TRANSMISSION LINE (G042-2 + 4269T)

TRANSMISSION LINE IS A DEVICE TO GUIDE ELECTRICAL ENERGY FROM ONE POINT TO ANOTHER.

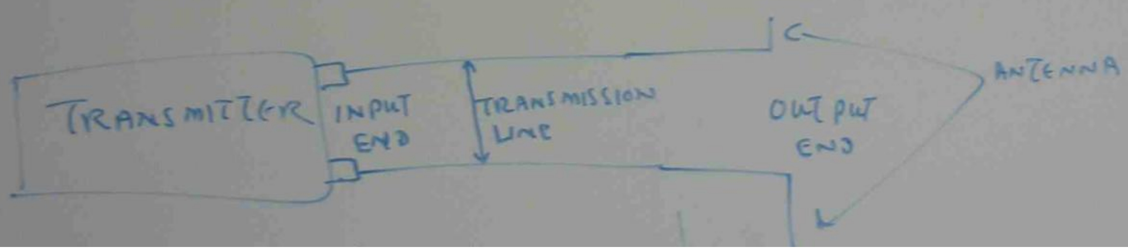
A TRANSMISSION LINE IS THE CONNECTION BETWEEN ELEMENTS THAT CARRY SIGNAL POWER

INPUT END

CONNECTION TO GENERATOR / TRANSMITTER

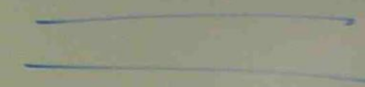
OUTPUT END

CONNECTION TO LOAD / RECEIVER



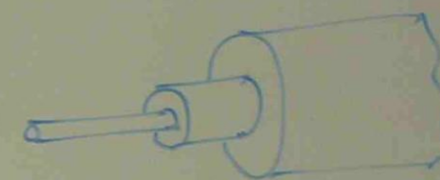
TYPES OF TRANSMISSION LINES

OPEN WIRE LINE – CONSISTING OF TWO PARALLEL WIRES



TWISTED PAIR LINE – TWO INSULATED WIRES TWISTED TOGETHER

CONCENTRIC/COAXIAL CABLE – CENTRAL WIRE CARRIES SIGNAL
OUTER SHEATH ACTS AS RETURN PATH



TRANSPOSITION OF LINE

TRANSPOSING – LINE SHALL BE ELECTRICALLY SYMMETRICAL WITH RESPECT TO IT'S SURROUNDINGS.

SHIELD PAIR CABLE

SHIELD PAIR CABLE CONTAINS TWO WIRES SURROUNDED AND SEPARATED BY A SOLID DIELECTRIC

- SUITABLE FOR LOW BIT RATE COMMUNICATION.

COAXIAL CABLE

FOR LONG DISTANCE (OR) DATA RATE IN EXCESS OF SEVERAL M BYTE/SEC) COAXIAL CABLE IS USED.

THE USE OF A PARTICULAR KIND OF TRANSMISSION LINE CABLE IS LIMITED BY

(1) RESISTANCE LOSS

(2) DIELECTRIC LOSS

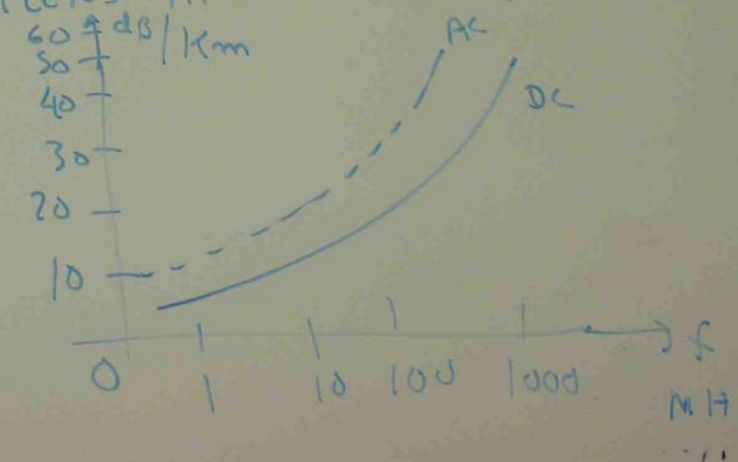
(3) RADIATION LOSS

THE ATTENUATION VALUES OF COAXIAL CABLE

10 dB/km AT 10 KHZ

50 dB/km AT 500 MHZ

FOR VERY LONG ROUTES, REPEATERS AND EQUALIZERS ARE NECESSARY.



