Fundamentos de Transformadores y Máquinas Eléctricas

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Clase 3

Ejemplo: La potencia real que una fuente suple a dos impedancias en paralelo es 1100w. Hallar;

ⓐ la potencia real que absorbe cada impedancia

ⓑ la corriente de la fuente

$\bar{Z}_1 = 3 + j4\,\Omega \qquad \bar{Z}_2 = 10\,\Omega$

ⓐ $P = \dfrac{|V|^2}{R} \qquad \bar{V}_1 = \bar{V}_2$

$V_1^2 = P_1 R_1 \qquad V_2^2 = P_2 R_2 \quad ; \; V_1^2 = V_2^2$

$P_1 R_1 = P_2 R_2 \quad ; \; P_1 + P_2 = P_T \qquad \left(\dfrac{P_1}{P_2} = \dfrac{R_2}{R_1} \right)$

$P_2 = P_T - P_1$

$P_1 R_1 = (P_T - P_1) R_2$

$P_1 R_1 = P_T R_2 - P_1 R_2$

$P_1 (R_1 + R_2) = P_T R_2$

$$P_1 = \frac{P_T}{R_1 + R_2} R_2 = \frac{(1100w)(10\Omega)}{(13\Omega)} = \underline{\underline{846.15w}}$$

$$\therefore \quad P_2 = \frac{P_1 R_1}{R_2} = \frac{(846.15w)(3w)}{10\Omega} = \underline{\underline{253.85w}}$$

(b)

$$P_2 = |\bar{I}_2|^2 R_2 \rightarrow I_2 = (P_2/R_2)^{\frac{1}{2}} = \sqrt{(253.85\,W)/(10\,\Omega)} = 5.04\,A$$

$$P_1 = |\bar{I}_1|^2 R_1 \rightarrow I_1 = (P_1/R_1)^{\frac{1}{2}} = \sqrt{(846.15)/(3)} = 16.79\,A$$

$$Q_1 = |\bar{I}_1|^2 X_1 = (16.79\,A)^2 (4\,\Omega) = 1128.2\,VARS$$

$$\bar{S}_2 = (253.85 + j0)\ VA$$

$$\bar{S}_1 = (846.15 + j1128.2)\ VARS$$

$$\Rightarrow \theta = \tan^{-1}\frac{Q_1}{P_1} = 53.13^\circ$$

$$\bar{I}_1 = 16.79\ \angle -53.13^\circ\ A$$

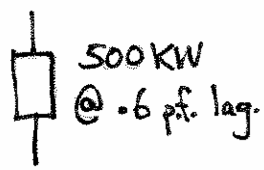
$$\bar{I}_2 = 5.04\ \angle 0^\circ\ A$$

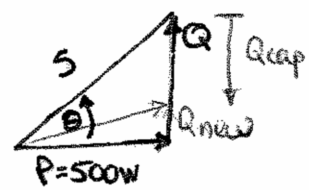
$$\bar{I}_T = \bar{I}_1 + \bar{I}_2 = 20.22\ \angle -41.63^\circ\ A$$

Corrección de Factor de Potencia
(Compensación en Paralelo)

Ejemplo: Una planta industrial absorbe 500 KW a 0.6 P.f. atrasado ("lagging")

ⓐ Compute los KVA de un banco de Capacitores que mejore el P.f. a 0.9 atrasado





$$P.F. = \cos\theta = \frac{P}{S}$$

$\rightarrow \quad S_{old} = \frac{P}{\cos\theta} = \frac{500KW}{.6} = 833.33\ KVA$

$\rightarrow \quad Q_{old} = (S^2 - P^2)^{\frac{1}{2}} = 666.66\ KVAR$

Queremos mantener P constante y variar Q, para tener un $P.F_{new} = .9$; El nuevo triangulo sería el de rojo

