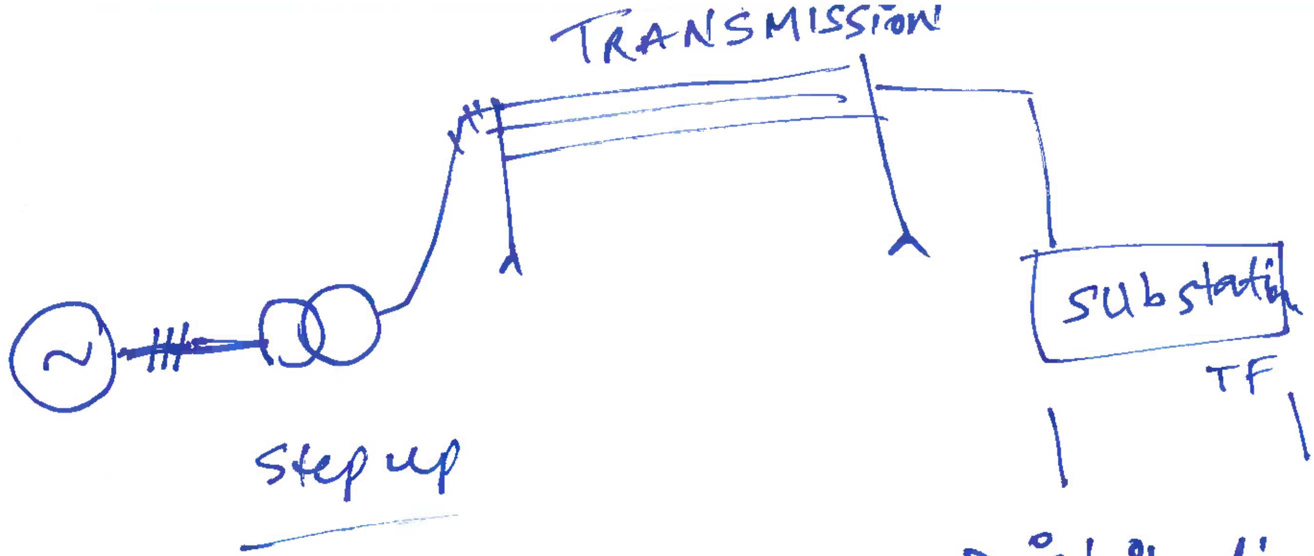
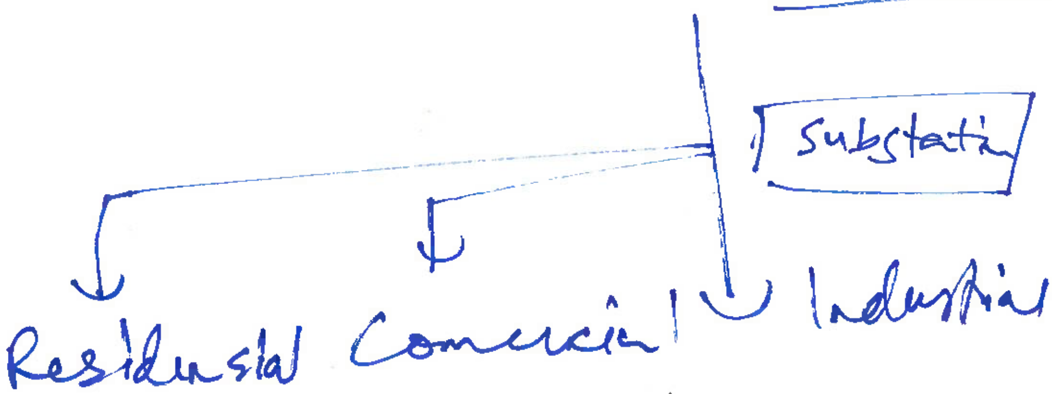
(1)



Distribution

22kV, 11 kV, 6.6kV

Pole or underground



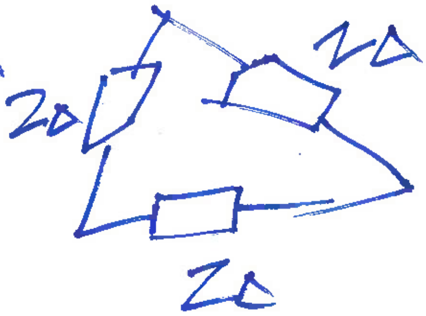
L_{P-P} $\quad V_L \longleftarrow V_{LL} = 400\,kV \quad 3\phi$

