

Date
16/08/19

UNIT - III

LONG TRANSMISSION LINES

* Long transmission lines:-

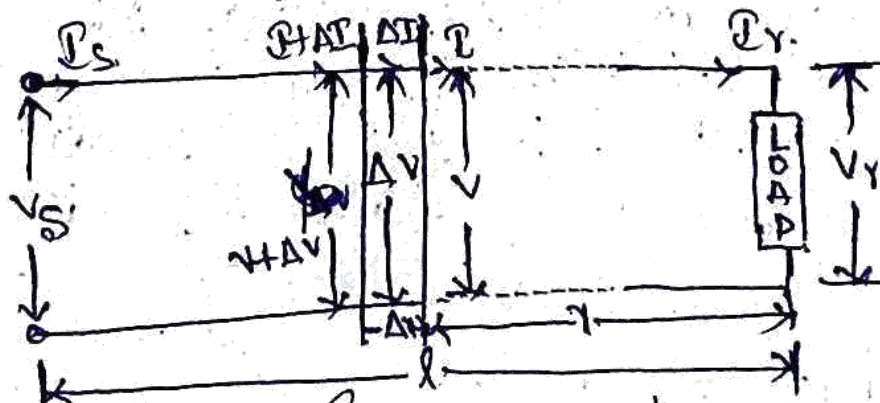
→ If length of line is > 160 km and operating voltage is > 100 kV. These kind of lines is known as long transmission lines.

→ The performance of transmission lines are using Regorius Method.

* The Performance Of Transmission lines Using Regorius Solution:-

→ This Method gives accuracy of Results for long transmission lines.

→ The Equivalent ckt for long transmission line as shown in below fig.



→ Let " Z " Series impedance per unit length

→ Let " Y " Shunt Admittance /unit length

* l = length of the line.

* $Z = z \cdot l$ = Total Series impedance of line.

* $Y = y \cdot l$ = Total Shunt Admittance of line.

→ Let us consider a very small element of length " Δx " at a distance of " x " m from the Receiving End of the line.

→ The Voltage and Current at a distance " x " m from the receiving End of line = V, I .

→ The Voltage and Current at a distance of " $x + \Delta x$ " is equals to $V + \Delta V, I + \Delta I$ from the single line diagram.

* Change in voltage = $\Delta V = I \cdot z \cdot \Delta x$

$$\Rightarrow \frac{\Delta V}{\Delta x} = I \cdot z \Rightarrow \frac{dV}{dx} = I \cdot z \quad \text{--- (1)}$$

* Change in Current = $\Delta I = V \cdot y \cdot \Delta x$

$$\Rightarrow \frac{\Delta I}{\Delta x} = V \cdot y \Rightarrow \frac{dI}{dx} = V \cdot y \quad \text{--- (2)}$$

* differentiate Eqn (1) →

$$\frac{d^2 V}{dx^2} = z \cdot \frac{dI}{dx}$$

$$\frac{d^2 V}{dx^2} = Z \cdot V \Rightarrow \frac{d^2 V}{dx^2} - Z V = 0.$$

the solution for above Eqn is

$$V = A e^{\sqrt{Y/Z} \cdot x} + B e^{-\sqrt{Y/Z} \cdot x} \rightarrow (3)$$

$$\frac{dV}{dx} = A \sqrt{Y/Z} \cdot e^{\sqrt{Y/Z} \cdot x} - B \sqrt{Y/Z} \cdot e^{-\sqrt{Y/Z} \cdot x}$$

from Eqn ①, $\frac{dV}{dx} = I Z$

$$I = A \sqrt{Y/Z} \cdot e^{\sqrt{Y/Z} \cdot x} - B \sqrt{Y/Z} \cdot e^{-\sqrt{Y/Z} \cdot x}$$

Here $\sqrt{Y/Z} = \frac{1}{Z_c} = \text{Characteristic Impedance.}$

$\sqrt{Y/Z} = \gamma = \text{propagation Constant.}$

$$I = A \times \frac{1}{Z_c} e^{+\gamma x} - B \times \frac{1}{Z_c} e^{-\gamma x} \rightarrow (4)$$