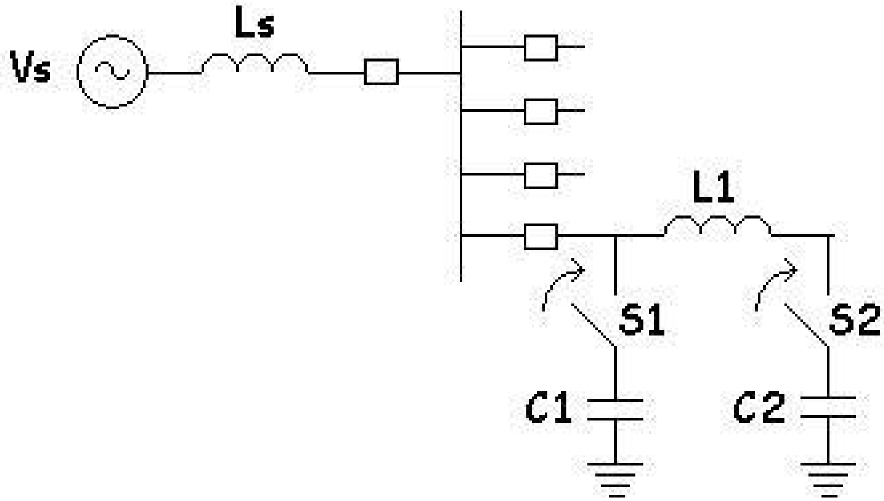
$\rightarrow \quad S_{new} = \frac{P}{PF_{new}} = \frac{500}{.9} = 555.55\ KVA$

$\rightarrow \quad Q_{new} = (S_{new}^2 - P^2)^{\frac{1}{2}} = 242.16\ KVAR$

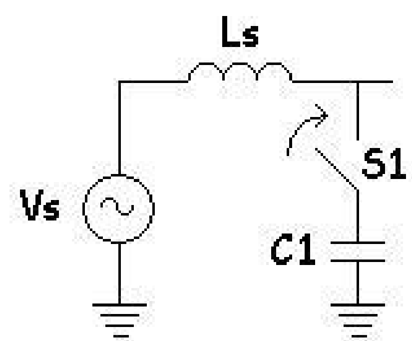
$Q_{old} - Q_{new} = Q_{CAP} = 425.5\ KVA$

$\bar{I}_{new} = ? \quad \bar{I}_{old} = ?$

Capacitor Banks

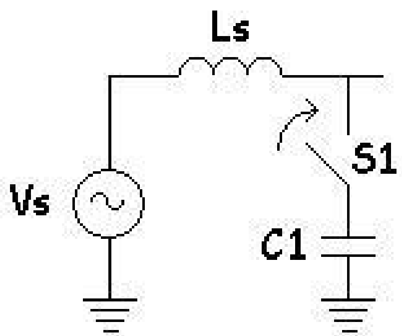


- Ignoring the rest of the feeders for the time being
- S1 closes



Capacitor Banks

- S1 closes



An in-rush current will oscilate at

$$f_0 = \frac{1}{2\pi\sqrt{L_s C_1}}$$

If V_s is 34.5 KV system with short Circuit capacity of $I_{sc} = 25$ KArms,

$C_1 = 18$ MVA and $C_2 = 10$ MVA

The analysis in three phase is:

$$S = \sqrt{3}\,V I \quad , \quad I = \frac{S}{\sqrt{3}\,V} = \frac{18 \text{ MVA}}{\sqrt{3}\,(34.5 \text{ KV})}$$

$$I(60\text{Hz}) = 301.2 \text{ A}$$

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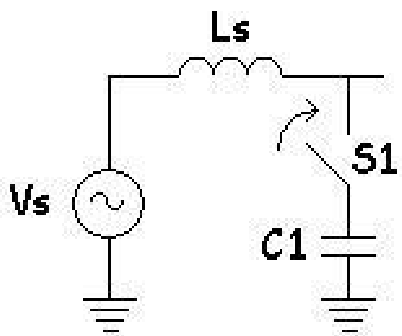
Capacitor Banks

