Tutorial 7: Solutions

1. Single phase motors are not able to start by themselves. This requires a polyphase source. 3-phase generators, motors and transformers are simpler, cheaper and more efficient. 3-phase transmission lines deliver more power for a given cost or for a given weight of conductor. Voltage regulation of a 3-phase system is inherently better. In case of star-connected source, the line voltage is √3 times the phase voltage. This helps in transmitting and distributing power with a higher voltage. The number of conductors required for transmission and distribution is reduced thus helps reducing the cost in case of a balanced three-phase system.

$$v_{ab} = v_{an} - v_{bn}$$

$$= V_P \angle 20^0 - V_p \angle - 100^0$$

$$= V_P \sin(\omega t + 20^0) - V_P \sin(\omega t - 100^0)$$

$$= V_p \times 2 \sin(\frac{\omega t + 20^0 - \omega t + 100^0}{2}) \cos \frac{\omega t + 20^0 + \omega t - 100^0}{2}$$

$$= V_p \times 2 \sin(60^0) \cos(\omega t - 40^0)$$

$$= \sqrt{3} V_p \cos(\omega t - 40^0)$$

$$= \sqrt{3} V_p \cos\left(90^0 - (\omega t + 50^0)\right)$$

$$= \sqrt{3} V_p \sin(\omega t + 50^0)$$

$$v_{ab} = \sqrt{3} V_p \sin(\omega t + 50^0) = V_L \angle 50^0$$

$$v_{bc} = \sqrt{3} V_p \sin(\omega t - 70^0) = V_L \angle -70^0$$

$$v_{ca} = \sqrt{3} V_p \sin(\omega t - 190^0) = V_L \angle -190^0$$

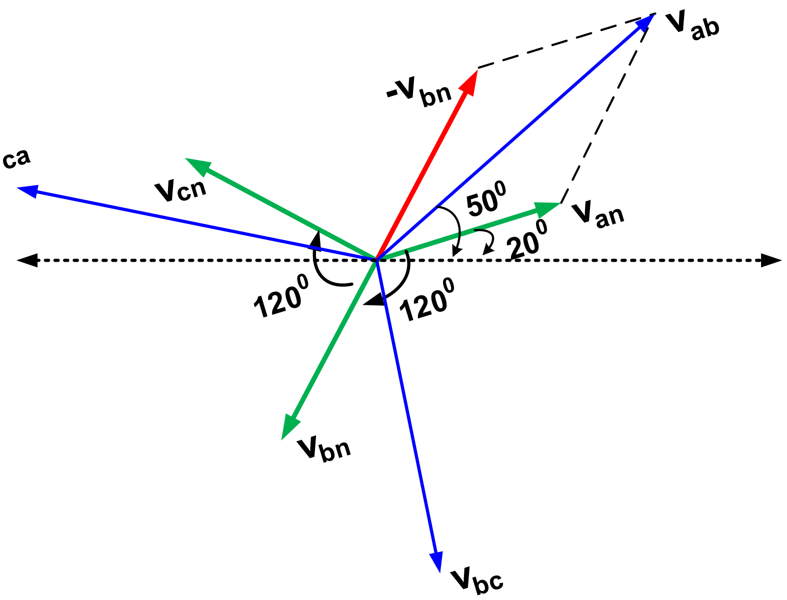

Fig.S1

2.

a.

$$I_{AN} = \frac{120\angle 0^0}{10} = 12\angle 0^0 \text{ A}$$
$$I_{NB} = \frac{120\angle 0^0}{10} = 12\angle 0^0 \text{ A}$$
$$\mathrm{I}_1 = \frac{120\angle 0^0 + 120\angle 0^0}{16 + j12} = 12\angle -36.87^0 \text{ A}$$
$$I_{aA} = I_1 + I_{AN} = 12\angle -36.87^0 + 12\angle 0^0 = 9.6 - j7.2 + 12 = 22.77\angle -18.43^0\ A$$
$$\mathrm{I_{nN} = I_{NB} - I_{AN} =\ 0\ A}$$