$\Rightarrow$ from Eqn ③ & ④

$$V = A e^{\sqrt{Y/Z} \cdot x} + B e^{-\sqrt{Y/Z} \cdot x}$$

$$V = A e^{\gamma x} + B e^{-\gamma x} \rightarrow (5)$$

$$I = A/Z_c e^{\gamma x} - B/Z_c e^{-\gamma x} \rightarrow (6)$$

Taking the Voltage and Current Equations at receiving End i.e., at $x=0$.

then, $V = V_r$, $I = I_r$.

$$V_r = A+B \quad ; \quad I_r = \frac{1}{Z_c} (A-B)$$

$$V_r = A+B \quad ; \quad I_r Z_c = (A-B)$$

Solving the above Equations,

$$V_r = A+B$$

$$I_r Z_c = A-B$$

$$V_r + I_r Z_c = 2A$$

$$\Rightarrow A = \frac{V_r + I_r Z_c}{2}$$

$$\therefore V_r = A+B \Rightarrow \frac{V_r + I_r Z_c}{2} + B$$

$$B = V_r - \frac{V_r + I_r Z_c}{2}$$

$$B = \frac{V_r - I_r Z_c}{2}$$

Substitute A, B Constants in (5) & (6)

$$V = \left(\frac{V_r + I_r Z_c}{2} \right) e^{\gamma x} + \left(\frac{V_r - I_r Z_c}{2} \right) e^{-\gamma x}$$

$$I = \frac{1}{Z_c} \left(\frac{V_r + I_r Z_c}{2} \right) e^{\gamma x} - \frac{1}{Z_c} \left(\frac{V_r - I_r Z_c}{2} \right) e^{-\gamma x}$$

$$\therefore V = \left(\frac{e^{\gamma x} + e^{-\gamma x}}{2} \right) V_r + Z_c \left(\frac{e^{\gamma x} - e^{-\gamma x}}{2} \right) I_r$$

$$I = \left(\frac{e^{\gamma x} - e^{-\gamma x}}{2} \right) V_r + \frac{1}{Z_c} \left(\frac{e^{\gamma x} + e^{-\gamma x}}{2} \right) I_r$$

Here, $\frac{e^{\gamma x} + e^{-\gamma x}}{2} = \cosh \gamma x$; $\frac{e^{\gamma x} - e^{-\gamma x}}{2} = \sinh \gamma x$.

$$\therefore V = \cosh \gamma x V_r + Z_c \sinh \gamma x \cdot I_r$$

$$I = \frac{1}{Z_c} \sinh \gamma x V_r + \cosh \gamma x \cdot I_r$$

Taking the length upto Sending End i.e. $x = l$.

$$V = V_s ; I = I_s$$

$$\therefore V_s = \cosh \gamma l V_r + Z_c \sinh \gamma l I_r \rightarrow \textcircled{7}$$

$$\therefore I_s = \frac{1}{Z_c} \sinh \gamma l V_r + \cosh \gamma l I_r \rightarrow \textcircled{8}$$

→ from Eqn $\textcircled{7}$ & $\textcircled{8}$ →

$$\boxed{\begin{aligned} A = D &= \cosh \gamma l \\ B &= Z_c \sinh \gamma l, \quad C = \frac{1}{Z_c} \sinh \gamma l \end{aligned}}$$

$$\rightarrow \% \text{ Voltage Regulation} = \frac{\text{No load voltage} - \text{full load}}{\text{full load voltage}} \times 100$$

$$V_s = A V_r + B I_r \text{ at No load.}$$

$$I_r = 0 \Rightarrow V_s = A V_r \text{ (No load).}$$

$$V_r (\text{No load}) = V_s / A$$

$$\boxed{\% \text{ V. R} = \frac{V_s / A - V_r}{V_r} \times 100}$$

17/08/19

* ABCD Constant using.

1. Convergent Series Real angle Method.
2. Convergent Series Complex angle Method.

(i) :-

→ In this method hyperbolic Cosines are Expressed by the trigonometric formula.

→ using this the line Constant are Calculated as follows.