- S1 closes



$$V = \sqrt{3}\, I\, X_C \,, \qquad X_{C_1} = \frac{V}{\sqrt{3}\, I} = \frac{34.5\,\text{KV}}{\sqrt{3}(301.2\text{A})}$$

$$X_{C_1}(60\text{Hz}) = 66.13\ \Omega$$

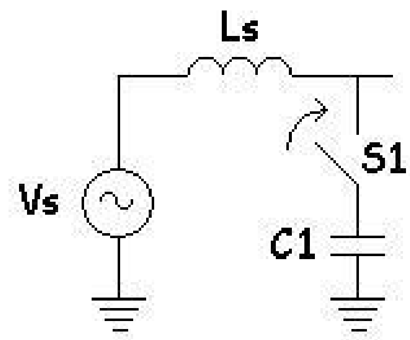
$$X_{C_1} = \frac{1}{\omega C_1} \,, \qquad C_1 = \frac{1}{\omega X_{C_1}} = \frac{1}{2\pi(60)(66.13}$$

$$C_1 = 40.11\,\mu\text{F}$$

$$X_{L_s} = \frac{V}{\sqrt{3}\, I_{sc}} \,, \qquad X_{L_s} = \frac{34.5\,\text{KV}}{\sqrt{3}\,(25\,\text{KA})} = 0.797\ \Omega$$

$$X_L = \omega L \,, \qquad L = \frac{X_L}{\omega} = \frac{0.797}{2\pi(60)} = 2.11\,\text{mH}$$

Capacitor Banks



If the switch S_1 closes when the voltage is at its peak, I lags V by $90°$, therefor when $I=0$ $V=V_{peak}$.

$$Z_o = \sqrt{\frac{L}{C_1}} = \sqrt{\frac{2.11\ mH}{40.11\ \mu F}} = 7.25\,\Omega$$

$$V_{peak} = \sqrt{3}\ I_{peak}\ Z_o =$$

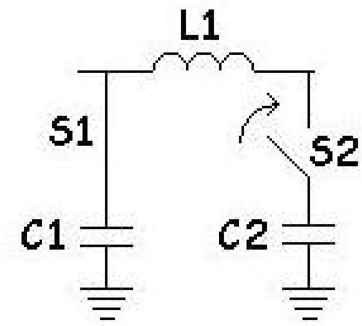
$$I_{peak} = \frac{V_{peak}}{\sqrt{3}\ Z_o} = \frac{\sqrt{2}\,(34.5\,kV)}{\sqrt{3}\ (7.25\,\Omega)} = 3.89\ KA$$

The frequency $$f_o = \frac{1}{2\pi\sqrt{LC_1}} = \frac{1}{2\pi\sqrt{(2.11\,m)(40.11\,\mu)}} = 547\ Hz$$

Since the operating current 301.2 A and the peak transient current is 3.9KA, the transient is approximatly 13 times bigger.

The frequency is about 9 times the power frequency.

Capacitor Banks



Then S_2 closes. C_1 and C_2 share the charge with L_1 in between, for $L_1 \cong 19\mu H$

$C_2 \Rightarrow 10\,MVA \qquad VA = \sqrt{3}\,VI$

$$I = \frac{VA}{\sqrt{3}\,V} = \frac{10\,MVA}{\sqrt{3}\,(34.5\,KV)} = 167.35\,A$$

$$X_{C_2} = \frac{V}{\sqrt{3}\,I} = \frac{34.5\,KV}{\sqrt{3}\,(167\,A)} = 119\,\Omega$$

$$C_2 = \frac{1}{\omega X_{C2}} = \frac{1}{2\pi(60)(119)} = 22.28\,\mu F$$

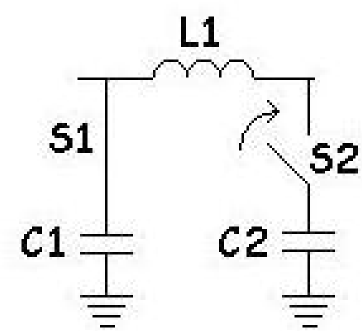
Capacitor Banks

During the high frecuency transient C_1 and C_2 share the current (charge), and become series conected

