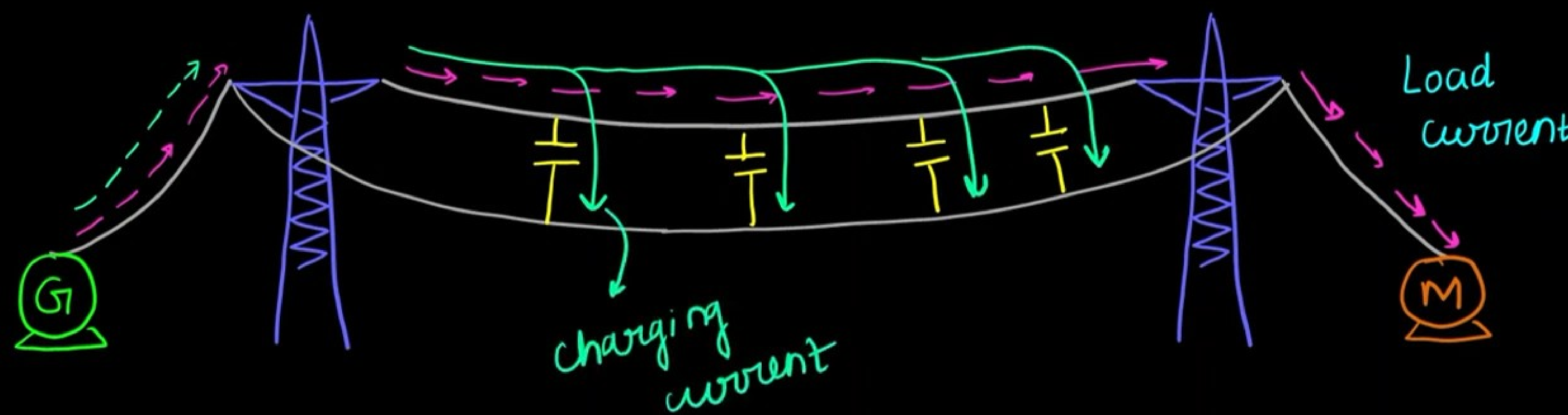
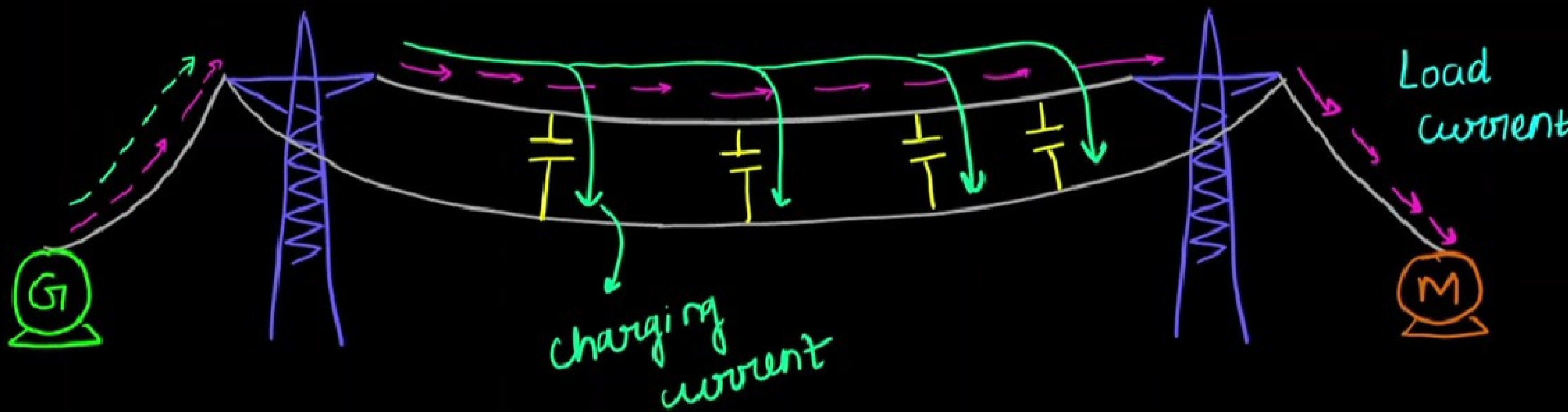

Load
current
G
M
charging
current


CHARGING CURRENT IN TL
-Dr. Pranjal Saxena
(Assistant Professor)
B.Tech, M.Tech, PhD
techinsight08@gmail.com
TechInsight

Charging current



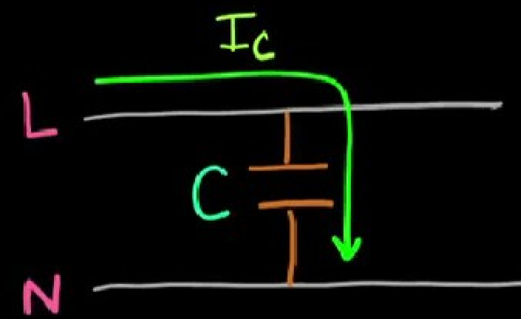
* current flow in TL due to the capacitance form b/w conductors is called Charging current

