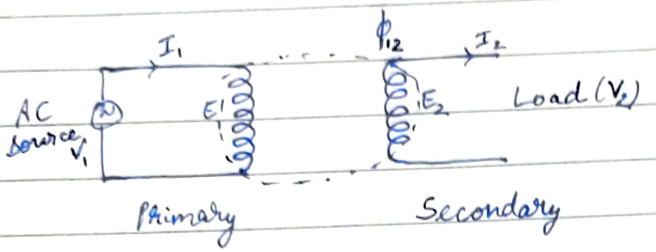
1st June, 2023

UNIT-5

Transformer



LV - Low Voltage
HV - High Voltage

1- ϕ Transformer
- Step Up
- Step down
- Isolation

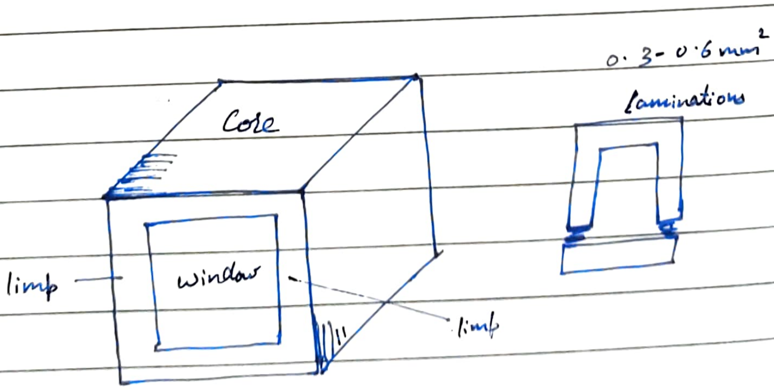
Step up → 220V (pri) / 440V (sec) - without change in freq.

pri → LV sec → HV

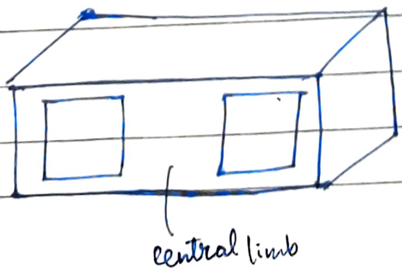
Step Down → 440 (pri) / 220 (sec)

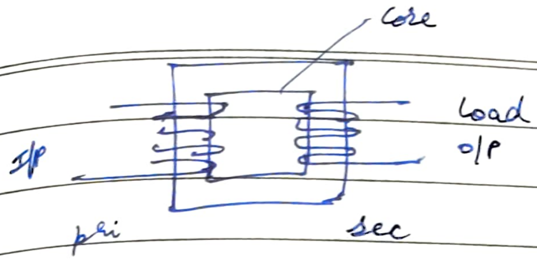
Isolation transformer (1:1) → 220/220

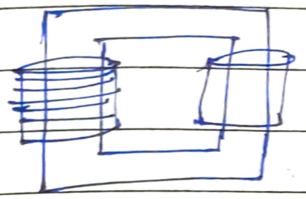
Construction: Core Type:

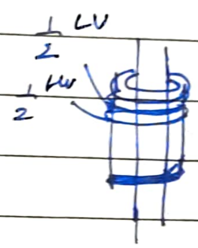


Shell Type









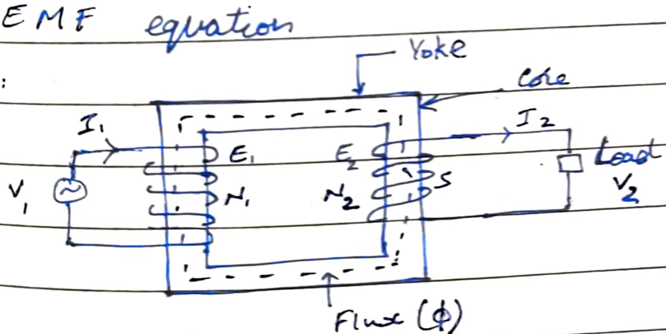
Parts of Transformer

Core
Winding
Transformer Tank
Transformer oil
Bush rings
Relay conservator

→ ~~Core Type Transformer~~

→ EMF equation

DERIVATION:



Let V_1 be the input voltage
E_1 be the emf induced in primary
N_1 be the no. of turns in primary
N_2 be the no. of turns in secondary
E_2 be the emf induced in secondary
ϕ be the flux in the core.