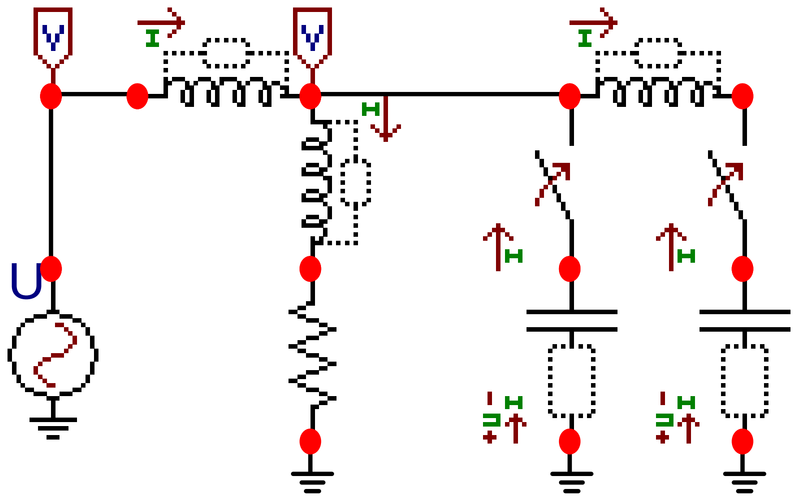
$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} \qquad Z_{o_1} = \sqrt{\frac{L_1}{C_e}} = \sqrt{L_1\left(\frac{C_1+C_2}{C_1 C_2}\right)} = 1.158\ \Omega$$

$$f_{o_1} = \frac{1}{2\pi\sqrt{L_1 C_e}} = \frac{1}{2\pi\sqrt{L_1\left(\frac{C_1 C_2}{C_1+C_2}\right)}} = 9.5\,KHz$$

$$I_{peak} = \frac{V_{peak}}{\sqrt{3}\, Z_{o_1}} = \frac{\sqrt{2}\,(34.5\,KV)}{\sqrt{3}\,(1.158\,\Omega)} = 24.3\,KA$$



Capacitor Banks



Assuming a load of 20MW @80% power factor lagging

- V_s=34.5kV
- L_s=2.11mH
- C_1=40.11uF
- L_1=19uH
- C_2=22.28uF
- R_{LOAD}=430ohm
- L_{LOAD}=707mH