MAXIMUM TRANSFER OF ELECTRICAL ENERGY

THE MAXIMUM (AND MOST EFFICIENT) TRANSFER OF ELECTRICAL ENERGY TAKES PLACE WHEN THE SOURCE IMPEDANCE IS MATCHED TO THE LOAD IMPEDANCE.

IF THE CHARACTERISTIC IMPEDANCE OF THE TRANSMISSION LINE AND LOAD IMPEDANCE ARE EQUAL, ENERGY FROM THE TRANSMITTER WILL TRAVEL DOWN THE TRANSMISSION LINE TO ANTENNA WITH NO POWER LOSS CAUSED BY REFLECTION.

CHARACTERISTIC IMPEDANCE (Z_0)

$$Z_0 = \frac{E}{I}$$ AT EVERY POINT ALONG THE LINE.

$\longrightarrow$

INPUT IMPEDANCE Z_0 | MAX POWER TRANSFER | LOAD IMPEDANCE Z_0

SURGE IMPEDANCE LOADING (SIL)

SURGE IMPEDANCE LOADING (SIL) OCCURS WHEN <REACTIVE POWER IS NEITHER PRODUCED NOR ABSORBED>

MVAR PRODUCED = MVAR USED

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

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

$$\left(Z_{\text{SURGE IMPEDANCE}}\right)^2 = \frac{1}{2\pi f C} \times 2\pi f L$$

$$Z_{\text{SURGE}}^2 = \frac{L}{C}$$

$$Z_{\text{SURGE}} = \sqrt{\frac{L}{C}}$$

V = THE VOLTAGE AT WHICH THE LINE IS ENERGIZED

X_C = LINE CAPACITIVE REACTANCE

X_L = LINE NATURAL INDUCTIVE REACTANCE

I = LINE CURRENT

SIGNIFICANCE OF SURGE IMPEDANCE

- PURELY RESISTIVE LOAD THAT IS EQUAL TO SURGE IMPEDANCE IS CONNECTED TO THE END OF LINE
- VOLTAGE AT RECEIVING END HAS THE SAME MAGNITUDE AS THE SENDING END.

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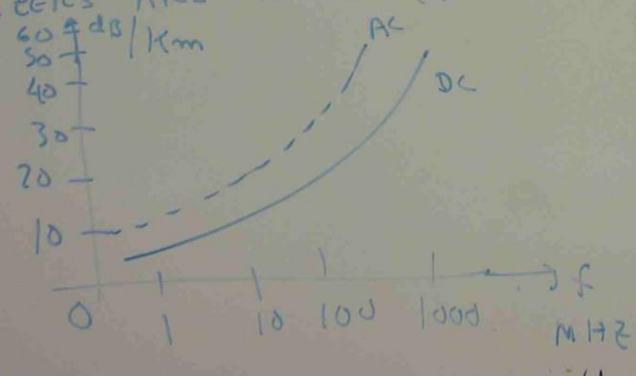

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Z_0	$\longrightarrow$	Z_0

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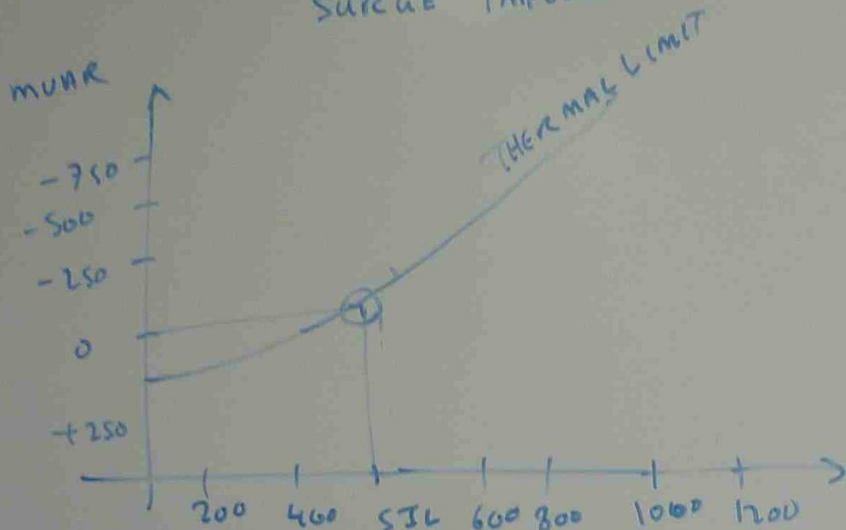
$$SIL\ (MW) = \frac{kV_{L-L}^2}{\text{SURGE IMPEDANCE}}$$



- WHEN A LINE IS LOADED ABOVE IT'S SIL IT ACTS LIKE A SHUNT REACTOR - ABSORBING MVAR FROM THE SYSTEM (ABSORB REACTIVE POWER TO DEPRESS SYSTEM VOLTAGE)
- WHEN A LINE IS LOADED BELOW IT'S SIL LIKE A SHUNT CAPACITOR - SUPPLYING MVAR TO THE SYSTEM. (SUPPLYING LAGGING POWER TO SYSTEM)

LONG & SHORT TRANSMISSION LINES

DC/ LOW FREQUENCY AC CIRCUIT – CHARACTERISTIC IMPEDANCE OF PARALLEL WIRE IS USUALLY IGNORED.

