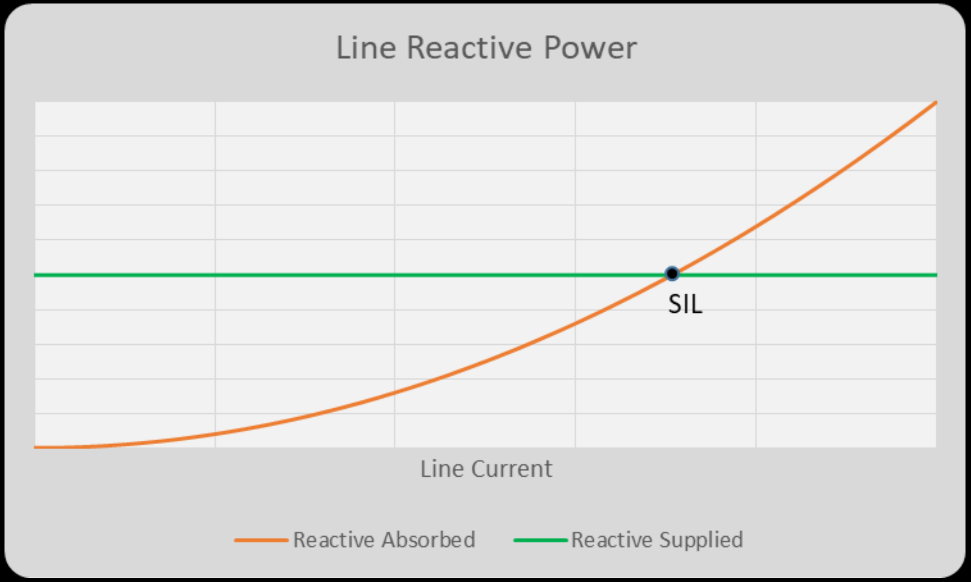
Surge Impedance and Surge Impedance Loading for Power Transmission Lines

If a transmission line is terminated with it's Surge Impedance…
The reactive power supplied by the line charging capacitance is equal to the reactive power absorbed by the line inductance.
Another way to say it: The line would be purely resistive…
sending end reactive = receiving end reactive
First… a conceptual look:



$$reacive\ power\ supplied = \frac{V^2}{X_c} = V^2 B$$
$$since\ voltage\ does\ not\ change\ much\ with\ current\ \ldots$$
$$reactive\ power\ suppled\ is\ relatively\ constant.$$
$$reacive\ power\ absorbed = I^2 X_L$$

Surge Impedance (Zo) is the Line's load impedance when reactive power supplied = reactive power absorbed.
So…

$$reacive\ power\ supplied = reacive\ power\ absorbed:$$
$$\frac{V^2}{X_c} = I^2 X_L$$
$$X_L X_c = \frac{V^2}{I^2}$$
$$but: \frac{V}{I} = impedance\ or\ surge\ impedance\ (Z_o)\ in\ this\ case$$
$$X_L X_c = Z_o^2$$
$$Z_o = \sqrt{X_L X_c} = \sqrt{\frac{\omega L}{\omega C}} = \sqrt{\frac{L}{C}} = \sqrt{\frac{X}{B}} \quad (independant\ of\ line\ length)$$

$$SIL \triangleq \frac{V^2}{Z_o} = V^2\sqrt{\frac{C}{L}} = V^2\sqrt{\frac{B}{X}}$$
$$if\ considering\ per\ unit:$$
$$SIL_{pu} = V_{pu}^2\sqrt{\frac{B_{pu}}{X_{pu}}}$$
$$since\ V_{pu} \approx 1.0$$
$$SIL_{pu} \approx \sqrt{\frac{B_{pu}}{X_{pu}}}$$

<-- This is a good approximation of SIL

SIL = MVA when line impedance is net resistive.

Bundling conductors will dramatically increase SIL

How line length and resistance impact Surge Impedance and max line loading…

As previously shown… Surge Impedance (and SIL) is independent of line length.
series inductance and shunt capacitance determines the Surge Impedance (and SIL).
However, regarding max line loading…
If the line is a short line (length < 50mi), the line will be thermally limited.
If the line is a medium line (50mi < length < 200mi)… it could be limited to less than the thermal limit without bundling, shunt and/or series compensation.
if you have a long line (length >200mi)… it will likely be stability limited and the limit could actually be less than the SIL.

some transmission line theory….
understand that line length is NOT physical length.
line length is electrical length or wavelength.
from communications 101, you know that:

$$f\lambda = V_p$$

$$where:$$

$$f = frequency\ of\ the\ signal$$

$$\lambda = wavelength\ (electrical\ length)$$

$$V_p = velocity\ of\ propogation$$

$$V_p \approx c = speed\ of\ light = 3 \cdot 10^8 \frac{m}{s}\ or\ 186282 \frac{mi}{s}$$

$$\therefore one\ wavelength\ of\ a\ line\ operating\ at\ 60Hz\ is\ 3105mi\ (5000km) \ldots \frac{1}{8} the\ circumference\ of\ the\ earth.$$

from the definition above:
short line < 1/64 wavelength
medium line 1/64 < wavelength < 1/16
long line > 1/16 wavelength

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Questions or Comments …

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