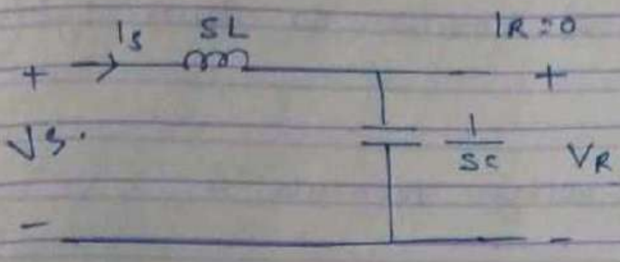
Lecture - 09 Calculation of line capacitance

Note: In long line and medium line we should neglect the Resistance.



When we apply voltage division rule across capacitor

$$V_R = V_s \left(\frac{\frac{1}{sc}}{sL + \frac{1}{sc}} \right)$$

$$= V_s \left(\frac{1}{1 + s^2 Lc} \right) \quad (\because s = j\omega)$$

$$= V_s \left(\frac{1}{1 + j\omega^2 Lj\omega} \right)$$

$$= \frac{V_s}{1 - \omega^2 LC}$$

$$= V_s \left(1 - \omega^2 LC\right)^{-1}$$

$$\boxed{V_R = V_s(1 + \omega^2 LC)}$$

other higher terms are neglected.

$V_R > V_s$ we are getting higher voltage in Receiving end side.

Therefore, change in Receiving end voltage.

$$\Delta V_R = V_R - V_s = V_s \omega^2 LC$$

That means we are getting higher voltage in

Receiving end side., this effect is Know as (Ferranti effect.

Note: and Ferranti effects occur in medium line and long line under no load condition or either lightly load conditions.

change in Receiving end voltage formula is

$$\Delta V_R = V_R - V_s = V_s \omega^2 LC$$

$\omega = 2\pi f$

$L = H$

$L_1 = H/m$ in the basis of per unit

$L_1 : F/m$. length.

$LC = L_1 C_1 l^2$ *

$$\Delta V_R = V_s (2\pi f)^2 L_1 C_1 l^2$$

if the unit is given F/m, and H/m, then this formula is used.

* $L_1 = 0.2 \ln\left(\frac{d}{r}\right)$ mH/Km $= \frac{\mu_0 \mu_r}{2\pi} \ln \frac{d}{r}$

(if the conductor is different

This not r' because conductor is considered as hollow conductor.

$C_1 = \frac{2\pi \epsilon_0 \epsilon_r}{\ln \frac{d}{r}}$ F/m

* IF we multiply both L_1 and C_1

$L_1 C_1 = \mu_0 \mu_r \epsilon_0 \epsilon_r$

Velocity of wave. $v = \frac{1}{\sqrt{L_1 C_1}}$ *

$$\Delta V_R = V_s (2\pi f)^2 L_1 C_1 l^2 \quad \text{---} (1)$$

$$v = \frac{1}{\sqrt{L_1 C_1}} \quad \text{---} (2)$$

If we compare both the formula

$$L_1 C_1 = \frac{1}{v^2}$$

Now if we put this value in equation (1)

$$\boxed{\Delta V_R = V_s (2\pi f)^2 \frac{1}{v^2} l^2}$$

— This is the another formula for change in Receiving end voltage.

* $$v = \frac{1}{\sqrt{L_1 C_1}} = \frac{l}{\sqrt{L_1 l C_1 l}} = \frac{l}{\sqrt{LC}}$$

$$= \frac{l \times 2\pi f}{\sqrt{(2\pi f L) \cdot (2\pi f C)}}$$

$$\boxed{v = \frac{2\pi f l}{\sqrt{X_L B}}}$$ *

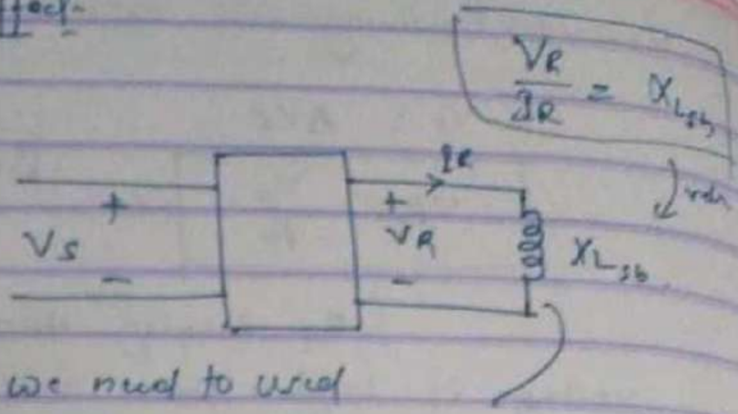
$X_L = 2\pi f L$

$B = 2\pi f C = \frac{1}{X_C}$

(Susceptance / Subpeedance)

→ So, this is another formula for the calculation of velocity of wave.