* charging current ⟶ due to line capacitance ⟶ pure leading
or
ZPF leading

Formulas for charging current

single phase line

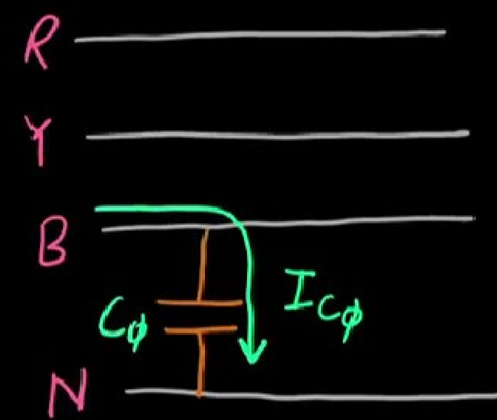
$$\boxed{I_c = 2\pi f C V}$$



3-ϕ line

$$\boxed{I_{C\phi} = 2\pi f C_\phi V_\phi}$$

charging current per phase



Features of charging current

1. Depends on;

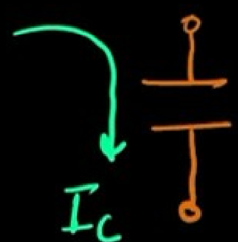
$$\boxed{I_c = 2\pi f C V}$$

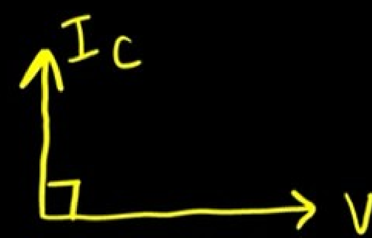
voltage

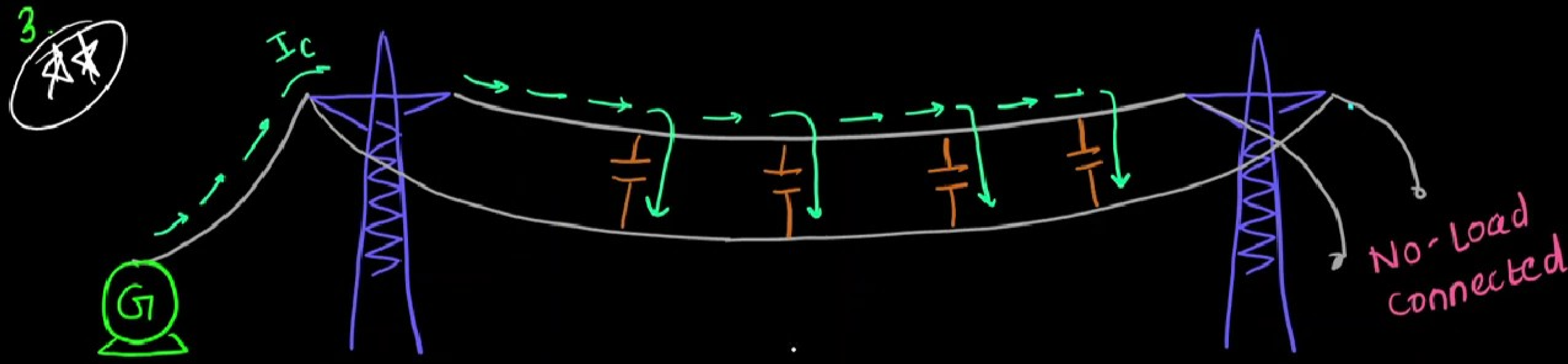
capacitance

operating frequency

2. Pure leading







charging current flows even when the line is