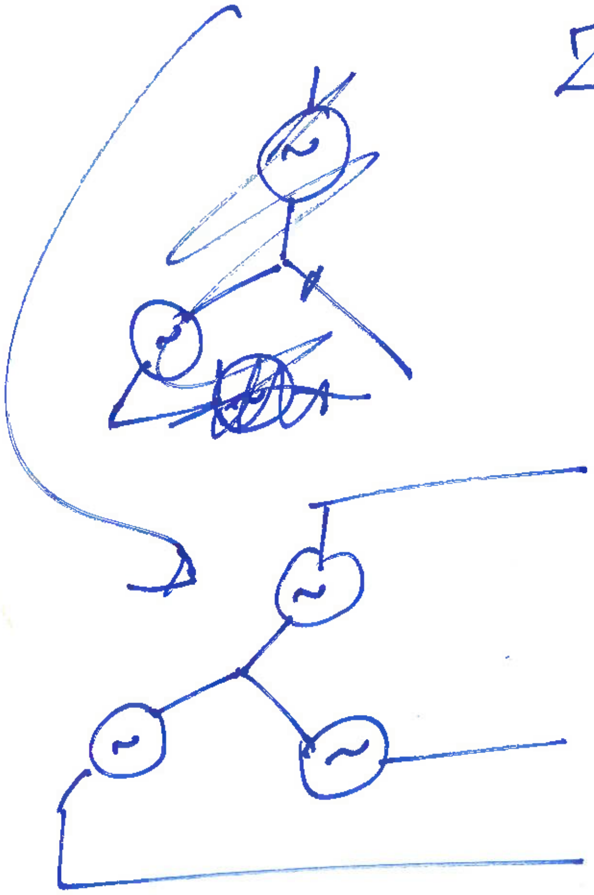
$$V_P = \frac{400\,kV}{\sqrt{3}}$$

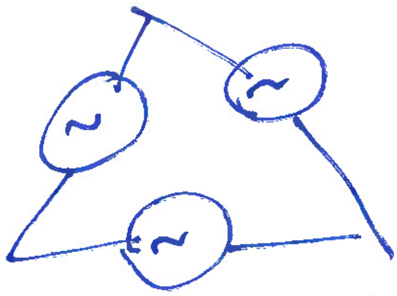
(2)

Star OR delta

$$Z_y = \frac{Z_\Delta}{3}$$







(3)

$S = 1000 \, kVA$

$V = 11 \, kV$

$L = 5 \, mH$

$R = 0.1 \, \Omega$

$$Z_{base} = \frac{V_n^2}{S}$$

$$R_{pu} = \frac{R}{Z_{base}}$$

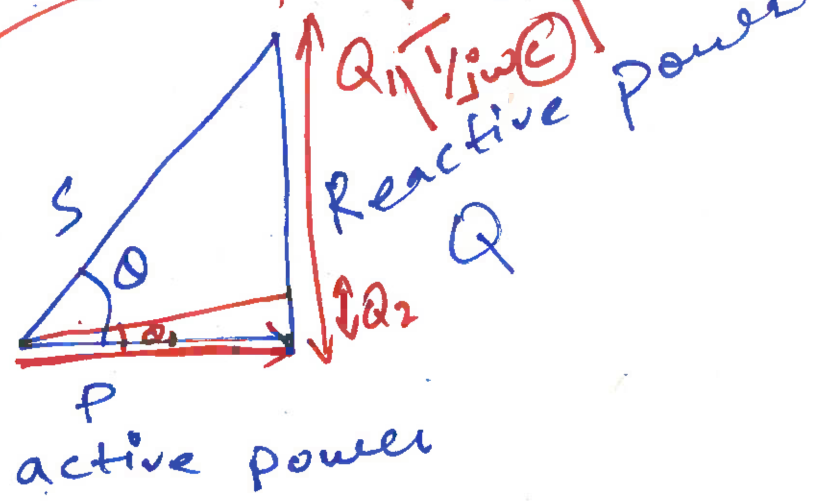
$$X_{pu} = \frac{\overbrace{2\pi f L}^{= X}}{Z_{base}}$$

