\pi\cdot t}{X/R}}$
3. Instantaneous (total current)...................... $i_{tot}(t, X/R, \alpha) := i_{dc}(t, X/R, \alpha) + i_{ac}(t, X/R, \alpha)$

For : >>

$X/R_x := 17$ $\alpha_x := 0deg$ $t := 0, 0.01 .. 10$



Two boundary conditions are considered here as follow:

- **Case 1:** At the time $t_0 := 0$, both current $i(t_0) := 0$ and *voltage* $v(t_0) := 0$. At 0.5 cycles the current finally reaches its maximum value . Not until the voltage goes negative can the current begin to decrease.
- **Case 2:** At the time $t_0 := 0$, the *voltage is at maximum value* ($v(t_0) = V_{max}$). Current wave is symmetrical with regard to current zero (no offset).