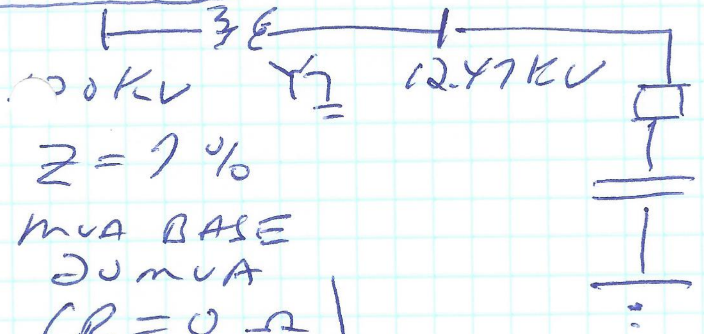
CAPACITOR SWITCHING EXAMPLE

ECE 587 - FALL 2019 (AUG. 28)



$Z = 7\%$

MVA BASE 20MVA

(R = 0 Ω)

5 MVAR CAPACITOR

$v_c(0) = +1000V$

FIND $v_c(t)$ WHEN CAPACITOR SWITCHED ON AT NEGATIVE SOURCE VOLTAGE PEAK.

$$\underset{p.u.}{X_T} = 0.07 \text{ p.u.} \Rightarrow Z_{BASE} = \frac{V_{BASE}^2}{S_{BASE}} = \frac{(12.47)^2}{20} = 7.78\,\Omega$$

$$L = \frac{X_T \times Z_{BASE}}{\underbrace{2\pi 60}_{\omega}} = \frac{(0.07)(7.78)}{377} = \boxed{1.44\,mH}$$

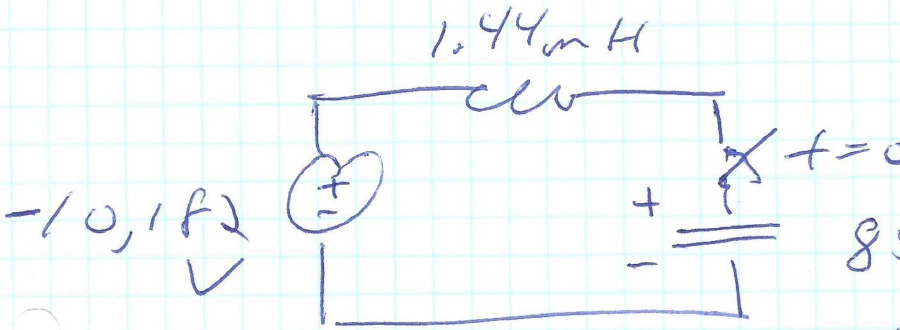
$$Q_{3\phi} = 5 \text{ MVAR} = \frac{(V_{LINE})^2}{X_C} = \frac{(V_{LINE})^2}{1/\omega C}$$

$$C = \frac{Q}{V^2 \omega} = \frac{5 \times 10^6}{(12470)^2\, 377} = \boxed{85.2\,\mu F}$$

$1\mu F = 10^{-6} F$

DC SOURCE APPROXIMATIONS

$$\sqrt{2}\,\frac{12{,}470}{\sqrt{3}} \sin(\omega \overset{t=0}{\cancel{t}} + \underset{-90°}{\theta}) = -10{,}182\,V$$



$v_c(0) = 1000$

$$\Rightarrow L\frac{di}{dt} + v_c(t) = v_s(0) \quad ; \quad i = C\frac{dv_c}{dt}$$

$$\left[LC\frac{d^2v_c(t)}{dt^2} + v_c(t) = v_s(0) \right] \frac{1}{LC}$$

$$\boxed{\frac{d^2v_c(t)}{dt^2} + \frac{1}{LC}v_c(t) = \frac{1}{LC}v_s(0)}$$

$$\frac{-10,182}{LC}$$

$$v_c(t) = v_{ss}(t) + v_{TR}(t)$$

$$v_{ss} = K \Rightarrow \cancel{\frac{d^2K}{dt^2}} + \frac{1}{LC}K = \frac{1}{LC}v_s(0)$$

$$0$$

$$K = v_s(0) \Rightarrow v_{ss}(t) = v_s(0)$$

CHAR. EQN $\quad s^2 + \frac{1}{LC} = 0 \Rightarrow s_1, s_2 = \pm j\frac{1}{\sqrt{LC}}$

$$\omega_0 = \frac{1}{\sqrt{LC}} = 2855 \ \frac{RAD}{SEC} \qquad = \pm j\omega_0$$