$$S_{pu} = \frac{S}{S_n}$$

$$V_{pu} = \frac{11 \, kV}{11 \, kV} = 1$$

(4) PF – PROBLEM

$$\frac{V^2}{\left|\frac{1}{j\omega C}\right|} = Q_1 - Q_2$$



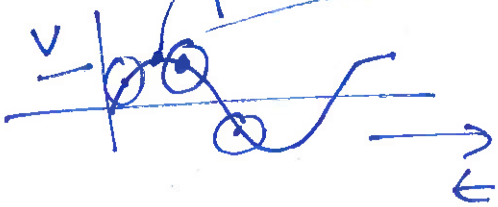
$$PF = \underline{\cos\theta} \simeq 1$$

$$\underline{V^2}\omega C = Q_1 - Q_2$$

$$C = \frac{Q_1 - Q_2}{V^2\omega}$$

IF $V = \sin\theta$

$$\boxed{1 = V}$$



(5)

$$3\phi = 35.4\,kV$$

$$V_{Ph} = \frac{35.4\,kV}{\sqrt{3}}\ V_{rms}$$

$$V_{Ph-Pk} = \frac{35.4\,kV\,\sqrt{2}}{\sqrt{3}}$$

OR

$$= 35.4\,kV\sqrt{\frac{2}{3}}$$

(6)

$X_{pu} = 2$

$R_{pu} = 0.5$

10 MVA

$V = 13.8\,kV$ — sys voltage

C 1 MVA

13.8 kV

$$X_{pu} = \frac{X}{Z_{base}}$$

$$R_{pu} = \frac{R}{Z_{base}}$$

$$X_c = \frac{V^2}{S}$$

$$Z_{base} = \frac{(13.8k)^2}{10\,MVA} = 19.4\Omega$$

$X_{pu} * Z_{base} = X$

$2 * 19.4 = X$

$X = 2\pi f L$

?

$R = R_{pu} * Z_{base}$

$R = 0.5 * 19.4\Omega$

7

$$X_C = \frac{V^2}{S} = \frac{(13.8k)^2}{1M}$$

$$X_C = ?$$

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

FROM SLIDE 15 $t' \cong 3.3$

$$t = t' * T$$

$$t = t' * \sqrt{LC}$$

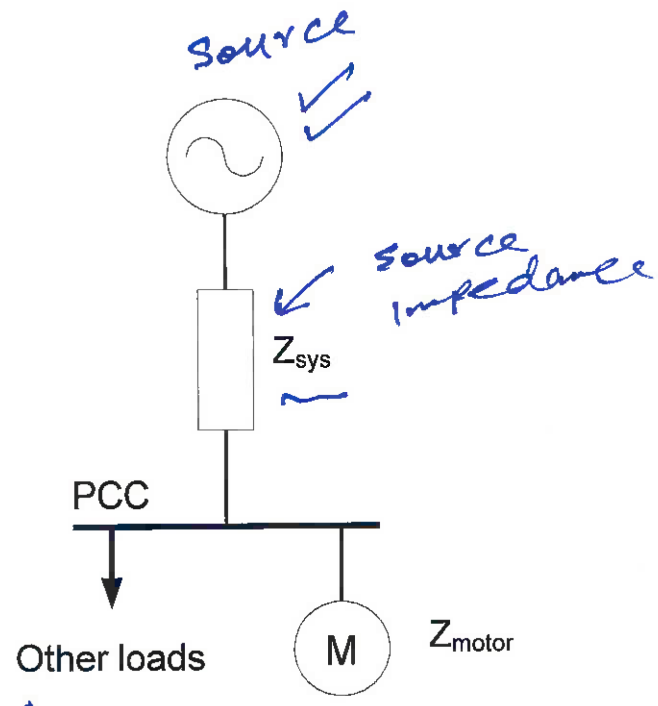
Sag Caused by Starting of Induction Motor