LINE CONNECTED TO DC SOURCE – BEHAVE AS RESISTOR

LOW FREQUENCY AC POWER – VOLTAGE ALONG ALL RESPECTIVE POINTS ON A LOW FREQUENCY LINE ARE EQUAL & INPHASED WITH EACH OTHER AT ANY POINT IN TIME.

WAVE LENGTH AND VELOCITY

$$\lambda = \frac{v}{f}$$

λ = WAVE LENGTH

v = VELOCITY OF PROPAGATION

f = FREQUENCY OF SIGNAL

SHORT LINE – LINE ACTS AS RESISTOR

LONG LINE – LINE'S OWN CHARACTERISTIC IMPEDANCE DOMINATES OVER LOAD IMPEDANCE IN DETERMINING CIRCUIT BEHAVIOUR.

PROPAGATION CONSTANT

γ = PROPAGATION CONSTANT

α = REAL PART (ATTENUATION CONSTANT)

β = IMAGINARY PART (PHASE CONSTANT)

$$\gamma = \alpha + i\beta \qquad i = \sqrt{-1}$$

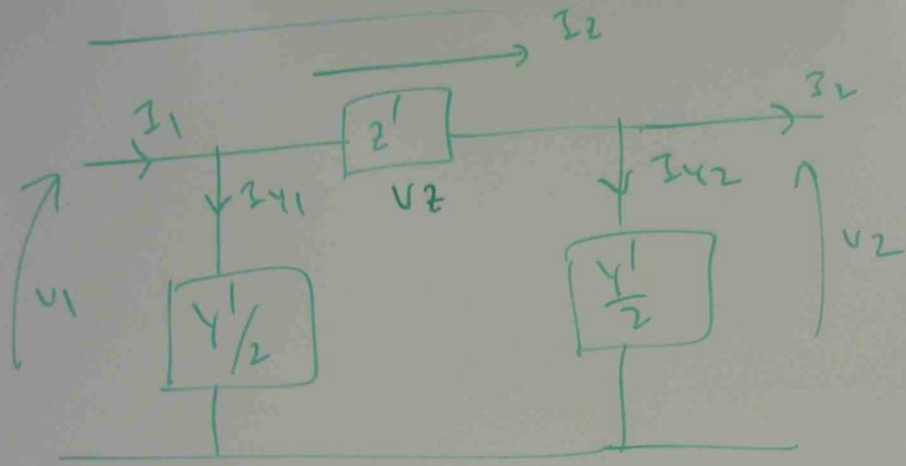
$$\frac{V_1}{V_2} = \frac{I_1}{I_2} = e^{\gamma}$$

$$\frac{I_1}{I_2} \times \frac{I_2}{I_3} \times \frac{I_{n-1}}{I_n} = \frac{I_1}{I_n}$$

$$e^{\gamma_1} \times e^{\gamma_2} \times e^{\gamma_3} = e^{\gamma}$$

$$\gamma_1 + \gamma_2 + \gamma_3 + \ldots = \gamma$$

LINE MODEL & SIL



$$V_1 = V_2 \cosh \gamma L + Z_c I_c \sinh \gamma L$$

$$I_1 = I_2 \cosh \gamma l + \frac{VZ}{Z_c} \sinh \gamma L$$

$$\sinh \gamma l = \gamma l + \frac{(\gamma l)^3}{3!} + \frac{(\gamma l)^5}{5!} + \frac{(\gamma l)^7}{7!}$$