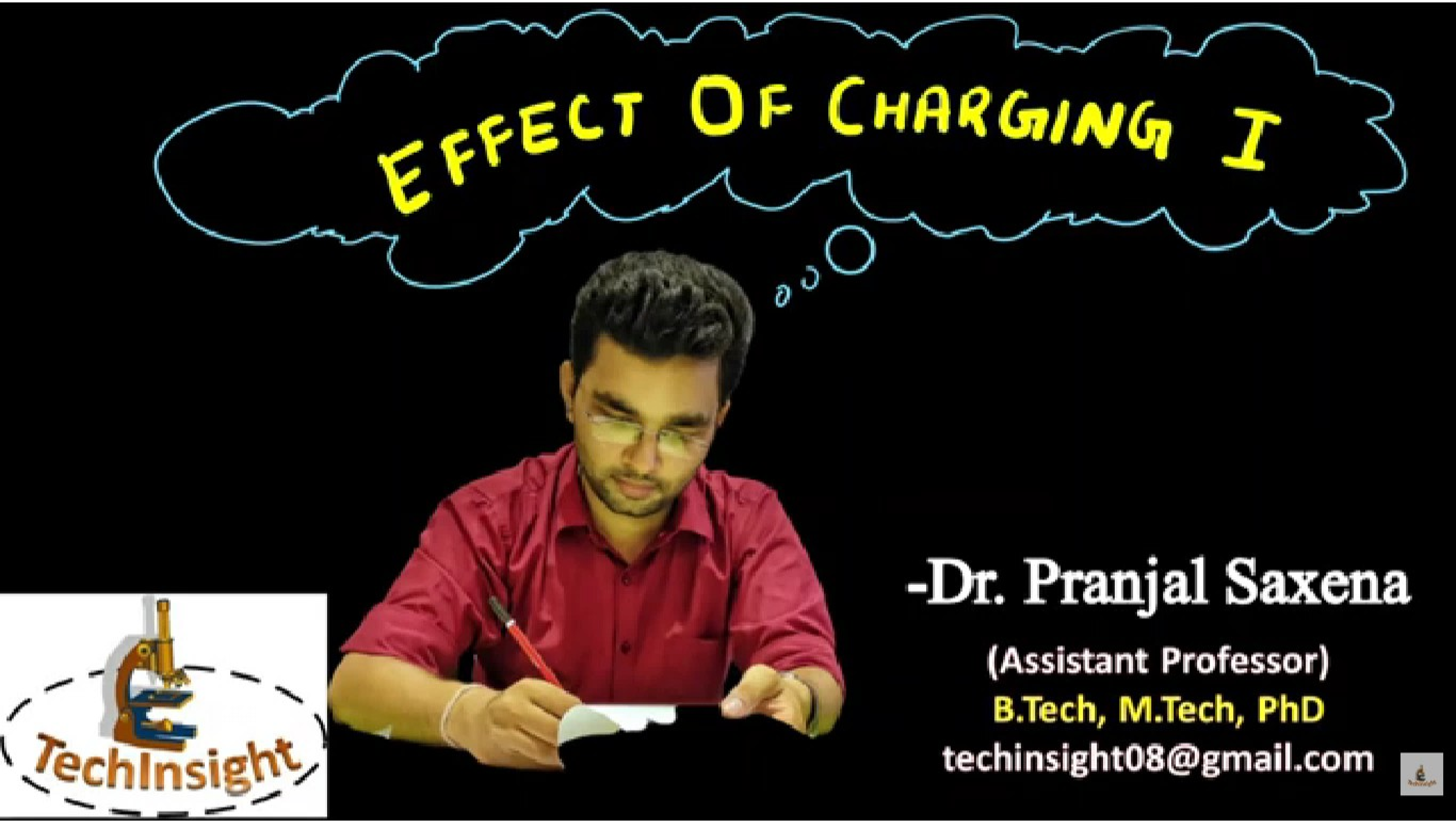
at no-load $\longrightarrow$ I_c independent of load

Effect of I_c only observed in long TL $\longrightarrow$ length > 100 km

Medium and
long TL

Approximate charging current of various OHTL

VOLTAGE LEVEL	CHARGING CURRENT (A/m)
765 kV	3.10 – 3.20
525 kV	2.05 – 2.20
345 kV	1.35 – 1.45
230 kV	0.90 – 0.98
115 kV	0.45 – 0.50


EFFECT OF CHARGING I
-Dr. Pranjal Saxena
(Assistant Professor)
B.Tech, M.Tech, PhD
techinsight08@gmail.com
TechInsight

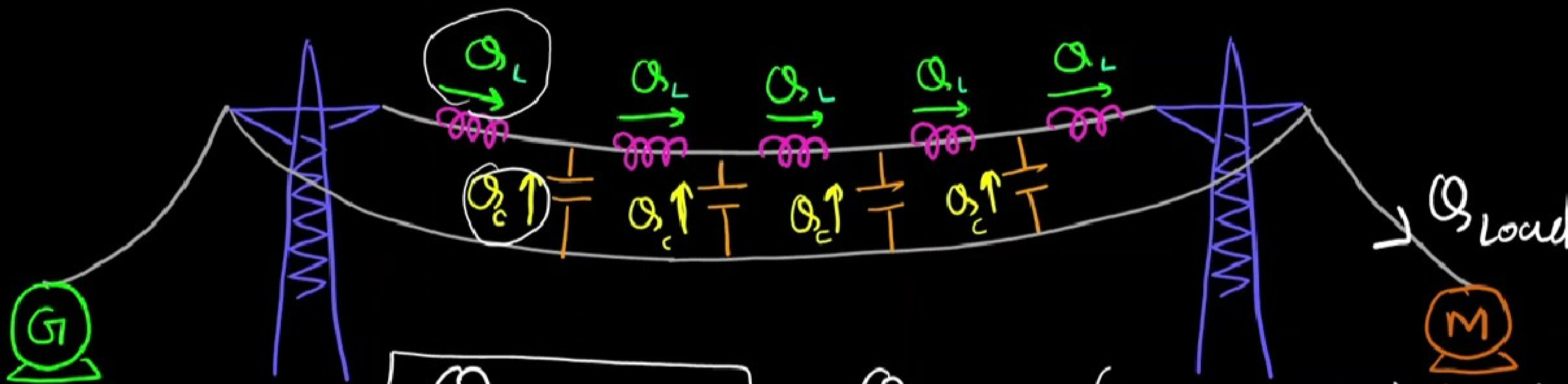
Reactive Power Generated.