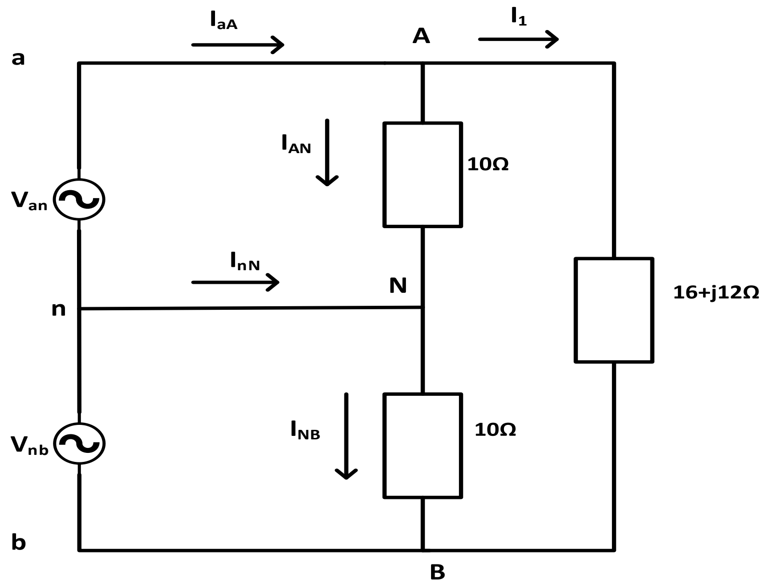

Fig.S2

b. When 10 Ω is connected in parallel with Z_{AN},

new $Z_{AN} = 5\Omega$, $I_{AN} = \frac{120\angle 0^0}{5} = 24\angle 0^0$ A

$$I_{aA} = I_1 + I_{AN} = 12\angle -36.87^0 + 24\angle 0^0 = 9.6 - j7.2 + 24 = 34.36\angle -12.09^0\ A$$
$$\mathrm{I_{nN} = I_{NB} - I_{AN}} = 12\angle 0^0 - 24\angle 0^0 = -12\angle 0^0\ A$$
$$I_{bB} = -(I_{NB} + I_1) = -22.77\angle -18.43^0\ A$$

3. Converting delta connected load to star connected load-

$$Z_2^{/} = \frac{Z_2^2}{3Z_2} = \frac{Z_2}{3} = 10 - j53.1\ \Omega$$

Total impedance per phase $= \frac{Z_1\, Z_2^{/}}{Z_1 + Z_2^{/}} = \frac{(20 + j37.7)(10 - j53.1)}{30 - j15.4} = 68.38\angle 9.89^0\ \Omega$

a. Line current = $\frac{398}{\sqrt{3}} \times \frac{1}{68.38\angle 9.89^0} = 3.36\angle -9.89^0$ A

b. P.F. = $\cos 9.89^0 = 0.985$ lagging

c. Total power = $\sqrt{3} \times V_L\, I_L^* = \sqrt{3} \times 398 \times 3.36\angle 9.89^0\ VA$

Reactive power $= 397.83\ VAR$

4. A The resistance value of the thermistor is

$$\mathrm{R}_{\mathrm{Therm}} = 10k\Omega - 120\Omega/^{\circ}C \times (T - 25^{\circ}C) \quad (1)$$

$$= \begin{cases} 10k\Omega & \text{at } 25^{\circ}\text{C} \\ 1k\Omega & \text{at } 100^{\circ}\text{C} \end{cases} \quad (2)$$

where T is the temperature in °C. A simple circuit to convert the $\Delta T \rightarrow \Delta R \rightarrow \Delta V$ is shown in Fig.S4(a). As the temperature changes from 25°C to 100°C, V_{OUT} increases from 4.5V to 8.1818V (=V_{REF}). We can compare the V_{OUT} value to 8.1818V to enable the alarm as shown in Fig.S4(b). One can generate the V_{REF} from the 9V battery using a resistive divider of 10$k\Omega$ and a 1$k\Omega$.

