Homework-06 ENGR 117 Due date 05/09/2022

5 Questions 20 points each

Q-1 Design an op amp-based low-pass filter with a cutoff frequency of 2500 Hz and a passband gain of 5 using a 10 nF capacitor. The input to the low-pass filter is 3.5 cos ωt V.

a) Draw your circuit, labeling the component values and output voltage.

b) If the value of the feedback resistor in the filter is changed but the value of the resistor in the forward path is unchanged, what characteristic of the filter is changed?

c) Find the output voltage when $\omega = \omega_c$.

d) Find the output voltage when $\omega = 0.125\ \omega_c$.

e) Find the output voltage when $\omega = 8\ \omega_c$.

Q-2 Write the relationship and draw phasor between phase and line quantities for a balanced 3 phase system if:

a. Star Connection (phasor diagram for phase voltages and Line voltages).
b. Delta Connection (phasor diagram for phase currents and Line currents).

Q-3 For each set of voltages, state whether or not the voltages form a balanced three-phase set. If the set is balanced, state whether the phase sequence is positive or negative. If the set is not balanced, explain why?

a) $v_a = 48\cos(314t - 45^\circ)$ V,

$v_b = 48\cos(314t - 165^\circ)$ V,

$v_c = 48\cos(314t + 75^\circ)$ V.

b) $v_a = 188\cos(250t + 60^\circ)$ V,

$v_b = -188\cos 250t$ V,

$v_c = 188\cos(250t - 60^\circ)$ V.

c) $v_a = 426\cos 100t$ V,

$v_b = 462\cos(100t + 120^\circ)$ V,

$v_c = 426\cos(100t - 120^\circ)$ V.

d) $v_a = 1121\cos(2000t - 20^\circ)$ V,

$v_b = 1121\sin(2000t - 50^\circ)$ V,

$v_c = 1121\cos(2000t + 100^\circ)$ V.

e) $v_a = 540\sin 630t$ V,

$v_b = 540\cos(630t - 120^\circ)$ V,

$v_c = 540\cos(630t + 120^\circ)$ V.

f) $v_a = 144\cos(800t + 80^\circ)$ V,

$v_b = 144\sin(800t - 70^\circ)$ V,

$v_c = 144\sin(800t + 50^\circ)$ V.

Q-4 A balanced three-phase circuit has the following characteristics.

- Y-Y connected;
- The line voltage at the source, $\mathbf{V}_{ab}$, is $110\sqrt{3}\angle -60^\circ$ V;
- The phase sequence is positive;
- The line impedance is $3 + j2\ \Omega/\phi$;
- The load impedance is $37 + j28\ \Omega/\phi$;

a) Draw the single-phase equivalent circuit for the a-phase.
b) Calculated the line currents for each phase.
c) Calculated the line voltages at the load in each phase.

Q-5 A balanced, three-phase circuit is characterized as follows:

- Y-Δ connected;
- Source voltage in the b-phase is $150\angle 135^\circ$ V;
- Source phase sequence is acb;
- Line impedance is $2 + j3\ \Omega/\phi$;
- Load impedance is $129 + j171\ \Omega/\phi$.

a) Draw the single phase equivalent a-phase.
b) Calculate the a-phase line current.
c) Calculate the a-phase line voltage for the three-phase load.

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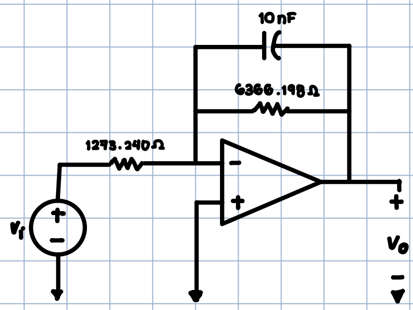
EEE 117

Q1 (a)



$\omega_c = 2\pi f = 2\pi(2500\text{ Hz}) = 5000\pi \text{ rad/s}$

$\omega_c = \dfrac{1}{R_2 C} \longrightarrow R_2 = \dfrac{1}{(5000\pi)(10\times10^{-9})} = 6\,366.198\,\Omega$

$K = \dfrac{R_2}{R_1} = 5 \longrightarrow R_1 = \dfrac{R_2}{5} = \dfrac{6\,366.198}{5} = 1273.240\,\Omega$

(b) R_2 changed

ω_c changed

K changed

(c) $|H(j\omega)| = \dfrac{R_2}{R_1} \cdot \dfrac{1/R_2C}{\sqrt{(1/R_2C)^2 + \omega^2}}$ $\qquad \omega = \omega_c = 5000\pi \text{ rad/s}$