Compensation of Ferranti effect-



$$V_R = \frac{V_S}{A}$$

We are using shunt reactor,
so, that voltage $V_R = V_S$, we need to used shunt reactor.
maximum receiving voltage should be equal to the sending end voltage.

$$V_S = AV_R + BI_R$$

$$\Rightarrow \quad V_R = AV_R + BI_R$$

$$\Rightarrow \quad V_R(1-A) = BI_R$$

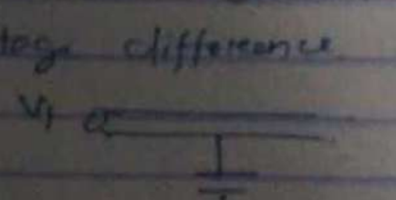
$$\Rightarrow \quad \frac{V_R}{I_R} = \boxed{\frac{B}{1-A} = X_{L_{sh}}} \; \Omega$$

Therefore, shunt reactor is required to compensate ferranti effect

* Capacitance of (single) transmission line →

$$\boxed{C = \frac{2\pi\epsilon_0\epsilon_r}{\ln\frac{d}{r}}} \; F/m$$

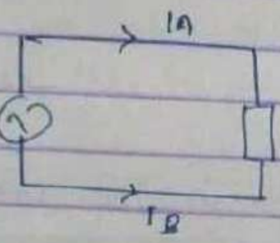
There is no r' because capacitance of solid conductor or holo conductor, we are considering in between the two conductor, capacitance is created due to voltage difference.

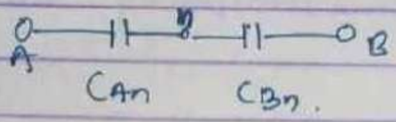


* Capacitance of 1 phase 2 wire line

$$C_{AB} = \frac{\pi \epsilon_0 \epsilon_r}{\ln \frac{d}{r}} \quad F/m$$

circuit 1 phase two wire line. $C_{eq} = C/2$



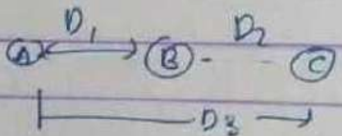


$$C_{An} = \frac{2\pi \epsilon_0 \epsilon_r}{\ln \frac{d}{r}}$$

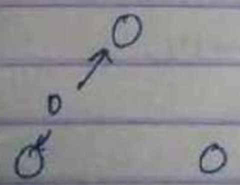
* capacitance of 3-Φ transmission line. for per phase.

Capacitance alway in phase form.

$$C_n = \frac{2\pi \epsilon_0 \epsilon_r}{\ln \frac{(D_1 D_2 D_3)^{1/3}}{r}}$$



if it in trangular form.



$$C_n = \frac{2\pi \epsilon_0 \epsilon_r}{\ln \frac{D}{r}}$$

* Bundled conductor -

$$C_n = \frac{2\pi \epsilon_0 \epsilon_r}{\ln \left(\frac{D_m}{D_s}\right)}$$

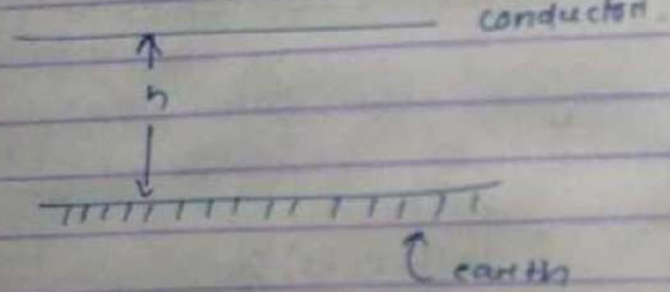
Capacitance for Double Circuit line

$$C_n = \frac{2\pi\epsilon_0\epsilon_r}{\ln\left(\frac{D_{m1} D_{m2} D_{m3}}{D_{s1} D_{s2} D_{s3}}\right)^{1/3}}$$

because, for doubled circuit line, we are using three phase transposed line.

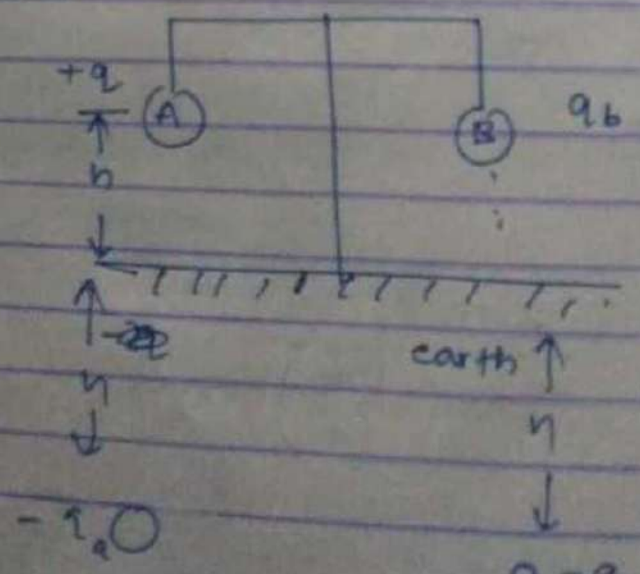
Effect of earth on capacitance between the conductor

As we know earth has infinite number of positive charge and infinite number of negative charge.



Note:
suppose if conductor is a positive then earth -ve charge create a additional electric field, due to this additional electric field, there is a capacitance created between conductor and Earth.

consider tower



same dist

so, this is create some additional electric field, and due to this additional electric field capacitance is created.

*

$$C_{AB} = \frac{\pi \epsilon_0 \epsilon_r}{\ln \frac{d}{r\sqrt{1+\frac{d^2}{4h^2}}}}$$

effect of earth for the calculation of capacitance.

Not: If you want to eliminate the effect of earth, then increase the height,

$$h \to \infty$$

$$C_{AB} = \frac{\pi \epsilon_0 \epsilon_r}{\ln \frac{d}{r}}$$

if h is ∞. (infinite)

so, By increasing the height we can eliminate effect of capacitance.