We know that,

$$A = D = \cosh \gamma l$$

$$B = Z_0 \sinh \gamma l$$

$$C = \frac{1}{Z_0} \sinh \gamma l.$$

$$\text{Here } \gamma = \sqrt{Y Z} = \alpha + j\beta$$

$$\cosh \gamma l = \cosh (\alpha + j\beta) l.$$

$$= (\cosh \alpha \cosh j\beta l + \sinh \alpha \sinh j\beta l) + j\beta l \sinh \alpha \cosh j\beta l.$$

$$\text{here, } \cosh j\beta l = \cosh \beta l.$$

$$\sinh j\beta l = j \sinh \beta l.$$

$$\therefore \cosh \alpha = \cosh(\alpha + j\beta) = \cosh \alpha \cosh \beta + j \sinh \alpha \sinh \beta$$

$$\text{ii) } \sinh \alpha = \sinh(\alpha + j\beta)$$

$$= \sinh \alpha \cosh \beta + j \cosh \alpha \sinh \beta$$

Here,

$$\cosh j\beta = \cosh \beta, \quad \sinh j\beta = j \sinh \beta$$

$$\therefore \sinh(\alpha + j\beta) = \sinh \alpha \cosh \beta + j \cosh \alpha \sinh \beta$$

$$\therefore A = D = \cosh \alpha = \cosh \alpha \cosh \beta + j \sinh \alpha \sinh \beta$$

$$B = z_c \sinh \alpha = z_c [\sinh \alpha \cosh \beta + j \cosh \alpha \sinh \beta]$$

$$C = \frac{1}{z_c} \sinh \alpha = \frac{1}{z_c} [\sinh \alpha \cosh \beta + j \cosh \alpha \sinh \beta]$$

(ii) Convergent Series Complex angle Method:-

We know that,

$$A = D = \cosh \alpha$$

$$B = z_c \sinh \alpha$$

$$C = \frac{1}{z_c} \sinh \alpha$$

$$\text{Let } \boxed{\alpha = 0}$$

$$A = D = \cosh 0, \quad B = z_c \sinh 0, \quad C = \frac{1}{z_c} \sinh 0$$

$$\begin{aligned}
 \therefore \cosh z &= 1 + \frac{z^2}{2!} + \frac{z^4}{4!} + \frac{z^6}{6!} + \dots \\
 &= 1 + \frac{(\sqrt{4z})^2}{2!} + \frac{(\sqrt{4z})^4}{4!} + \frac{(\sqrt{4z})^6}{6!} + \dots \\
 &= 1 + \frac{4z}{2!} + \frac{(4z)^2}{4!} + \dots
 \end{aligned}$$

$$\begin{aligned}
 \therefore \sinh z &= z + \frac{z^3}{3!} + \frac{z^5}{5!} + \frac{z^7}{7!} + \dots \\
 &= (\sqrt{4z}) + \frac{(\sqrt{4z})^3}{3!} + \frac{(\sqrt{4z})^5}{5!} + \frac{(\sqrt{4z})^7}{7!} + \dots \\
 &= \sqrt{4z} + \frac{4z\sqrt{4z}}{3!} + \dots
 \end{aligned}$$

$$\therefore A = D = \cosh z = 1 + \frac{4z}{2!} + \frac{(4z)^2}{4!} + \dots$$

$$B = z_c \sinh z = z_c \left[\sqrt{4z} + \frac{4z\sqrt{4z}}{3!} + \dots \right]$$

$$C = \frac{1}{z_c} \sinh z = \frac{1}{z_c} \left[\sqrt{4z} + \frac{4z\sqrt{4z}}{3!} + \dots \right]$$

Problems:- 14/08/19

1. A $\underline{3-\phi}$ $\underline{200 \text{ kms}}$ long transmission line has the following constants. $\underline{\text{Resistance/ph/km}} = 0.15 \Omega$, $\underline{\text{Reactance/ph/km}} = 0.2 \Omega$, $\underline{\text{Shunt Admittance/ph/km}} = 1.2 \times 10^{-6} \text{ S}$. Calculate by regulus Method by Sending End voltage and Current when the line is delivering load of $\underline{20 \text{ MW}}$ at $\underline{0.8 \text{ p.f}}$ lagging. at $\underline{110 \text{ kV}}$

Sol:- 19/08/19

Given data,

length (l) = 200 kms.