$3! = 3 \times 2 \times 1$, $5! = 5 \times 4 \times 3 \times 2 \times 1$

$$\tanh \gamma l = \gamma l - \frac{(\gamma l)^3}{3} + \frac{2(\gamma l)^5}{15} - \frac{17(\gamma l)^7}{315}$$

$$\tanh \gamma l = \frac{\sinh \gamma l}{\cosh \gamma l}$$

$$\cosh \gamma l = \frac{\tanh \gamma l}{\sinh \gamma l}$$

l = LENGTH OF THE LINE

γ = PROPAGATION CONSTANT

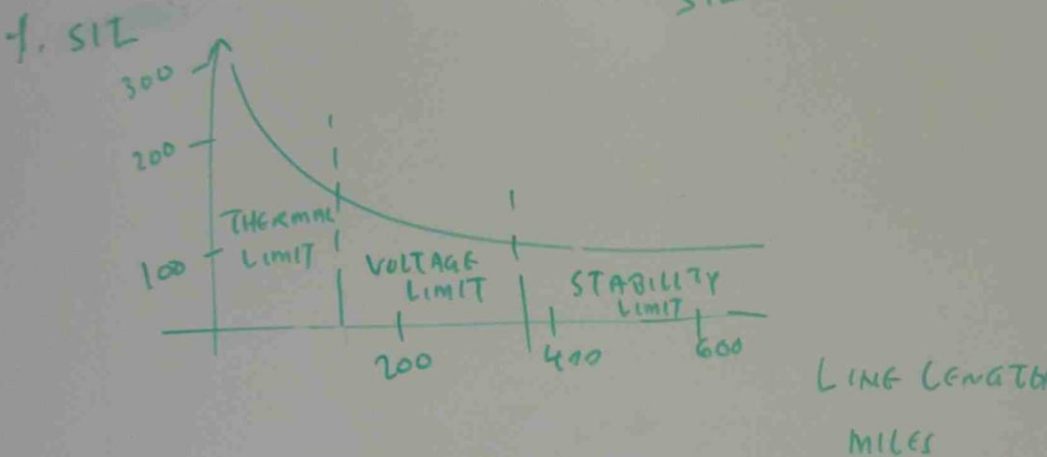
$Z_c = \sqrt{\frac{L}{C}}$ = CHARACTERISTICS IMPEDANCE

$$Z' = Z_c \sinh \gamma l$$

$$Y' = \frac{2}{Z_c} \tanh \frac{\gamma l}{2}$$

P_{IL} = SURGE IMPEDANCE LOADING POWER $= \dfrac{|V_1|^2}{Z_c}$ (1ϕ)

$$P_{SIL\ 3\phi} = \frac{|V_{1\,LL}|^2}{Z_c}$$



- ✱ POWER LIMIT DECREASES WITH LINE LENGTH
- ✱ SHORT LINES ARE LIMITED BY THERMAL PROBLEMS
- ✱ MEDIUM LINES TEND TO BE LIMITED BY VOLTAGE RELATED PROBLEMS
- ✱ VERY LONG LINES ARE LIMITED BY STABILITY PROBLEMS.

COMPLEX POWER

$$V_1 = |V_1| \, e^{j\theta_1}$$

$$V_2 = |V_2| \, e^{j\theta_2}$$

$$z' = |z'| \, e^{j\angle z'}$$

SERIES IMPEDANCE

S_{12} = COMPLEX POWER FLOW FROM SENDING END TO RECEIVING END.

$$S_{12} = V_1 \, I_z^* + |V_1|^2 \left(\frac{Y'}{2}\right)^*$$

$$I_t = 3 + \tilde{j}4$$

$$I_t^* = 3 - \tilde{j}4$$

BUT

$$I_Z = \frac{V_1 - V_2}{Z'}$$

$$S_{12} = V_1 \left(\frac{V_1 - V_2}{Z'} \right)^* + |V_1|^2 \left(\frac{Y'}{2} \right)^*$$

$$S_{12} = \frac{V_1 V_1^* - V_1 V_2^*}{(Z')^*} + |V_1|^2 \left(\frac{Y'}{2} \right)^*$$

$$S_{12} = \frac{|V_1|^2}{Z'^*} - \frac{|V_1||V_2| \, e^{j\theta_{12}}}{Z'^*} + |V_1|^2 \left(\frac{Y'}{2} \right)^*$$

REAL POWER $(P_{12}) = \dfrac{|V_1|\,|V_2| \sin \theta_{12}}{Z_c \sin \beta l}$ (OR) $\dfrac{|V_1|\,|V_2| \sin \theta_{12}}{X}$

REACTIVE POWER $(Q_{12}) = \dfrac{|V_1|^2}{X} - \dfrac{|V_1|\,|V_2| \cos \theta_{12}}{X}$

BALANCED LINE

TWO CENTER CONDUCTORS FOR SIGNAL SURROUNDED BY SHIELD

UNBALANCED LINE

SIGNAL IS CARRIED BY CENTRAL CONDUCTOR AND RETURNED BY OUTER SHIELD.