$|H(j\omega_c)| = \left[\dfrac{6\,366.198}{1273.240}\right] \cdot \dfrac{1/(6\,366.198)(10\text{nF})}{\sqrt{\left[1/(6\,366.198)(10\text{nF})\right]^2 + (5000\pi)^2}} = 3.54$

$\angle H(j\omega_c) = 180 - \tan^{-1}(\omega R_2 C)$

$= 180 - \tan^{-1}\left[(5000\pi)(6366.198)(10\times10^{-9})\right]$

$= 135°$

$\dfrac{V_o}{V_i} = 3.54\angle 135°$ $\qquad V_o = 3.54\angle 135°\ V_i$

$= (3.54\angle 135°)(3.5\cos 5000\pi t)$

$= \boxed{12.39 \cos(5000\pi t + 135°)\text{ V}}$

(d) $|H(j\omega)| = \dfrac{R_2}{R_1} \cdot \dfrac{1/R_2C}{\sqrt{(1/R_2C)^2 + \omega^2}}$ $\qquad \omega = 0.125\,\omega_c = 0.125(5000\pi) = 625\pi$

$H(j\omega_c)| = \left[\dfrac{6\,366.198}{1273.240}\right] \cdot \dfrac{1/(6\,366.198)(10\text{nF})}{\sqrt{\left[1/(6\,366.198)(10\text{nF})\right]^2 + (625\pi)^2}} = 4.96$

$\angle H(j\omega_c) = 180 - \tan^{-1}(\omega R_2 C)$

$= 180 - \tan^{-1}\left[(625\pi)(6366.198)(10\times10^{-9})\right]$

$= 172.87°$

$\dfrac{V_o}{V_i} = 4.96\angle 172.87°$ $\qquad V_o = 4.96\angle 172.87°\ V_i$

$= (4.96\angle 172.87°)(3.5\cos 625\pi t)$

$= \boxed{17.36 \cos(625\pi t + 172.87°)\text{ V}}$

(e) $|H(j\omega)| = \frac{R_2}{R_1} \cdot \frac{1/R_2C}{\sqrt{(1/R_2C)^2 + \omega^2}}$ $\qquad \omega = 8\omega_c = 8(5000\pi) = 40k\pi$

$$|H(j\omega_c)| = \left[\frac{6366.198}{1273.240}\right] \cdot \frac{1/(6366.198)(10nF)}{\sqrt{\left[1/(6366.198)(10nF)\right]^2 + (40k\pi)^2}} = 0.62$$

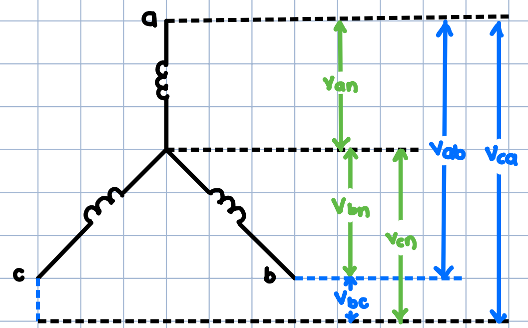
$$\begin{aligned} \angle H(j\omega_c) &= 180 - \tan^{-1}(\omega R_2 C) \\ &= 180 - \tan^{-1}\left[(40k\pi)(6366.198)(10\times10^{-9})\right] \\ &= 97.125^\circ \end{aligned}$$

$\frac{V_o}{V_i} = 0.62\angle 97.125^\circ$ $\qquad V_o = 0.62\angle 97.125^\circ V_i$

$$= (0.62\angle 97.125^\circ)(3.5\cos 40k\pi t)$$

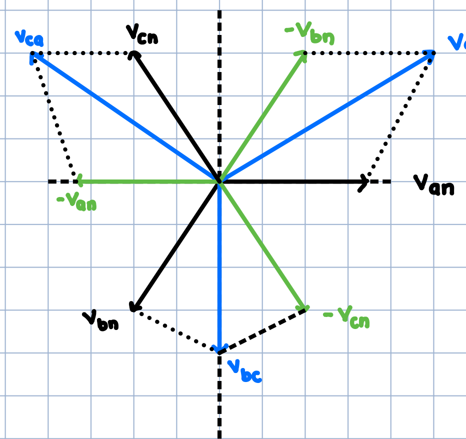
$$= \boxed{2.17\cos(40000\pi t + 97.125^\circ)\,V}$$

Q2 (a)



Phase voltage : V_{an}, V_{bn}, V_{cn}

Line voltage : V_{ab}, V_{bc}, V_{ca}



$$|V_{ab}|^2 = |V_{an}|^2 + |V_{bn}|^2 + 2|V_{an}||V_{bn}|\cos 60^\circ$$

balanced system : $|V_{an}| = |V_{bn}| = |V_{cn}| = V_\varphi$

$V_{ab} = \sqrt{3}V_\varphi$ angle $+30^\circ$ from ref. axis and $+30^\circ$ from V_{an}