Resistance (R) = 0.15Ω ,

Reactance = 0.2Ω ,

Shunt Admittance (Y) = $1.2 \times 10^{-6} \text{ S}$.

$P_r = 20 \text{ MW}$

$\cos \phi_r = 0.8$

$V_s = 110 \text{ kV}$.

18/08/19

② A 3- ϕ , 50 Hz 180 km long transmission line. 3- Conductors of each 0.6 cm radius, spaced at the corners of an Equilateral triangle of side 3 m, the Resistance of Each Conductor is $0.2 \Omega/\text{km}$. and the line delivers 200 MVA at 110 kV at 0.9 p.f lagging.

- (i) Determine ABCD Constants.
- (ii) Sending End Voltage and Current.
- (iii) Efficiency & Regulation.

Sol :- Given data,

$$\text{length } (l) = 180 \text{ km.}$$

$$r = 0.6 \text{ cm} = 0.006 \text{ m} = r'$$

$$\text{Side} = 3 \text{ m.}$$

$$R = 0.2 \Omega/\text{km.}$$

$$P_r = 200 \text{ MVA}$$

$$\cos \phi_r = 0.9$$

$$V_r = 110 \text{ kV.}$$

$$C = 2 \times 10^{-9} \ln \frac{D}{r'}$$

$$= 2 \times 10^{-9} \ln \frac{3}{0.006}$$

$$L = 1.29 \times 10^{-8} \text{ km.}$$

$$\Rightarrow C = \frac{10^{-9}}{18 \ln(P/g)} = \frac{10^{-9}}{18 \ln\left(\frac{3}{0.6 \times 10^{-2}}\right)}$$

$$C = 8.93 \times 10^{-12} / \text{km.}$$

$$\therefore \gamma = X_c = 2\pi f C$$

$$= 2\pi \times 50 \times 8.93 \times 10^{-12}$$

$$\gamma = 2.80 \times 10^{-9}$$

$$X_L = 2\pi f L$$

$$X_L = 2\pi \times 50 \times 1.29 \times 10^{-8}$$

$$X_L = 4.05 \times 10^{-6}$$

$$\Rightarrow Z = R + jX_L$$

$$Z = 0.2 + j(4.05 \times 10^{-6})$$

$$Z = 0.2 \angle 16.10^\circ$$

$$\therefore \text{Resistance for } 180 \text{ km} = 180 \times 0.2 = 36 \Omega$$

$$\text{Reactance for } 180 \text{ km} = 180 \times 4.05 \times 10^{-6}$$

$$= 7.29 \times 10^{-4}$$

$$\text{Admittance for } 180 \text{ km} = 2.80 \times 10^{-9} \times 180$$

$$= 5.04 \times 10^{-7}$$

$$Z = 36 + j 7.29 \times 10^{-4}$$

$$Z = \frac{36 \angle 0.116}{36 \angle 0.116} \times 10^{-3}$$

$$\Rightarrow YZ = (5.04 \times 10^{-7}) (36 \times 10^3 \angle 0.001)$$

$$YZ = 1.81 \times 10^{-5} \angle 0.001$$

$$\Rightarrow (YZ)^{\sim} = (1.81 \times 10^{-5} \angle 90.001)^{\sim}$$

$$(YZ)^{\sim} = 3.29 \times 10^{-10} \angle -179.99$$

$$\Rightarrow \sqrt{YZ} = (3.29 \times 10^{-10})^{1/2} \angle \frac{-179.99}{2}$$

$$= 1.81 \times 10^{-5} \angle -89.99$$

ABCD Constants:-

$$A = 1 + \frac{1.81 \times 10^{-5} \angle 90.001}{2} + \frac{3.29 \times 10^{-10} \angle -179.99}{4 \times 3 \times 2 \times 1}$$