$$L \underset{\text{Lagging } Q}{\overset{\text{leading } Q}{\rightleftarrows}} C$$

L:
- deliver leading Q
- Absorb lagging Q

C:
- deliver lagging Q
- absorb leading Q

NOTE:- convention: lagging Q → Q



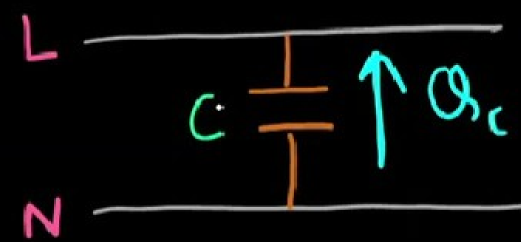
$$\boxed{Q_{\text{Net demand}}} = \underline{Q_{Load}} + (Q_{L_T} - Q_{C_T})$$ Load

→ absorb reactive power Q_L

→ deliver reactive power Q_C

single phase

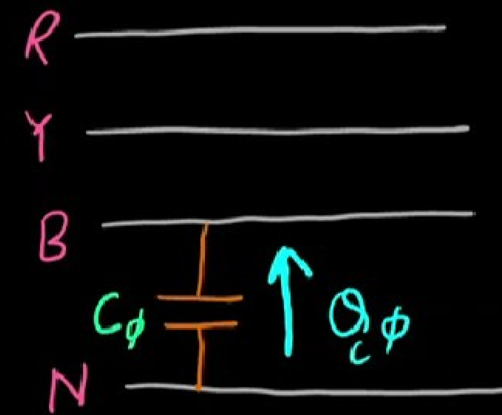
$$\boxed{Q_c = V I_c} \qquad \boxed{Q_c = \frac{V^2}{X_c}}$$



3-ϕ supply

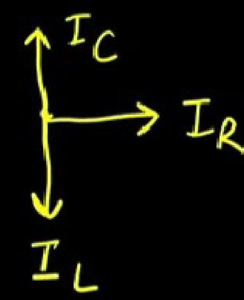
$$\boxed{Q_{c\phi} = \frac{V_\phi^2}{X_{c\phi}}} \qquad \boxed{X_{c\phi} = \frac{1}{\omega C_\phi} = \frac{1}{2\pi f C_\phi}}$$

Total; $Q_{3\phi} = 3 Q_{c\phi} = \boxed{3 V_\phi I_{c\phi}}$



Effect of charging current

1. Reduces reactive power demand $\longrightarrow Q_L - Q_C$

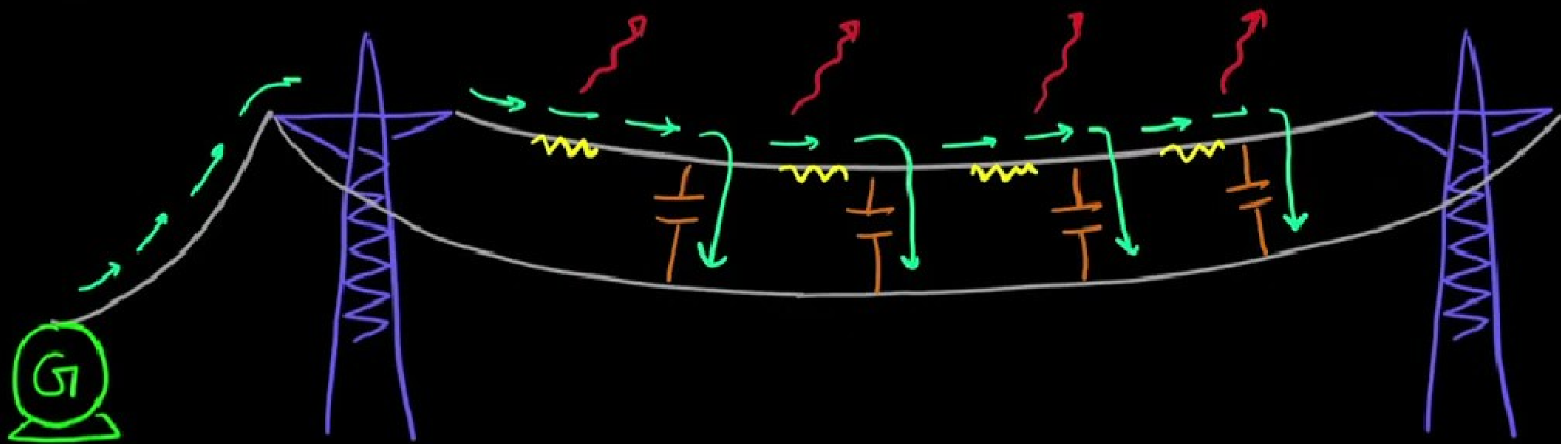
2. Cancel lagging current demand $\longrightarrow$ 