$$v_c(t) = -10,182 + A_1\cos(2855t) + A_2\sin(2855t)$$

$$v_c(0) = 1000 = -10,182 + A_1 + 0$$

$$A_1 = 1000 + 10,182 = \boxed{11,182\ V = A_1}$$

$$\frac{dv_c(0)}{dt} = 0 + 0 + \omega A_2(1) = 0$$

$$C\frac{dv_c(0)}{dt} = i_L(0) = 0 \qquad \boxed{A_2 = 0}$$

$$v_C(t) = \underline{-10{,}182} + 11{,}182\cos(2855t)$$

$$= \underbrace{v_s(0)}_{\text{AT SWITCHING}} - \underbrace{(v_s(0) - v_C(0))}_{v_{sw}(0)}\cos(\underline{\omega_0 t})$$

v_C PEAK AT $\omega_0 t = \pi = 2855t$

$$v_{C\,PEAK} = -10{,}182 + 11{,}182(-1)$$

$$= \underline{-21{,}364\,V}$$

ADD DAMPING

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4.1

$$\frac{X}{R} = 6 \Rightarrow X = X_T \times Z_{BASE} = 0.5443 \Rightarrow R = \frac{0.5443}{6} = \underline{0.091\ \Omega}$$

NOTE IF IN PROBLEM STATEMENT I SAID

$$Z = 7\% \text{ WITH } X/R = 6 \Rightarrow |Z| = 0.5443$$

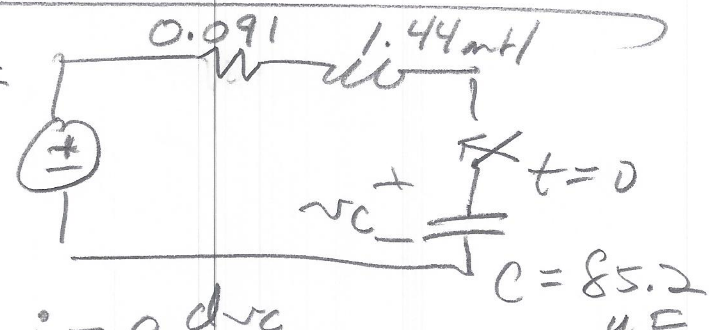
$$|Z| = \sqrt{R^2 + X^2} \Rightarrow 0.5443 = \sqrt{R^2 + (6R)^2}$$

$$R = \frac{0.5443}{\sqrt{37}} = 0.0895\ \Omega \quad \text{A LITTLE DIFFERENT}$$

$$X = 6R = \underline{0.5368\ \Omega} \quad \text{A LITTLE DIFFERENT}$$

ANYWAYS
HAVE EQUIVALENT CIRCUIT

$v_s(0) = 10,182$



$v_C(0) = 1000$

$$L\frac{di}{dt} + Ri + v_C(t) = v_s(0); \quad i = C\frac{dv_C}{dt}$$

SUBSTITUTING

$$LC\frac{d^2 v_C}{dt^2} + RC\frac{dv_C}{dt} + v_C(t) = v_s(0)$$

$$\boxed{\frac{d^2 v_C}{dt^2} + \frac{R}{L}\frac{dv_C}{dt} + \frac{1}{LC}v_C = \frac{1}{LC}v_s(0)}$$

$$v_C(t) = v_{SS}(t) + v_{TR}(t)$$

FOR DC FORCING FUNCTION $\quad v_{SS}(t) = K$ CONSTANT

$$\frac{d^2 K}{dt^2} + \frac{R}{L}\frac{dK}{dt} + \frac{1}{LC}K = \frac{1}{LC}v_s(0)$$

$$\boxed{v_{SS}(t) = v_s(0)}$$

CHAR EQN.
$$s^2 + \frac{R}{L}s + \frac{1}{LC} = 0$$

$$a = 1,\ b = \frac{R}{L} = 63.2,\ c = \frac{1}{LC} = 8.15\times 10^6$$

$$s_1, s_2 = -\frac{b}{2} \pm \frac{\sqrt{b^2-4ac}}{2} = -31.6 \pm j\,2855$$

$$v_c(t) = v_s(0) + e^{-31.6t}\left[A_1\cos(2855t) + A_2\sin(2855t)\right]$$

$$v_c(0) = -10{,}182 + A_1 = 1{,}000 \Rightarrow \boxed{A_1 = 11{,}182}$$

$$\frac{dv_c(0)}{dt} = 0 + (-31.6)e^0\left[A_1(1) + A_2(0)\right] + e^0\left[-A_1\,2855\sin(0) + A_2\,2855\cos(0)\right] = 0$$

$$\Rightarrow -31.6A_1 + A_2\,2855 = 0$$

$$A_2 = \frac{+31.6A_1}{2855} = \frac{+31.6}{2855}(11{,}182) = +124$$

$$\Rightarrow v_c(t) = -10{,}182 + 11{,}182e^{-31.6t}\cos(2855t) + 124e^{-31.6}\sin(2855t)$$

$t \geq 0$

CHANGES PEAK VOLTAGE BY JUST A SMALL AMOUNT, BUT DECAYS EXPONENTIALLY