$$A = 0.99 \angle 0.000578$$

$$B = Z_c \left[\sqrt{YZ} + \frac{YZ \sqrt{YZ}}{3!} + \frac{(YZ)^2 \sqrt{YZ}}{5!} + \dots \right]$$

$$\frac{Y}{Z_c} = \sqrt{\frac{Y}{Z}} = \sqrt{\frac{5.04 \times 10^{-7}}{36}} = 1.18 \times 10^{-4} \angle 0.001$$

$$Z_c = 8474.576 \angle -0.001$$

$$B = 8474.576 \angle -44.99^\circ \left[\sqrt{1.81 \times 10^5 \angle -89.9^\circ} + \frac{(1.81 \times 10^5 \angle 90.09^\circ)}{3 \times 2 \times 1} \right]$$

$$= 8474.576 \angle -44.99^\circ (1.81 \times 10^5 \angle -89.90^\circ)$$

$$B = 0.15 \angle -134.89^\circ$$

$$\Rightarrow C = \frac{1}{Z_c} \left[\sqrt{Y Z} + \frac{Y Z \sqrt{Y Z}}{31} + \dots \right]$$

$$= (1.18 \times 10^{-4} \angle -44.99^\circ) (1.81 \times 10^5 \angle -89.90^\circ)$$

$$C = 2.13 \times 10^{-9} \angle -44.9^\circ$$

$$\Rightarrow \text{Receiving End voltage } V_r = \frac{110}{\sqrt{3}} = 63.50 \text{ kVA}$$

$$\Rightarrow \text{Receiving End Current } I_r = \frac{P_r}{\sqrt{3} \times V_r}$$

$$= \frac{200 \times 10^6}{\sqrt{3} \times 110 \times 10^3}$$

$$I_r = 1049.72 \angle -25.84^\circ$$

$$\Rightarrow V_s = \cosh \theta V_r + Z_c \sinh \theta I_r$$

$$= (0.99 \angle 0.005^\circ) (63.50 \times 10^3)$$

$$+ (0.15 \angle -134.89^\circ) (1049.72 \angle -25.84^\circ)$$

$$V_s = 62 \text{ } \underline{-0.042 \text{ kV}} \quad 107.38 \text{ } \underline{-0.04}$$

$$\Rightarrow P_s = C V_r + D P_r$$

$$P_s = (2.13 \times 10^{-9} \text{ } \underline{-449}) (63.50 \times 10^3) + (0.99 \text{ } \underline{0.0005})$$

$$(1049.72 \text{ } \underline{-25.84})$$

$$P_s = 1039.22 \text{ } \underline{-25.83}$$

$\Rightarrow$ Regulation :-

$$\% \text{ V.R} = \frac{V_{s/A} - V_r}{V_r} \times 100$$

$$= \frac{62.62 - 110}{110} \times 100$$

$$\boxed{\text{V.R.} = 43.07\%}$$

$\Rightarrow$ Efficiency :-

$$\% \eta = \frac{\text{Sending End Power}}{\text{receiving End power}} \times 100$$

$$\text{Sending i/p power} = P_r + \text{losses}$$

$$\text{losses} = 3 (P_s) R = 3 \times (1039.22) \times 32$$

$$= 103677908 \text{ W}$$

$$= 3.67 \text{ MW}$$

~~Sending i/p power $P_{in} = 200 \text{ MW} + 103.67$
 $= 303.67 \text{ MW}$~~

~~$\% \eta = \frac{200 \times 10^6 \times 0.9}{303.67 \times 10^6 \times 0.9} \times 100$~~

~~$\% \eta = 58.13 \%$~~

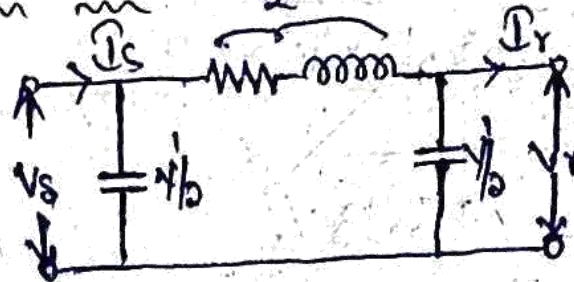
→ Sending End power, $P_s = \sqrt{3} V_L I_L \cos \phi$