$\longrightarrow$ current in TL $\downarrow$

3. η of TL improves $\longrightarrow I_T = \sqrt{I_R^2 + (I_L - I_c)^2} \longrightarrow \underbrace{(I_T)^2 R}_{\text{losses}} \downarrow$

4. voltage Regulation of TL $\uparrow$ $\longrightarrow$ $\dfrac{V_s - V_R}{V_s} \uparrow$ because of I_c

5. Power loss due to charging current, even when line is not loaded.

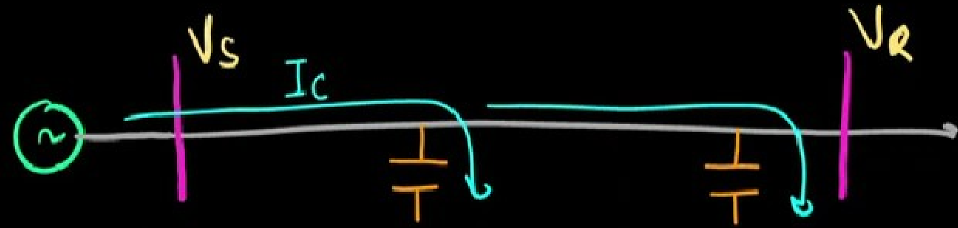


- No-Load connected
- Large TL

* Power loss due to charging current = $\frac{I_c^2 R}{3}$ $\longrightarrow$ very small

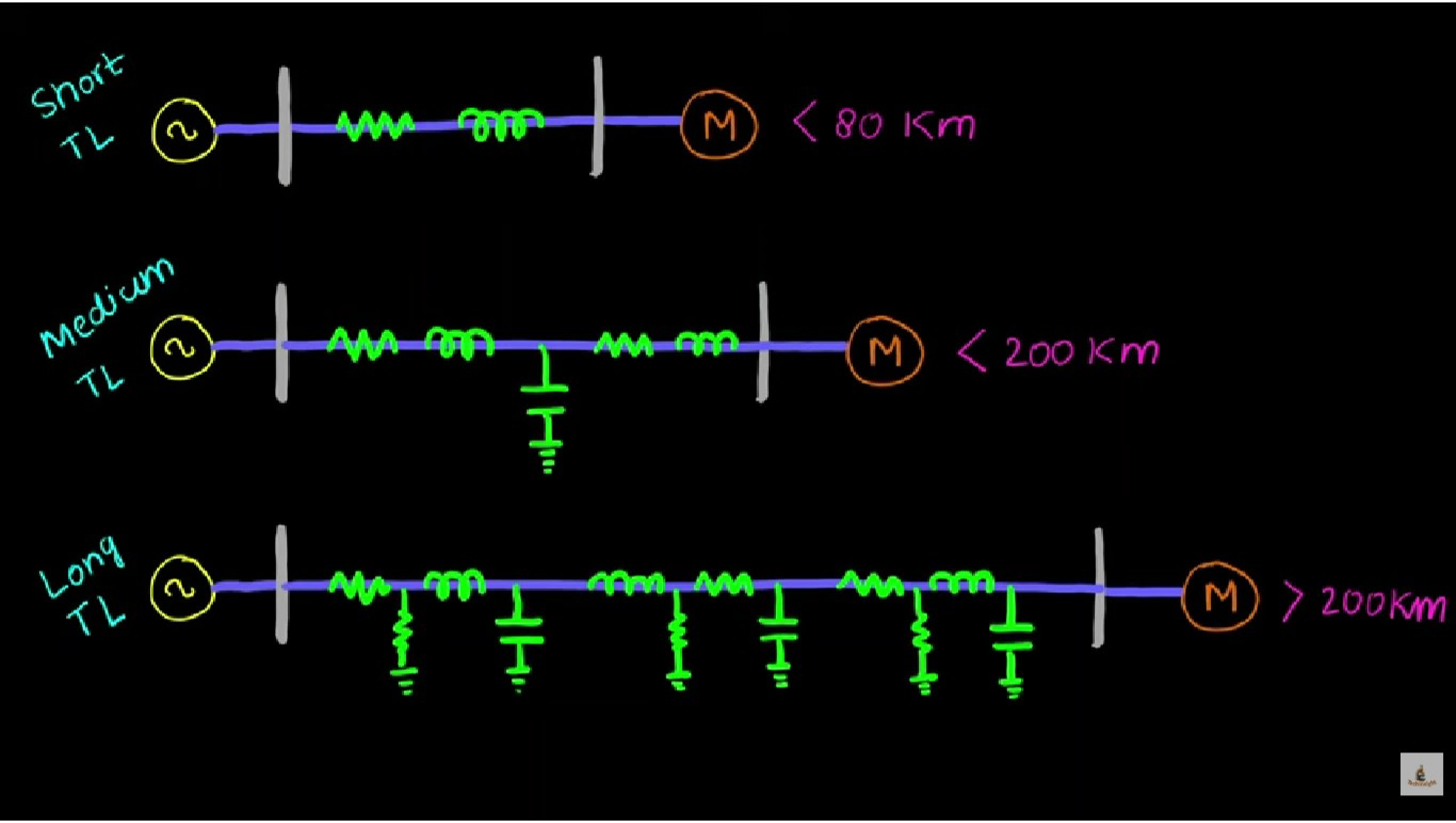
$I_c \rightarrow$ charging current $R \rightarrow$ Total Resistance

