EEEIU - Nguyễn Đình Ngọc Huy

The inductor:

If the current is constant (DC curr) the inductor behave as a S-C:

$i = \text{constant}, \frac{di}{dt} = 0, \boxed{v = 0}$

$L_{eq} = L_1 + L_2 + \dots + L_n$ (series)

$L_{eq} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + L_n$ (parallel)

The capacitor:

If the voltage is constant (DC V) The capacitor behave as a open-cir

$v = \text{constant}, \frac{dV}{dt} = 0, \boxed{i = 0}$

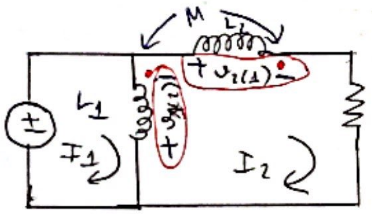
$C_{eq} = \frac{1}{C_1} + \frac{1}{C_2} + \dots \frac{1}{C_n}$ (series)

$C_{eq} = C_1 + C_2 + \dots C_n$ (parallel)

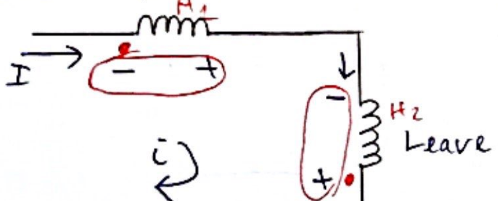
Mutual Inductor:

$\boxed{M = k\sqrt{L_1 L_2}}$, $k: 0 \to 1$

Cách xét dot convention:



Determine polarity on the Dot based on whether the current enter or leave the Dot.



KVL: $-v_{M_1} - v_{M_2}$

$= M\frac{di}{dt} \cdot X_L - M\frac{di}{dt} \cdot X_L$

Sinusoid - Phasor Transformation

$V_m \cos(\omega t + \theta) = V_m \angle \theta$

$V_m \sin(\omega t + \theta) = V_m \angle(\theta - 90°)$

Circuit technique analysis:

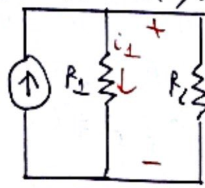
Voltage-Divider (series):

$v = v_s \frac{R_1}{R_1 + R_n}$

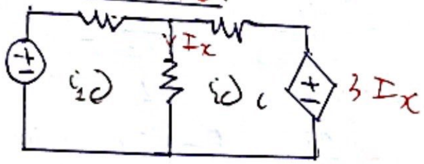
Current-Divider (Parallel):

$i_1 = \frac{R_2}{R_1 + R_2} i_s$

$i_2 = \frac{R_1}{R_1 + R_2} i_s$

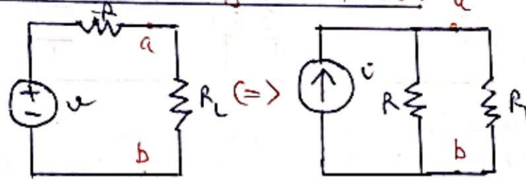


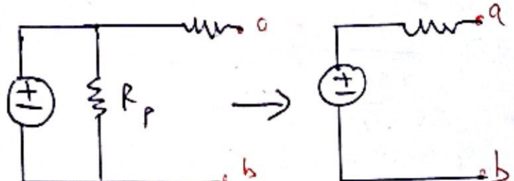
Dependent Source:

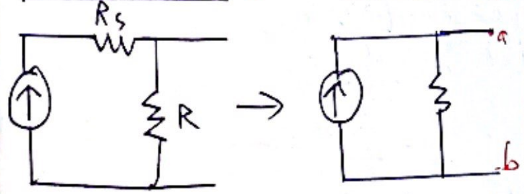


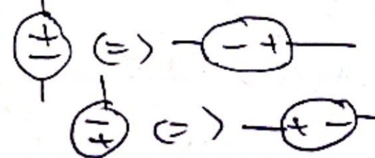
$I_x = I_1 - I_2$

Source Transformation:

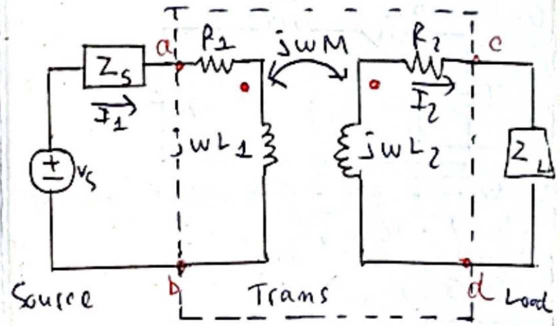








Transformer circuit analysis



Mesh current eq: $V_s = I_1(Z_s + R_1 + j\omega L_1) - j\omega M I_2$ (1); $0 = -j\omega M I_1 + (R_2 + j\omega L_2 + Z_L) I_2$ (2)

$Z_{11} = Z_s + R_1 + j\omega L_1$ = total self-impedance of the 1st winding

$Z_{22} = R_2 + j\omega L_2 + Z_L$ = " 2nd winding

$I_1 = \frac{Z_{22}}{Z_{11} \cdot Z_{22} + \omega^2 M^2} \cdot V_s$

$I_2 = \frac{j\omega M}{Z_{11} Z_{22} + \omega^2 M^2} V_s = \frac{j\omega M}{Z_{22}} I_1$

Impedance at the terminal source

$Z_{ab} = \frac{V_{AB}}{I_1} = \frac{V_s - I_1 \cdot Z_s}{I_1}$

$\Rightarrow Z_{AB} = R_1 + j\omega L_1 + Z_R$

$Z_R = \frac{\omega^2 M^2}{R_2 + j\omega L_2 + Z_L} = \boxed{\frac{\omega^2 M^2}{|Z_{22}|^2} \cdot Z_{22}^*}$

Be careful with Z_{22}^*

Maximum Power Transfer:

$$\boxed{Z_L = Z_{th}^* \qquad P_{max} = \frac{1}{8}\frac{|V_{th}|^2}{R_L}}$$

(Maximum average power absorbed)

Power Calculation:

Average Power:

$P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$

Reactive Power:

$Q = \frac{1}{2} V_m I_m \sin(\theta_v - \theta_i)$

Average Real Power:

$P = \frac{1}{2} \mathrm{Re}[VI^*]$ ($VI^* = V_m I_m \angle$ [illegible])

=> For Purely resistive circuit:

$\boxed{\theta_v = \theta_i \Rightarrow P = \frac{1}{2}|I|^2 R_{eq}}$

Purely reactive circuit:

$\boxed{\theta_v - \theta_i = \pm 90° \Rightarrow P = \frac{1}{2} V_m I \cos 90° = 0}$

Two special case:

$Z = R: P = \frac{|V|^2}{2R}$

R absorbs power at all time, while reactive load L or C absorb zero average power.

Rms Value:

$P = \frac{V_{rms}^2}{R} = I_{rms}^2 \cdot R$

Complex Power:

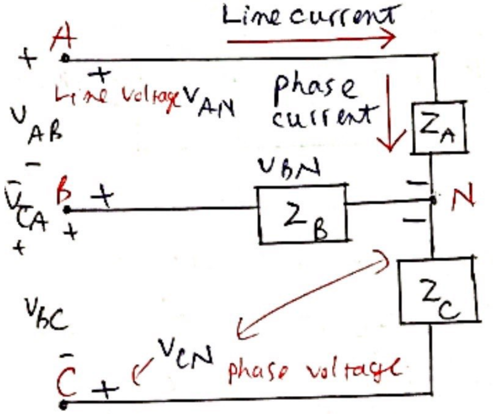
$S \pm P$ $P + jQ$

$|S| = \sqrt{P^2 + Q^2}$

$S = \frac{1}{2} V I^* = V_{eff} I_{eff}^*$

$= I_{eff}^2 Z = \frac{V_{eff}^2}{Z^*}$

Balanced Three-Phase Circuit



* Line current:

$\bar{I}_{aA} = \frac{V_{aA}}{Z_\phi}$, $\bar{I}_{bB} = \bar{I}_{aA}\angle -120°$

$\bar{I}_{cC} = \bar{I}_{aA}\angle +120°$

* Phase voltage (Load):

$\bar{V}_{AN} = \bar{I}_{aA} Z_A$ $\quad \bar{V}_{CN} = \bar{V}_{AN}\angle +120°$

$\bar{V}_{BN} = \bar{V}_{AN}\angle -120°$,

* Phase Source (V_n)

$\bar{V}_{an} = \bar{V}_{a'n} - \bar{I}_{aA} Z_{la}$

$\bar{V}_{bn} = \bar{V}_{an}\angle -120°$, $\bar{V}_{cn} = \bar{V}_{an}\angle +120°$

* Line voltage (Load)

$\bar{V}_{AB} = \sqrt{3}\,\bar{V}_{AN}\angle +30°$

$\bar{V}_{BC} = \bar{V}_{AB}\angle -120°$

$\bar{V}_{CA} = V_{AB}\angle +120°$

* Line voltage (Source):

$\bar{V}_{ab} = \sqrt{3}\,\bar{V}_{an}\angle +90°$

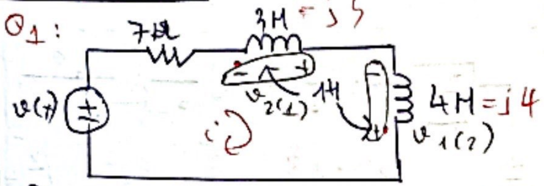
$\bar{V}_{bc} = \bar{V}_{ab}\angle -120°$

$\bar{V}_{ca} = \bar{V}_{ab}\angle +120°$

$$\boxed{P = 3\times|V_{AN}||I_{AN}|\cos(\varphi_v - \varphi_i)}$$

Mock Test:

Q1:



a) Write eq in time domain

$-v(t) + 7i + 3\frac{di}{dt} + 4\frac{di}{dt} - \frac{di}{dt} - \frac{di}{dt} = 0$

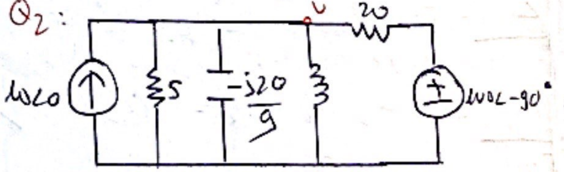
$\Leftrightarrow -v(t) + 7i + 5\frac{di}{dt} = 0$

b) Given $v(t) = 10\cos s(t)$. Write eq in phasor domain.

KLV: $-10 + 7I + j3I + j4I - jI - jI = 0$

$\Leftrightarrow -10 + 7I + j5I = 0$

Q2:



Node-voltage at V:

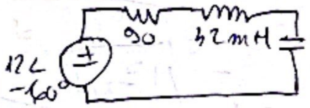
$\frac{V - 100\angle -90°}{20} + \frac{V}{j5} + \frac{V}{-j\frac{20}{9}} + \frac{V}{5} = 10$

$\Leftrightarrow V\left(\frac{1}{20} + \frac{1}{j5} + \frac{j9}{20} + \frac{1}{5}\right) = 10 - j5$

$\Rightarrow V\left(\frac{1}{4} + \frac{j}{4}\right) = 10 - j5$

$\Rightarrow V = 10 - j30 = 31.62\angle -71.57°$

$v(t) = 31.62\cos(5000t - 71.57°)$



Find C to obtain $I = |I|\angle -105°$

$|I| = \frac{12\angle -60°}{|Z|\angle\theta_Z} \Rightarrow |I| = -60 - \theta_Z$

a) $-60° - \theta_Z = -105° \Rightarrow \theta_Z = 45°$

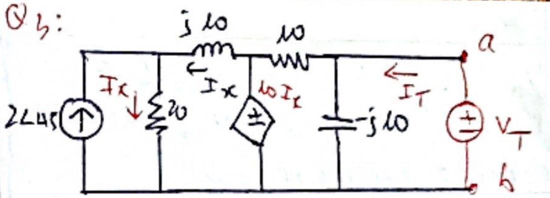
$Z = 90 + j\omega L + \frac{1}{j\omega C} = 90 + j\left(\omega L - \frac{1}{\omega C}\right)$