$V_{s(L-L)} = \sqrt{3} \times 62.14 \times 0.9$

24/08/19

ABCD Parameters Of long Transmission lines :-

(i) Nominal π -N/W :-



→ let us consider a Nominal π -N/W for long transmission line which is shown in the fig. we know that the ABCD parameters for medium transmission lines for π -N/W is

$$A = D = (1 + YZ/2), \quad B = Z, \quad C = Y(1 + YZ/4)$$

Here, Y, Z = Admittance & impedance for medium lines

let Y', Z' = Admittance & impedance for long lines.

$$\text{let } Y = Y', \quad Z = Z'$$

∴ for long lines using Regorius Solution,

$$A = D = \cosh r l; \quad B = Z_c \sinh r l, \quad C = 1/Z_c \sinh r l$$

$$\therefore B = Z = Z' = Z_c \sinh r l$$

$$\therefore Z' = \sqrt{Z'/Y} \cdot \sinh r l$$

$$Z = \sqrt{Z'/Y} \cdot \sinh r l / \sqrt{Z'/Y}$$

$$z' = z \cdot \frac{\sinh \eta}{r}$$

$$z' = z \cdot \frac{\sinh \eta}{r}$$

Now,

$$A = D = \left(1 + \frac{\sqrt{z'}}{2} \right) = \cosh \eta = \frac{1 + \frac{\sqrt{z'}}{2}}{2}$$

$$\frac{\sqrt{z'}}{2} = -1 + \cosh \eta$$

$$\frac{\sqrt{z'}}{2} = \cosh \eta - 1$$

$$\frac{\sqrt{z'}}{2} \cdot z_c \sinh \eta = \cosh \eta - 1$$

$$\frac{\sqrt{z'}}{2} \cdot z_c \cdot 2 \frac{\sinh \eta}{2} \cdot \frac{\cosh \eta}{2} = 2 \times \frac{\sinh \eta}{2}$$

$$\frac{\sqrt{z'}}{2} \cdot z_c \cdot \cosh \frac{\eta}{2} = \sinh \frac{\eta}{2}$$

$$\frac{\sqrt{z'}}{2} = \frac{1}{z_c} \cdot \frac{\sinh \eta}{2}$$

$$\frac{\sqrt{z'}}{2} = \sqrt{\frac{1}{z}} \cdot \frac{\sinh \eta}{2}$$

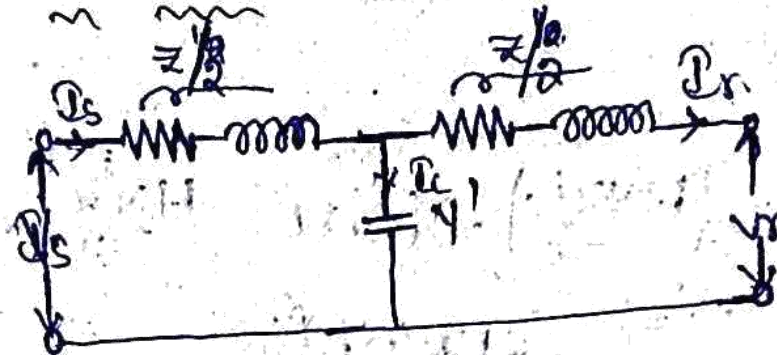
$$\sqrt{\frac{1}{z}} \cdot \frac{\sqrt{z} \cdot 1}{2} = \frac{\sinh \eta}{2}$$

$$\frac{\sqrt{z'}}{2} = \frac{1}{z} \cdot \frac{\sinh \eta}{2}$$

∴ ABCD parameters,

$$A = D = \left(1 + \frac{Y'Z'}{2}\right), \quad B = Z', \quad C = Y' \left(1 + \frac{Y'Z'}{4}\right).$$

Nominal T-N/w :-



We know that the ABCD parameters in medium transmission lines for T-N/w.