6.

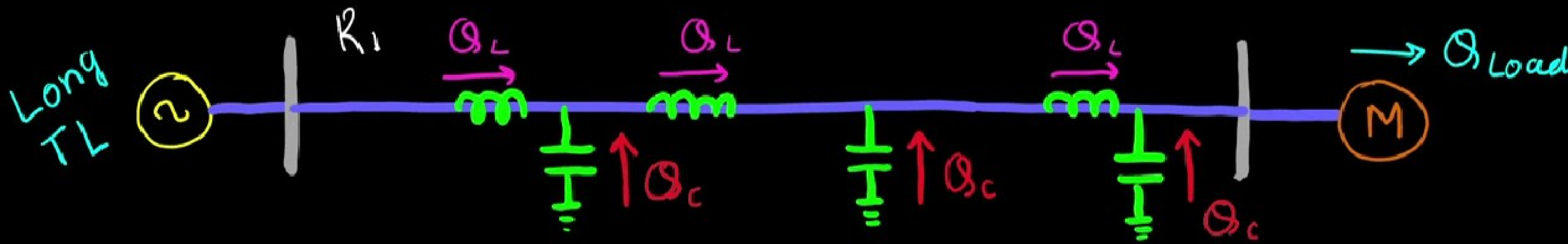


$$\boxed{V_R > V_S}$$

charging current causes, $V_R > V_S$ → Ferranti Effect



Short TL
< 80 Km
Medium TL
< 200 Km
Long TL
> 200Km
M
M
M



$$\boxed{Q_{demand} = Q_L + Q_{Load} - Q_c}$$

generally, $Q_L + Q_{Load} > Q_c$

$\therefore$ $Q_{supply} \leq Q_{demand}$ - - - - → $V_S > V_R$ (Normally)

During Night ⟶ $Q_{Load} \simeq 0$

Ferranti Effect

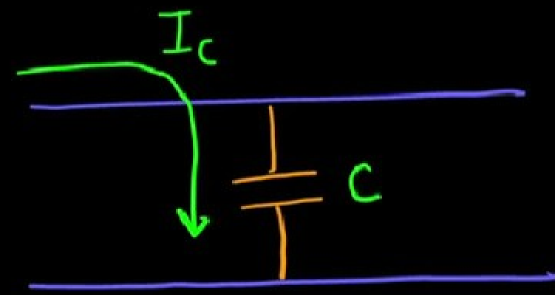
$Q_L < Q_c \longrightarrow -Q_{demand} \longrightarrow \boxed{Q_{supply} > Q_{demand}}$


FERRANTI EFFECT
-Dr. Pranjal Saxena
(Assistant Professor)
B.Tech, M.Tech, PhD
techinsight08@gmail.com
TechInsight

Ferranti Effect

"Phenomenon in which receiving end voltage (V_R) exceeds sending end voltage (V_s)."

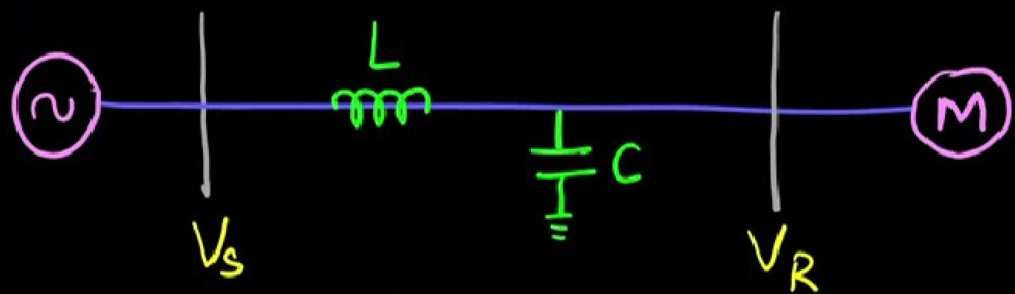
* Occur due to line capacitance (c) and charging current (I_c)