- Using voltage divider, standing voltage Vsag at the node of motor starting

$$V_{sag} = \frac{Z_{motor}}{Z_{motor} + Z_{sys}}$$

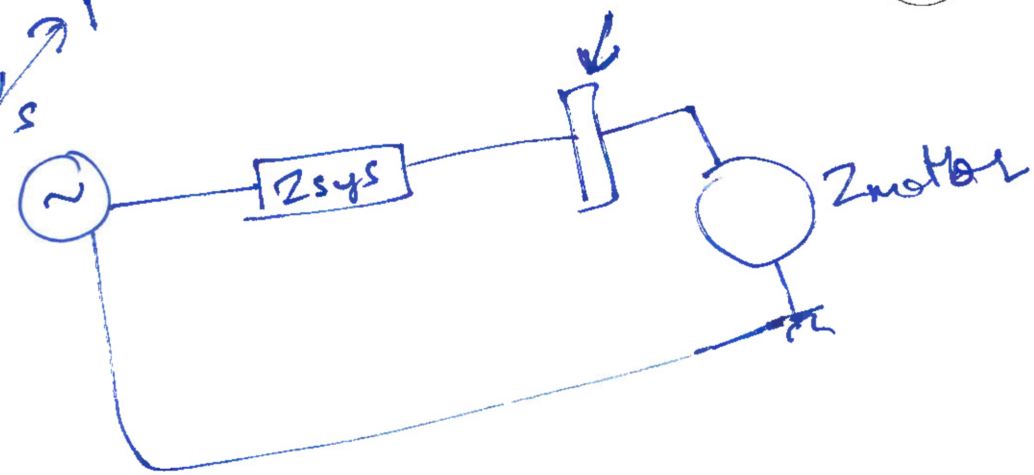
✓ Assuming source voltage of 1.0 p.u.,

✓ At starting, Z_{motor} is locked-rotor impedance



$$V = \frac{Z_{motor}}{Z_{sys} + Z_{motor}} \times V_s$$

$$V_{sag} = \frac{Z_{motor}}{Z_{sys} + Z_{motor}}$$



Sag Caused by Starting of Induction Motor

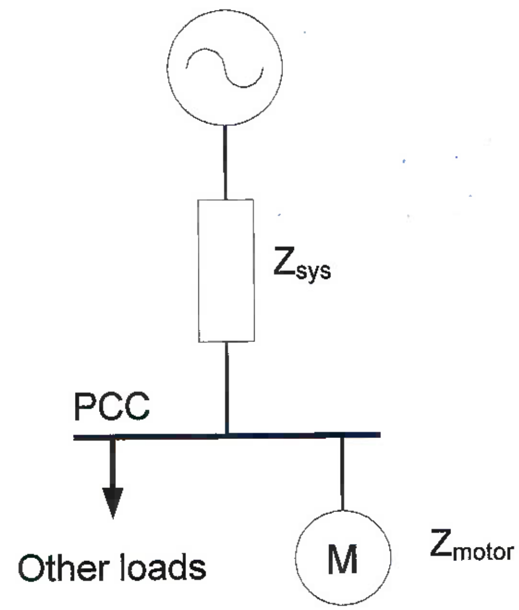
- When starting a motor from source with a short circuit capacity S_{source}.

$$Z_{sys} = \frac{V_n^2}{S_{source}} \; ; \; Z_{motor} = \frac{V_n^2}{\beta S_{motor}}$$

✓ V_n is rated voltage

✓ β is the ratio between the motor's starting current and the nominal current i.e. ratio of locked-rotor current at rated voltage to rated current

✓ S_{motor} is the motor rated apparent power



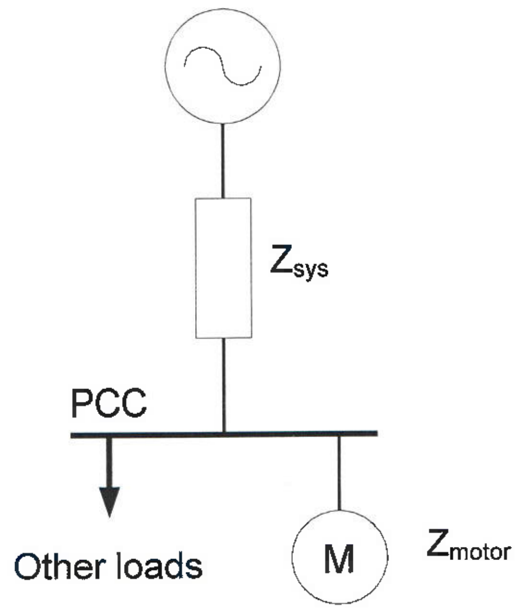
Sag Caused by Starting of Induction Motor