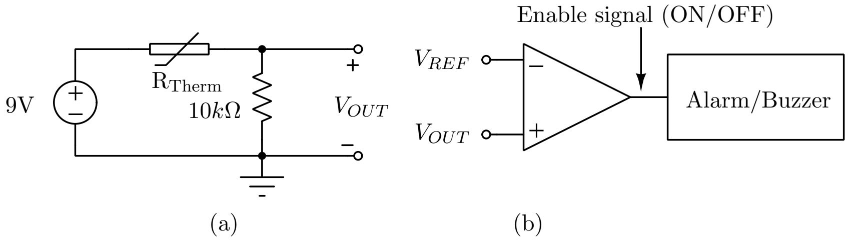

Fig.S4(a) A thermistor based temperature-to-voltage conversion (b) A comparator enabled alarm system.

5. The temperature-to-voltage conversion circuit shown in Fig.S4(a) can also be used here.

- Divide the temperature range into 16 levels and assign a 4-bit code to each level as shown in Fig.S5(a).
- Compute the V_{OUT} corresponding to each level as shown in Fig.S5(a).
- We need 16 V_{REF} values to know the exact temperature[1].
- A priority encoder can be used to encode the outputs of the 16 comparators into 4-bits. A 16-to-4 bit priority encoder outputs the 4-bit binary code corresponding to the highest priority input which is set to high (maximum decimal).

[1] In a typical implementation, voltage levels (instead of temperature) are equally divided so that the 16 V_{REF} values can be generated from a single resistive divider loop

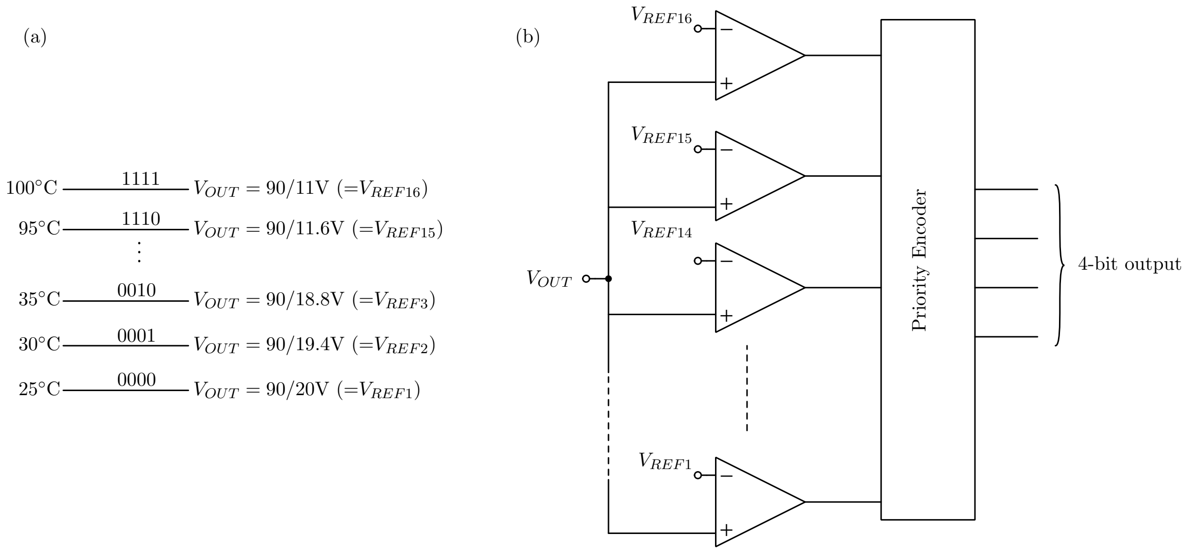

Fig.S5(a) 16 temperature levels and the corresponding V_{OUT} values. (b) A comparator enabled alarm system.