* Conditions for ferranti Effect

1. Long Transmission line ($l > 200km$)
2. Light load or No-load (Night Time)

Magnitude of Ferranti Effect



$V_S < V_R$

$V_R = V_s + \Delta V_R$ → voltage rise due to Ferranti effect

$$\boxed{\Delta V_R = V_S \omega^2 l^2 CL}$$

where; V_S : supply voltage $\omega = 2\pi f$ C, L → line capacitance and inductance

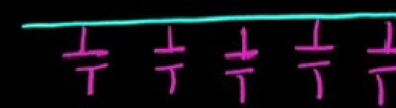
Features of Ferranti Effect

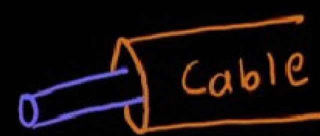
1. Ferranti Effect $\propto l^2$

   $\propto f^2$

2. Ferranti effect $\xrightarrow[\text{reason}]{\text{main}}$ Line Capacitance.

   Increases
   - → length
   - → Cable





3. Ferranti effect → High in long OHTL
   - → High in short Transmission Cable

* In Cable:→ $L_{cable} \simeq 0.5$ to 0.7 times of L_{OHTL}

  $C_{cable} \simeq 20$ to 60 times of C_{OHTL}

Effect of Ferranti Effect

1. V_R shoots $\longrightarrow$ $V_R > V_S$ (voltage swell)

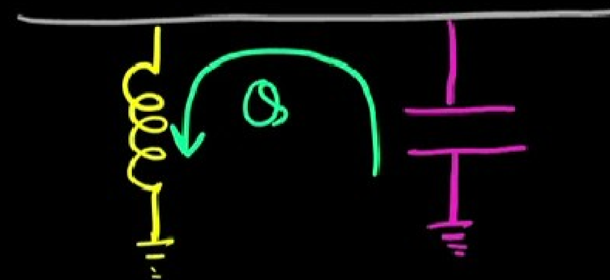
2. Insulator damage

3. Load damage $\longrightarrow$ due to High receiving end voltage

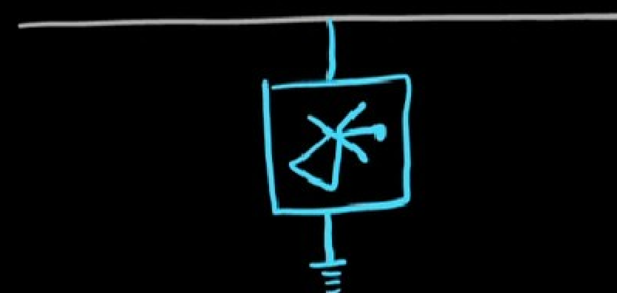
4. Un-necessary tripping of over-voltage relay

How to limit Ferranti Effect

1. Install shunt Reactor



2. Install FACTS Devices



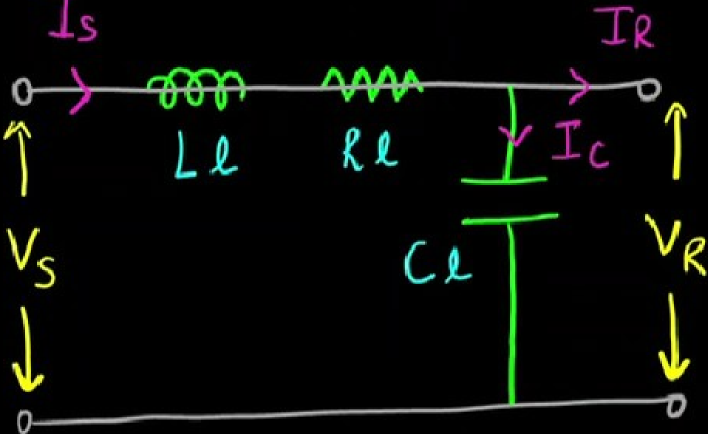
3. Avoid no-load situation


FERRATI EFFECT DERIVATION
-Dr. Pranjal Saxena
(Assistant Professor)
B.Tech, M.Tech, PhD
techinsight08@gmail.com
TechInsight