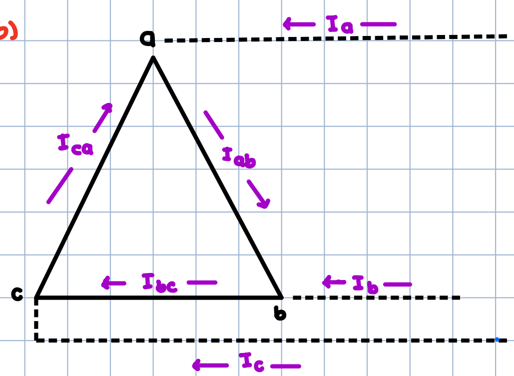
$V_{bc} = \sqrt{3}V_\varphi$ angle -90° from ref. axis and $+30^\circ$ from V_{bn}

$V_{ca} = \sqrt{3}V_\varphi$ angle $+150^\circ$ from ref. axis and $+30^\circ$ from V_{cn}

$V_{line} = \sqrt{3}V_{phase}$

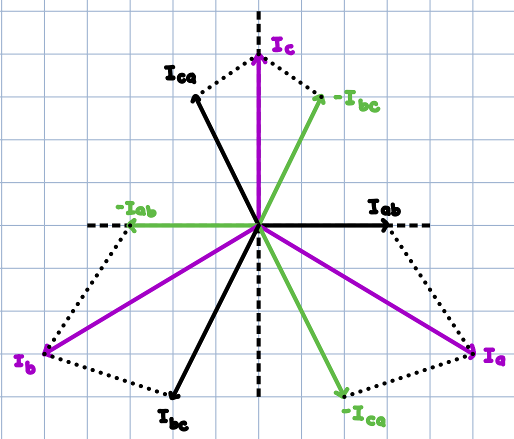
Line voltage leads phase voltage by 30°

(b)



Phase current : I_{ab}, I_{bc}, I_{ca}

Line current : I_a, I_b, I_c



$|I_a|^2 = |I_{ab}|^2 + |I_{ca}|^2 + 2|I_{ab}||I_{ca}|\cos 60°$

balanced system : $|I_{ab}| = |I_{bc}| = |I_{ca}| = I_\varphi$

$I_a = \sqrt{3}\, I_\varphi$ angle $-30°$ from ref. axis and $-30°$ from I_{ab}

$I_b = \sqrt{3}\, I_\varphi$ angle $-150°$ from ref. axis and $-30°$ from I_{bc}

$I_c = \sqrt{3}\, I_\varphi$ angle $+90°$ from ref. axis and $-30°$ from I_{ca}

$I_{Line} = \sqrt{3}\, I_{phase}$

Q3. (a) $V_a = 48\angle -45°$

$V_b = 48\angle -165°$

$V_c = 48\angle 75°$

$V_a + V_b + V_c = 0$

$(48\angle -45°) + (48\angle -165°) + (48\angle 75°) = 0$

$0 + j0 = 0$ Three-phase set voltages is balanced

balanced form:

$V_a = 48\cos(314t - 45°)\ V$

$V_b = 48\cos(314t - 45° - 120°)\ V$

$V_c = 48\cos(314t - 45° + 120°)\ V$

Phase sequence : abc
positive

(b) $V_a = 188\cos(250t + 60°)\ V = 188\angle 60°\ V$

$V_b = 188\cos(250t + 180°)\ V = 188\angle 180°\ V$

$V_c = 188\cos(250t - 60°)\ V = 188\angle -60°\ V$

$V_a + V_b + V_c = 0$

$(94 + j94\sqrt{3}) + (-188 + j0) + (94 - j94\sqrt{3}) = 0$

$0 + j0$

Three-phase set voltages is balanced

balanced form:

$V_a = 188\cos(250t + 60°)\ V$

$V_b = 188\cos(250t + 60° + 120°)\ V$

$V_c = 188\cos(250t + 60° - 120°)\ V$

phase sequence : acb
negative

(c) magnitude of phase voltage V_b is not equal to V_a and V_c.
Therefore, three-phase voltage are unbalanced

(d) $V_a = 1121\cos(2000t - 20°)\ V = 1121\angle -20°\ V$

$V_b = 1121\cos(2000t - 50° - 90°)\ V = 1121\angle -140°\ V$

$V_c = 1121\cos(2000t + 100°)\ V = 1121\angle 100°\ V$

$V_a + V_b + V_c = 0$

$(1121\angle -20°) + (1121\angle -140°) + (1121\angle 100°) = 0$

$0 + j0 = 0$

Three-phase set voltages is balanced

balanced form:

$V_a = 1121\cos(2000t - 20°)\ V$

$V_b = 1121\cos(2000t - 20° - 120°)\ V$

$V_c = 1121\cos(2000t - 20° + 120°)\ V$

phase sequence: abc
positive

(e) $V_a = 540\angle -90°\ V$

$V_b = 540\angle -120°\ V$

$V_c = 540\angle 120°\ V$

$V_a + V_b + V_c = 0$

$(540\angle -90°) + (540\angle -120°) + (540\angle 120°) = 0$

$-540 - j540 \neq 0$

Three-phase set voltages is unbalanced

(f) $V_a = 144\cos(800t + 80°)\ V \quad = 144\angle 80°\ V$

$V_b = 144\cos(800t - 70° - 90°)\ V \quad = 144\angle -160°\ V$

$V_c = 144\cos(800t + 50° - 90°)\ V \quad = 144\angle -40°\ V$

$V_a + V_b + V_c = 0$

$(144\angle 80°) + (144\angle -160°) + (144\angle -40°) = 0$

$0 + j0 = 0$ Three-phase set voltages is balanced

balanced form:

$V_a = 144\cos(800t + 80°)\ V$

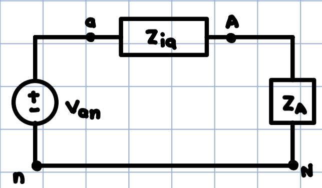
$V_b = 144\cos(800t + 80° - 240°)\ V$

$V_c = 144\cos(800t + 80° - 120°)\ V$

phase sequence : acb

negative

Q4 (a)



$V_{an} = \dfrac{V_{ab}}{\sqrt{3}\angle 30°} = \dfrac{110\sqrt{3}\angle -60°}{\sqrt{3}\angle 30°} = 110\angle -90°\ V$

$Z_{1a} = 3 + j2\ \Omega \quad = \sqrt{13}\angle 33.69°\ \Omega/\phi$

$Z_A = 37 + j28\ \Omega = 46.4\angle 37.12°\ \Omega/\phi$

(b) $I = \dfrac{V}{Z} \longrightarrow I_{aA} = \dfrac{V_{an}}{Z_{1a} + Z_A} = \dfrac{0 - j110}{(3+j2)+(37+j28)}$

$= -1.32 - j1.76 = 2.2\angle -126.87°\ A$

$I_a = \boxed{2.2\angle -126.87°}\ A$

$I_b = 2.2\angle -126.87 + 120°$

$= \boxed{2.2\angle -6.87°\ A}$

$I_c = 2.2\angle -126.87 - 120°$

$= \boxed{2.2\angle -246.87°\ A}$

(c) $V_{AN} = I_{aA} Z_A$

$= (2.2\angle -126.87°)(46.4\angle 37.12°)$

$= 102.08\angle -89.75°\ V$

$V_{ab} = (\sqrt{3}\angle 30°)V_{AN}$

$= (\sqrt{3}\angle 30°)(102.08\angle -89.75°)$

$= 176.81\angle -59.75°\ V$

LOAD: $V_{ab} = \boxed{176.81\angle -59.75°\ V}$

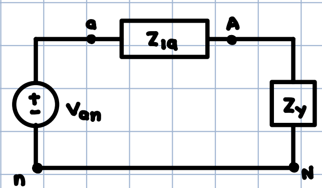
$V_{ac} = 176.81\angle -59.75° + 120°$

$= \boxed{176.81\angle 60.25°\ V}$

$V_{bc} = 176.81\angle -59.75° - 120°$

$= \boxed{176.81\angle -179.75°\ V}$

Q5 (a)



$V_{an} = 150\angle 135° - 120°$

$= 150\angle 15°\ V$

$Z_Y = \dfrac{Z_\Delta}{3} = \dfrac{129 + j171}{3} = 43 + j57\ \Omega/\phi$

$Z_{1a} = 2 + j3\ \Omega/\phi$

(b) $I = \dfrac{V}{Z} \longrightarrow I_{aA} = \dfrac{V_{an}}{Z_{1a} + Z_Y} = \dfrac{150\angle 15°}{(43+j57)+(2+j3)}$

$= 1.57 - j1.24 = \boxed{2\angle -38.30°\ A}$

(c) $V_{AN} = Z_Y I_{aA} = (43 + j57)(2\angle -38.30°)$

$= 142.80\angle 14.67°\ V$

$V_{AB} = (\sqrt{3}\angle 30°)V_{AN}$

$= (\sqrt{3}\angle 30°)(142.80\angle 14.67°)$

$= \boxed{247.34\angle 44.67°\ V}$