EEE- 601
POWER SYSTEM ANALYSIS
Unit-1

Transmission Fault Analysis

- The cause of electric power system faults is insulation breakdown/compromise.
- This breakdown can be due to a variety of different factors:
  - Lightning ionizing air,
  - Wires blowing together in the wind,
  - Animals or plants coming in contact with the wires,
  - Salt spray or pollution on insulators.

Transmission Fault Types

- There are two main types of faults:
  - symmetric faults: system remains balanced; these faults are relatively rare, but are the easiest to analyze so we'll consider them first.
  - unsymmetric faults: system is no longer balanced; very common, but more difficult to analyze (considered in EE 368L).
- The most common type of fault on a three phase system by far is the single line-to-ground (SLG), followed by the line-to-line faults (LL), double line-to-ground (DLG) faults, and balanced three phase faults.

Fault Analysis

- Fault currents cause equipment damage due to both thermal and mechanical processes.
- Goal of fault analysis is to determine the magnitudes of the currents present during the fault:
  - need to determine the maximum current to ensure devices can survive the fault,
  - need to determine the maximum current the circuit breakers (CBs) need to interrupt to correctly size the CBs.

BALANCED THREE PHASE FAULT

- ❖ All the three phases are short circuited to each other and to earth.

- ❖ Voltages and currents of the system balanced after the symmetrical fault occurred. It is enough to consider any one phase for analysis.

SHORT CIRCUIT CAPACITY

- ❖ It is the product of magnitudes of the prefault voltage and the post fault current.
- ❖ It is used to determine the dimension of a bus bar and the interrupting capacity of a circuit breaker.

Short Circuit Capacity (SCC)

$$|SCC| = |V^0||I_F|$$

$$|I_F| = \frac{|V_T|}{|Z_T|}$$

$$|SCC|_{1\phi} = \frac{|V_T|^2}{|Z_T|} = \frac{S_{b,1\phi}}{|Z_T|_{p.u}} MVA/\phi$$

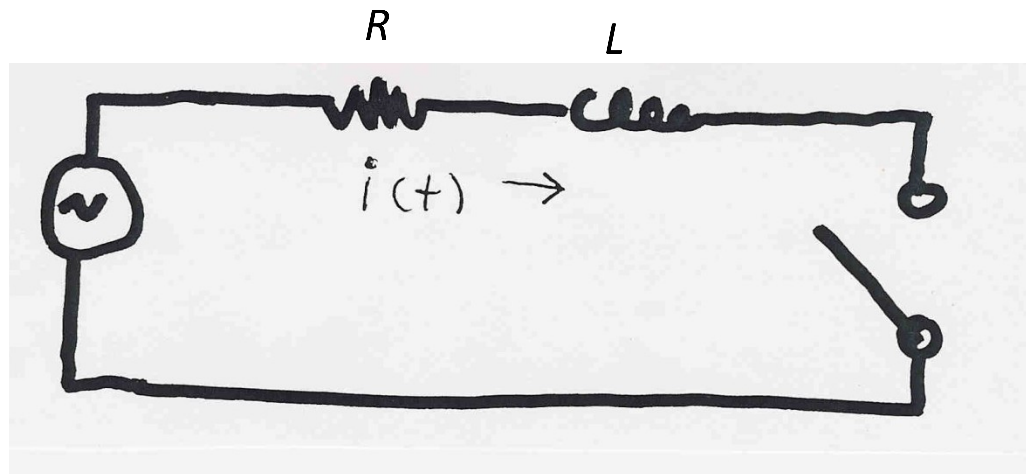
$$|SCC|_{3\phi} = \frac{S_{b,3\phi}}{|Z_T|_{p.u}} MVA$$

$$I_f = \frac{|SCC|_{3\phi} * 10^6}{\sqrt{3} * V_{L,b} * 10^6}$$

RL Circuit Analysis

- To understand fault analysis we need to review the behavior of an *RL* circuit

$$v(t) = \sqrt{2}V\cos(\omega t + \alpha)$$



(Note text uses sinusoidal voltage instead of cos!)
Before the switch is closed, $i(t) = 0$.
When the switch is closed at t=0 the current will have two components: 1) a steady-state value 2) a transient value.

RL Circuit Analysis, cont'd

1. Steady-state current component (from standard phasor analysis)

Steady-state phasor current magnitude is $I_{ac} = \frac{V}{Z}$,

where $Z = \sqrt{R^2 + (\omega L)^2} = \sqrt{R^2 + X^2}$

and current phasor angle is $-\theta_Z$, $\theta_Z = \tan^{-1}(\omega L / R)$

Corresponding instantaneous current is:

$$i_{\text{ac}}(t) = \frac{\sqrt{2} V \cos(\omega t + \alpha - \theta_Z)}{Z}$$

RL Circuit Analysis, cont'd

2. Exponentially decaying dc current component

$$i_{dc}(t) = C_1 e^{-t/T}$$

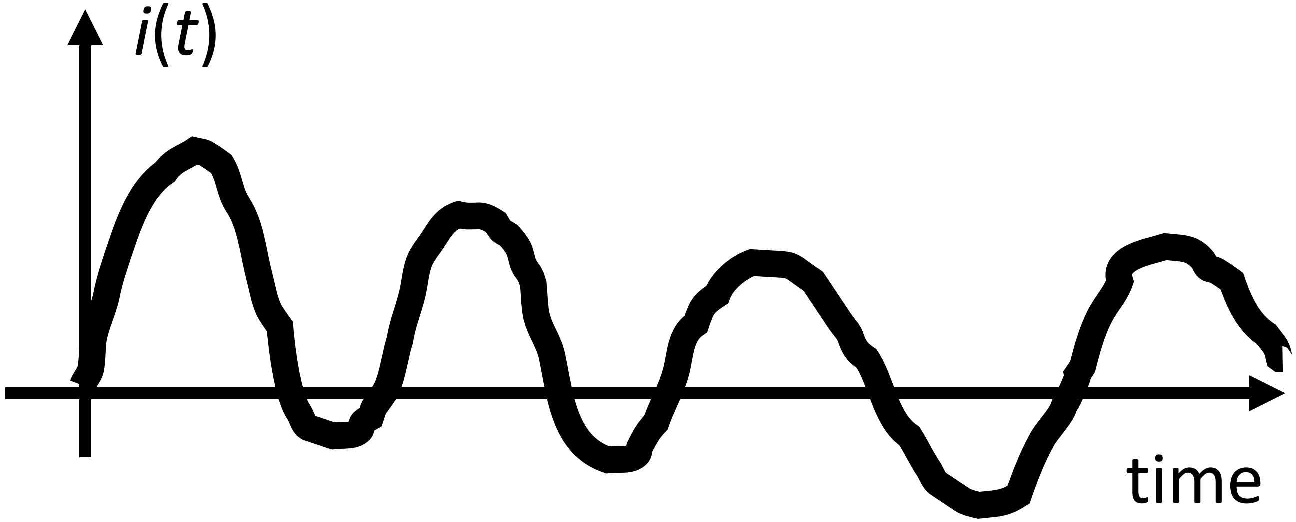
where T is the time constant, $T = L/R$

The value of C_1 is determined from the initial conditions:

$$i(0) = 0 = i_{\text{ac}}(t) + i_{\text{dc}}(t) = \frac{\sqrt{2}V}{Z}\cos(\omega t + \alpha - \theta_Z) + C_1 e^{-t/T}$$

$$C_1 = -\frac{\sqrt{2}V}{Z}\cos(\alpha - \theta_Z) \quad \text{which depends on } \alpha$$

Time varying current



Superposition of steady-state component and exponentially decaying dc offset.

RL Circuit Analysis, cont'd

Hence $i(t)$ is a sinusoidal superimposed on a decaying dc current. The magnitude of $i_{\text{dc}}(0)$ depends on when the switch is closed. For fault analysis we're just concerned with the worst case.

Highest DC current occurs for: $\alpha = \theta_Z - \pi, C_1 = \frac{\sqrt{2}V}{Z}$

$$i(t) = i_{ac}(t) + i_{dc}(t)$$

$$i(t) = -\frac{\sqrt{2}V}{Z}\cos(\omega t) + \frac{\sqrt{2}V}{Z}e^{-t/T}$$

$$= \frac{\sqrt{2}V}{Z}(-\cos(\omega t) + e^{-t/T})$$

RMS for Fault Current

The interrupting capability of a circuit breaker is specified in terms of the RMS current it can interrupt.

The function $i(t) = \frac{\sqrt{2}V}{Z}(-\cos(\omega t) + e^{-t/T})$ is not periodic, so we can't formally define an RMS value.

However, if T □ ve can approximate the current as a sinusoid plus a time-invarying dc offset.

The RMS value of such a current is equal to the square root of the sum of the squares of the individual RMS values of the two current components.

RMS for Fault Current

$$\mathrm{I}_{\mathrm{RMS}} = \sqrt{I_{ac}^2 + I_{dc}^2},$$

$$\text{where } I_{ac} = \frac{V}{Z}, I_{dc} = \frac{\sqrt{2}V}{Z} e^{-t/T} = \sqrt{2} I_{ac} e^{-t/T},$$

$$= \sqrt{I_{ac}^2 + 2I_{ac}^2 e^{-2t/T}}$$

This function has a maximum value of $\sqrt{3}\, I_{ac}$. Therefore the worst case effect of the dc component is included simply by multiplying the ac fault currents by $\sqrt{3}$.

Generator S.C. Example, cont'd

Substituting in the values

$$I_{ac}(t) = 1.05\left[\frac{1}{1.1} + \left(\frac{1}{0.24} - \frac{1}{1.1}\right)e^{-t/2.0} + \left(\frac{1}{0.15} - \frac{1}{0.24}\right)e^{-t/0.035}\right]$$

$$I_{ac}(0) = 1.05/0.15 = 7 \text{ p.u.}$$

$$I_{base} = \frac{500\times10^6}{\sqrt{3}\,20\times10^3} = 14,433 \text{ A} \quad I_{ac}(0) = 101,000 \text{ A}$$

$$I_{DC}(0) = 101 \text{ kA} \times \sqrt{2}\, e^{t/0.2} = 143 \text{ k A} \quad I_{RMS}(0) = 175 \text{ kA}$$

Thank you