Ferranti Effect Calculation

→ To calculate ferranti effect, we use approximate model of long TL

↳ use lumped R, L, C



L → inductance per unit length

C → Capacitance per unit length

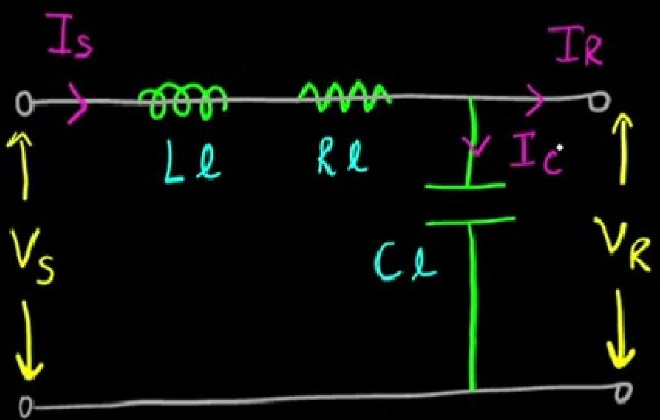
R → Resistance per unit length

l → length of Long TL

For ferranti, we consider no-load

$$I_R = 0$$

$$\therefore \boxed{I_s = I_C}$$



$$I_s = I_c = \frac{V_s}{(X_L + X_c + R\ell)}$$

→ Neglecting Resistance compare to X_L and X_c

$$\therefore \quad I_s = I_c = \frac{V_s}{X_L + X_c}$$

$$= \frac{V_s}{\left(j\omega L\ell + \frac{1}{j\omega C\ell}\right)}$$

→ In long TL at no-load, Capacitive reactance is quite large compared to inductive reactance.

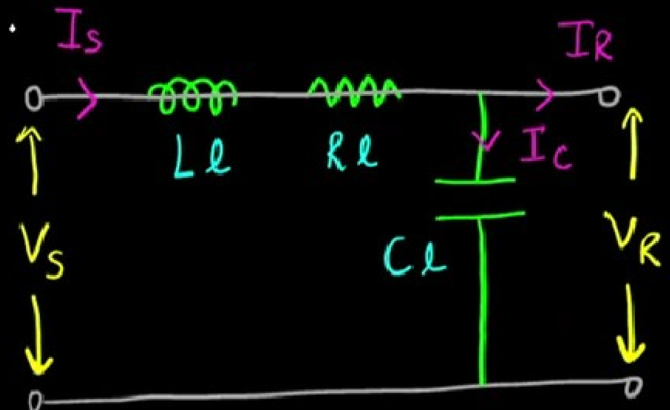
$$\therefore X_L << X_C$$

$$\therefore I_C \simeq \frac{V_S}{X_C} = \frac{V_S}{1/j\omega C l} \simeq j\omega C l V_S$$

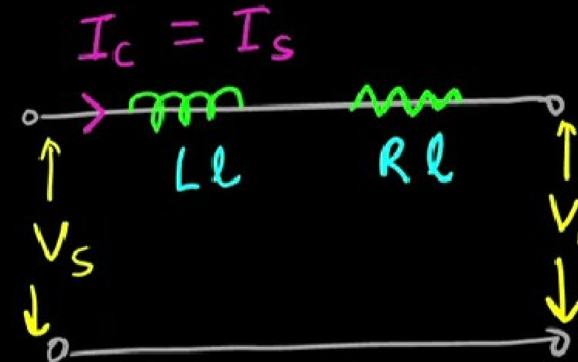
$$\therefore \boxed{I_C \simeq j\omega C l V_S}$$

purely capacitive

↳ charging current

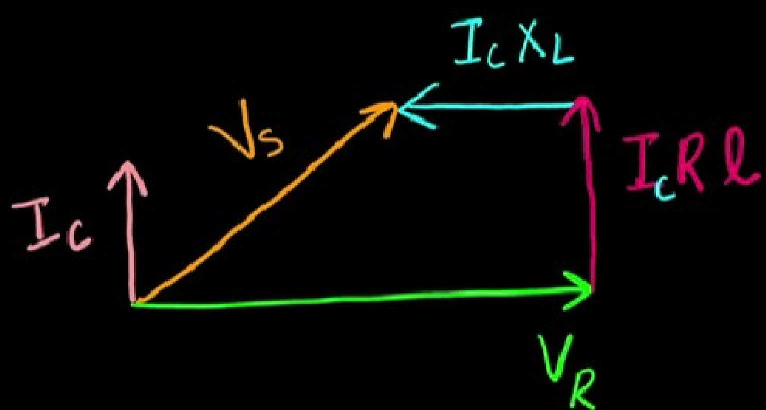


$\Rightarrow$



$\boxed{I_R = 0}$

No load



$$\boxed{V_S = V_R + jI_C X_L + I_C R l}$$

Phasor diagram

→ Calculating magnitude of voltage rise

$$V_R = V_S - jI_C X_L - I_C R l$$

Since, R is very negligible compare to X_L

$$V_R = V_S - jI_C X_L$$

also, $I_C = j\omega C l V_s$

$$\therefore \quad V_R = V_S - j\omega C l V_s . j\omega L l$$

$$V_R = V_S - j^2 \omega^2 l^2 CL$$

$$\boxed{V_R = V_s + \omega^2 l^2 CL}$$