$$A = D = \left(1 + \frac{YZ}{2}\right), \quad C = Y, \quad B = Z \left(1 + \frac{YZ}{4}\right).$$

Here, Y, Z = Admittance and impedance for medium line.
 Y', Z' = Admittance and impedance for long line.

$$\text{let } Y = Y', \quad Z = Z'.$$

∴ for long lines Using Regorous Solution.

$$A = D = \cosh \gamma l, \quad B = Z_c \sinh \gamma l, \quad C = \frac{1}{Z_c} \sinh \gamma l.$$

$$\therefore C = Y = Y' = \frac{1}{Z_c} \sinh \gamma l.$$

$$Y' = \sqrt{\frac{Y}{Z}} \cdot \sinh \gamma l.$$

$$= \sqrt{\frac{Y}{Z}} \cdot \sqrt{YZ} \cdot l \cdot \frac{\sinh \gamma l}{\sqrt{YZ} \cdot l}.$$

$$Y' = Y l \cdot \sinh \gamma l$$

$$A = D = \frac{1+y'z}{2} = 1 + \frac{y'z'}{2} = \cosh \eta$$

$$1 + \frac{y'z'}{2} = \cosh \eta$$

$$\frac{y'z'}{2} = \cosh \eta - 1$$

$$z'/2 \cdot y' = \cosh \eta - 1$$

$$z'/2 \cdot 1/z_c \cdot \sinh \eta = \cosh \eta - 1$$

$$z'/2 \cdot \sqrt{1/z_c} \sinh \eta = \cosh \eta - 1$$

$$z'/2 \cdot \sqrt{1/z_c} \cdot 2 \frac{\sinh \eta}{2} \frac{\cosh \eta}{2} = 2 \frac{\sinh \eta}{2}$$

$$z'/2 = \sqrt{z_c} \cdot \frac{\sinh \eta}{2}$$

$$z'/2 = \sqrt{z_c} \cdot \frac{\sqrt{z_c} \cdot 1}{2} \cdot \frac{\sinh \eta}{\frac{\sqrt{z_c} \cdot 1}{2}}$$

$$z'/2 = \frac{z_c}{2} \cdot \frac{\sinh \eta}{1/2}$$

∴ ABCD parameters,

$$A = D = 1 + \frac{y'z'}{2}$$

$$C = y'$$

$$B = z' \left(1 + \frac{y'z'}{4} \right)$$

Characteristic Impedance (Z_c) :-

→ It is defined as a square root of line impedance to the line Admittance.

i.e., $Z_c = \sqrt{\frac{Z}{Y}}$

→ The impedance of the line is depending upon length of the line, the various Radius of conductor and Spacing b/w the conductors. As the impedance depends upon the characteristics of the Parameters. So that, this impedance is known as Characteristic Impedance

→ For the lossless line $R=0$. then, Characteristic impedance is given by,

$$Z_c = \sqrt{\frac{R + jX_L}{jX_C}} = \sqrt{\frac{jX_L}{X_C}} = \sqrt{\frac{L}{C}}$$

→ The Characteristic impedance for overhead line is 400Ω . for under ground cable is 40Ω approximately.

Surge Impedance loading :-

→ The Surge impedance loading of the line is the power loading of the transmission line when the line is lossless.

→ The transmission lines produces Reactive power (MVAR or KVAR) Due to the Natural Capacitance.

→ The amount of MVAR produced is depending upon the line Capacitive Reactance and Voltage.

$$\text{MVAR produced} = \frac{(KV)^2}{X_c}$$

under ideal Condition.

$$\text{MVAR absorbed} = I^2 X_L$$

under ideal Condition,

$$\text{MVAR Produced} = \text{MVAR absorbed.}$$

$$\frac{(KV)^2}{X_c} = I^2 X_L$$

$$\frac{KV}{I} = \sqrt{X_L X_c}$$

$$= \frac{|I|}{|I|} \sqrt{X_L X_c}$$

$$\boxed{SIL = Z = \sqrt{Y/c}}$$

→ Transmission line surge impedance is Nothing but 'MW' loading. At which the line MVAR. uses is Equals to line MVAR production.