Surge Impedance Loading (SIL)

Surge impedance loading (SIL) of a transmission line is the MW loading of a transmission line at which natural power balance occurs. The following brief article explains the concept of SIL.

Transmission lines produce reactive power (MVar) due to their natural capacitance. The amount of MVar produced is dependent on the transmission line's capacitive reactance (X_C) and the voltage (kV) at which line is energized. In equation form the MVar produced by a transmission line is:

$$\text{MVar}_{\text{Produced}} = \frac{V^2}{X_C}$$

Transmission lines also use reactive power to support their magnetic fields. Magnetic field strength is dependent on the magnitude of the current flow through the line and the line's natural inductive reactance (X_L). It follows that the amount of MVar used by a transmission line is a function of current flow and inductive reactance. In equation form the MVar used by a transmission line is:

$$\text{MVar}_{\text{Used}} = I^2 X_L$$

A transmission line's SIL is the MW loading (at unity power factor) at which the line's MVar usage is equal to the line's MVar production. In equation form SIL occurs when:

$$\text{MVar}_{\text{Used}} = \text{MVar}_{\text{Produced}}$$

$$I^2 X_L = \frac{V^2}{X_C}$$

Rearranging terms:

$$X_L X_C = \frac{V^2}{I_2}$$

If the square root of both sides of the above equation is taken and then substitute in the formulas for $X_L = (2\pi f L)$ and $X_C = 1/2\pi f L$ arrive at:

$$\sqrt{\frac{2\pi f L}{2\pi f C}} = \sqrt{\frac{V^2}{I^2}}$$

Rearranging variables yields:

$$\frac{V}{I} = \text{Impedance} = \sqrt{\frac{L}{C}} = \text{Surge Impedance}$$

The term $\sqrt{\frac{L}{C}}$ in the above equation is called the "surge impedance". The significance of the surge impedance is that if a purely resistive load that is equal to surge impedance were connected to the end of a transmission line with no resistance a voltage surge introduced to the sending end of the line would be absorbed completely at the receiving end. The voltage at the receiving end would have the same magnitude as the sending end voltage and would have a phase angle that is lagging with respect to the sending end by an amount equal to the time required to travel across the line from sending to receiving end.

The concept of a surge impedance is more readily applied to telecommunication systems than to power systems. However, we can extend the concept to the power transferred across a transmission line. The surge impedance loading or SIL (in MW) is equal to the voltage squared (in kV) divided by the surge impedance (in ohms). In equation form:

$$\text{SIL (in MW)} = \frac{\text{kV}_{\text{L-L}}^2}{\text{Surge Impedance}}$$

Note in this formula that SIL is dependent only on the kV the line is energized at and the line's surge impedance. The line length is not a factor in the SIL or surge impedance calculations. Therefore the SIL is not a measure of a transmission line's power transfer capability as it does not take into account the line's length nor does it consider the strength of the local power system.

The value of SIL to a System Operator is realizing that when a line is loaded above its SIL it acts like a shunt reactor – absorbing MVar from the system – and when a line is loaded below its SIL it acts like a shunt capacitor – supplying MVar to the system.

Figure 1 contains a graphic of the concept of SIL. This particular line has an SIL of 450 MW. Therefore if the line is loaded to 450 MW (with no MVar) flow, the MVar produced by the line will exactly balance MVar used by the line.

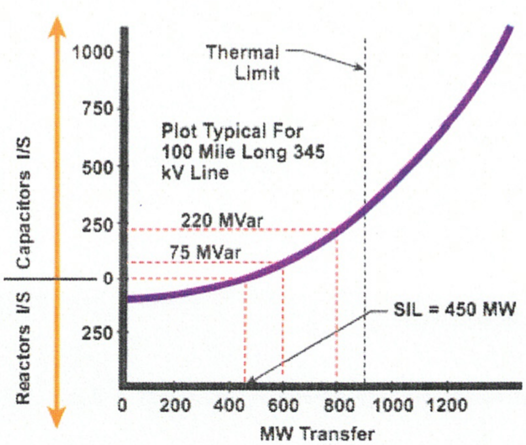

Figure 1
Surge Impedance Loading of a Transmission Line