$\Rightarrow \theta_Z = \tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{90}\right) = 1$

$\Rightarrow C = 2.86\,\mu F$

b) $|I| = \frac{12}{\sqrt{90^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} =$ [illegible] 0.982

Q3:



$\frac{V_1}{10} + \frac{V_1 - 10I_x}{j10} - 2\angle 45° = 0$

$\ldots \Rightarrow V_{th} = \frac{-j10}{10 - j10}(10 I_x)$ (1)

We also have $I_x = \frac{V_1}{10}$ (2)

It follow from the circuit that $10 I_x = (20 + j10) I_x$

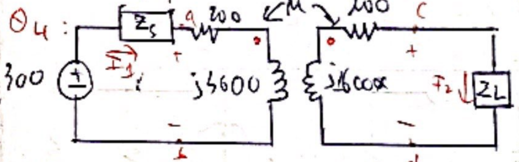
Therefore, $I_x = 0$ and

$I_T = \frac{V_T}{-j10} + \frac{V_T}{10} =$

From (1)(2) $V_{th} = 10\angle 45°$

$Z_{th} = \frac{V_T}{I_T} = 5 - j5\,(\Omega)$

Q4:



$Z_s = 500 + j200$, $Z_L = 800 - j2500$

a) $Z_{11} = Z_s + 200 + j3600 = 700 + j3700$

$Z_{22} = Z_L + 100 + j1600 = 900 - j900$

b) $Z_r = \frac{(\omega M)^2}{|Z_{22}|^2} Z_{22}^* = 800 + j800$

$M = 0.5\sqrt{9\times4} = 3H$ $\quad j\omega M = j1200$

c) The scaling factor which Z_{22}^* is reflected is 8/9

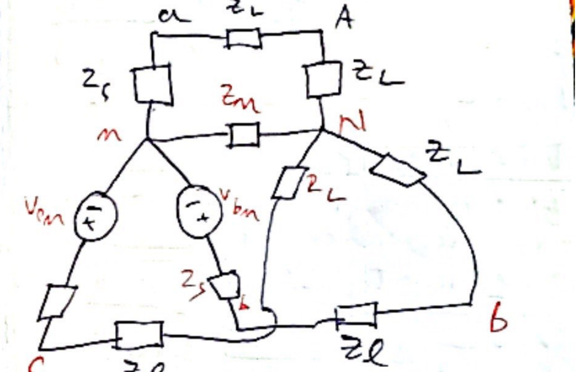
d) $Z_{ab} = 200 + j3600 + 800 + j800 = 1000 + j4400$

g) $I_1 = \frac{300\angle 0°}{700 + j3700} = 79.67\angle -79.29°$ mA

$V_{th} = j1200\times(79.67\angle -79.29)\times 10^{-3} = 95.60\angle 10.71$ V

$Z_{th} = 100 + j1600 + \left(\frac{1200}{|700 + j3700|}\right)^2 \times (700 - j3700) = 171.09 + j1224.26$

Q6: A Y-Y connected 3-phase circuit is depicted. It is known that $V_{an} = 220\angle 0°$ (V rms). $V_{bn} = 220\angle -120°$ (V rms), $V_{cn} = 220\angle 120°$. $Z_s = Z_\ell = Z_N = 0°$. And $Z_L = 50 + j10$



a) $I_{AN} = ?$ b) V_{Ab} ?

e) Total avg P.

Sol: a) $I_{AN} = \frac{220\angle 0°}{Z_L} = 4.31\angle -11.3°$ Arms

b) $V_{ab} = (\sqrt{3}\angle 30°)\cdot(220°\angle 0°) = 381\angle 30°$ Vrms

c) $P = 3|V_{AN}||I_{AN}|\cos(\theta_v - \theta_i)$

$= 3\times 220\times 4.31\cos(0 + 11.3) = 278$