$$V_{sag} = \frac{Z_{motor}}{Z_{motor} + Z_{sys}}$$

$$V_{sag} = \frac{\frac{V_n^2}{\beta S_{motor}}}{\frac{V_n^2}{\beta S_{motor}} + \frac{V_n^2}{S_{source}}}$$

$$V_{sag} = \frac{\frac{1}{\beta S_{motor}}}{\frac{S_{source}+\beta S_{motor}}{\beta S_{motor} S_{source}}}$$

$$V_{sag} = \frac{S_{source}}{S_{source}+\beta S_{motor}}$$



- The corresponding per-unit change in voltage or voltage sag,

$$\Delta V = 1 - V_{sag} = 1 - \frac{S_{source}}{S_{source} + \beta S_{motor}} = \boxed{\frac{\beta S_{motor}}{S_{source} + \beta S_{motor}}}$$

$$\boxed{\Delta V = 1 - V_{sag} \approx \frac{\beta S_{motor}}{S_{source}}} \quad for\ S_{source} \gg \beta S_{motor}$$

$$\frac{S_{source} + \beta S_{motor} - S_{source}}{S_{source} + \beta S_{motor}}$$

Motor-Starting Methods

Ps $\frac{V_{pri}}{2M}$ M

- Autotransformer with turn ratio α = N2 / N1

$$V_{start} = V_{sec} = \underbrace{N_2 / N_1}_{\alpha} V_{pri} = \alpha V_{pri}$$

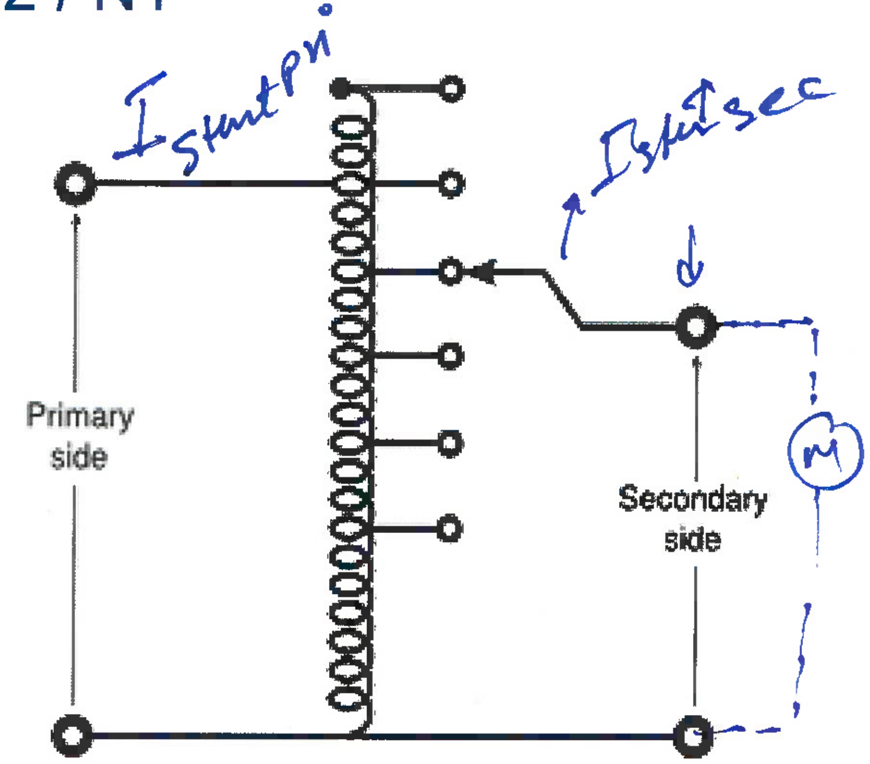
$$\Rightarrow I_{start-sec} = \frac{V_{sec}}{Z_{motor}} = \frac{\alpha V_{pri}}{Z_{motor}}$$

$$I_{start-sec} = \alpha I_{start-original}$$

$$I_{start-pri} = \alpha I_{start-sec}$$

$$\therefore I_{start-pri} = \alpha^2 I_{start-original}$$

$$\Rightarrow \beta_{autotransformer} = \alpha^2 \times \beta_{original}$$



$$\beta = \frac{I_{start}}{I_{nominal\ current}}$$