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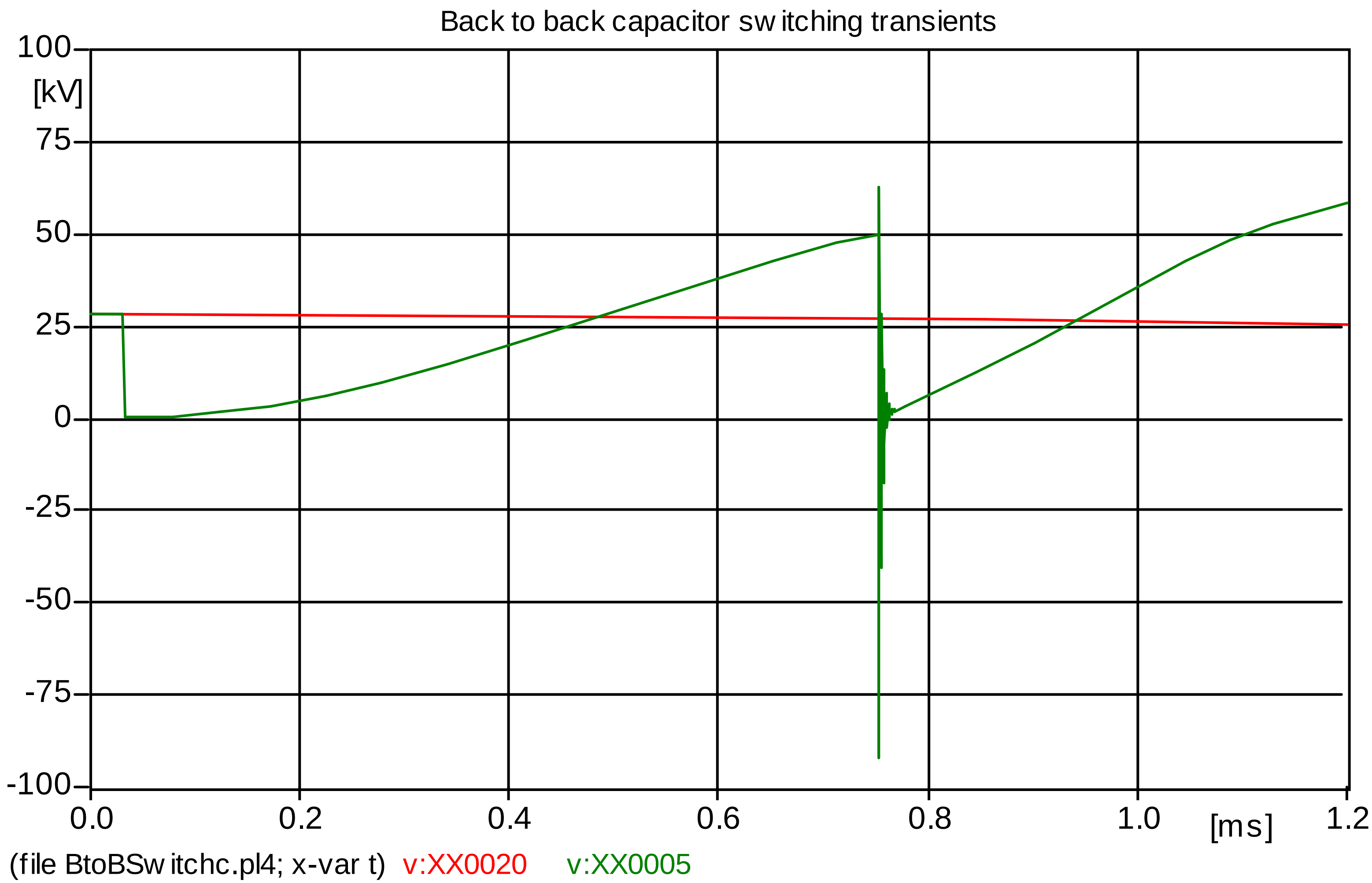
Capacitor Banks



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(b) Si en lugar de un Banco de Capacitores se añade un Motor Sincrónico (500 hp, 90% eff, 100% P.F.) operando a plena carga, computar el P.F. de la Planta. ($1 hp \cong 746 W$)

→ 500 hp son a la salida del motor. La potencia que se suple al motor será

$$P_M = \frac{Hp}{eff} = \frac{500\,hp}{.9}\left(\frac{.746\,kw}{1\,hp}\right) = 414.44\ KW$$

100% PF $= \frac{P}{S} = 1$

→ $P_m = S_m$ No hay Q

$\rightarrow$ $P_{new} = P_{old} + P_m = 500KW + 414.44KW = 914.44$

$\rightarrow$ $Q_{old} = 666.66$ KVAR

$\rightarrow$ $S_{new} = \sqrt{P_{new}^2 + Q_{old}^2} = 1131.66$ KVA

$$P.F_{new} = \cos\theta = \frac{P_{new}}{S_{new}} = 0.81$$

$\bar{I}_{new} = ?$