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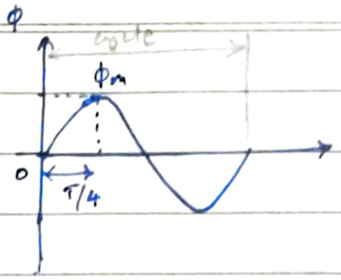

Let $\phi_m \rightarrow$ final flux

initial flux $\rightarrow 0$

Time taken is $T/4$

$\therefore$ EMF induced in 1 turn $= \dfrac{\text{final flux} - \text{initial flux}}{\text{time taken}}$

$$= \frac{\phi_m - 0}{T/4}$$

$$= \frac{4\phi_m}{T}$$

$$= 4\phi_m f$$

EMF induced in primary $E_1 = 4\phi_m f N_1$

wkt $E_{rms} = 1.11\, E_{avg}$

$$\therefore \boxed{E_1 = 4.44\,\phi_m f N_1} \quad -①$$

$||^{ly}$ $\boxed{E_2 = 4.44\,\phi_m f N_2}$ $-②$

Ideal transformer, $kVA\ o/p = kVA\ I/p$

$V_2 I_2 = V_1 I_1$

$E_1 = V_1$ & $E_2 = V_2$

$$\boxed{K = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}}$$

Transformer ratio

Date: / /

→ Losses in Transformer

- Core loss / Iron loss (W_i / W_c) →
  - Hysteresis Loss (W_h)
  - Eddy current (W_e)

  } Fixed loss
- Copper loss (I^2R Loss) } Variable loss

Q1. A single phase transformer has 400 primary turns and 1000 secondary turns. The net cross section area of the core is 60 sq. cm. If primary winding to be connected to a 50 Hz supply at 500 V. Calculate peak value of flux density in the core and voltage induced in the secondary windings.

Sol. $N_1 = 400$, $N_2 = 1000$, $f = 50\text{Hz}$

$A = 60 \times 10^{-4}\ m^2$, $V_1 = 500V$

$$B_m = \frac{\phi_m}{A}$$

B_m → flux density

$$E_1 = 4.44\ \phi_m f N_1$$

$$E_1 = 4.44\ B_m (A) f N_1$$

$$500 = 4.44\ B_m (60 \times 10^{-4}) \times 50 \times 400$$

$$B_m = 0.94\ Wb/m^2$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} \Rightarrow E_2 = \frac{1000}{400} \times 500 = 1250\ V$$

Q2. The required no load ratio in a single phase 50Hz core type transformer is 6000/250 V. Find the no. of turns in each winding if the flux is to be about 0.06 Wb

Sol. $E_1 = V_1 = 6000\ V$, $f = 50\text{Hz}$

$E_2 = V_2 = 250\ V$, $\phi = 0.06\ Wb$

$N_1 =$

$E_1 = 4.44\ \phi_m f N_1$

$6000 = 4.44\ (0.06)\ 50\ N_1$

$N_1 = 450$ turns

$250 = 4.44\ (0.06)\ 50\ N_2$

$N_2 = 19$ turns

Q3. A 5kVA, 50Hz single phase transformer has primary and secondary turns 120 and 80. At certain flux density the induced emf per turn in primary is 2.5V. Determine primary and secondary voltage. Also calculate current in both the windings.

Sol. $N_1 = 120$ $\quad E_1 = 2.5 \times 120 = 300V$

$N_2 = 80$

$\frac{E_2}{E_1} = \frac{N_2}{N_1} \Rightarrow E_2 = \frac{80}{120} \times 300 = 200V$

$o/p = 5 \times 10^3\ VA = V_2 I_2$

$V_2 I_2 = 5000$

$I_2 = \frac{5000}{200} = 25A$

$\frac{E_2}{E_1} = \frac{I_1}{I_2}$

$I_1 = \frac{200}{300} \times 25$

$= 16.66\ A$

2nd June, 2023

Q4. A 125 kVA transformer has a primary voltage of 2000V at 60Hz. If the no. of turns on primary equals 182 and the secondary equals 40

Find : a) secondary no load voltage

b) flux in the core

c) full load primary and secondary currents. Neglect losses

[4M]

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Sol. $V_2 I_2 = 125 \times 10^3 \; VA$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$E_2 = V_2$ $\quad V_2' = V_1 \times \frac{N_2}{N_1} = 2000 \times \frac{40}{182} = 439.56 \; V$

$V_1 = 4.44 \; \phi_m f N_1$

$2000 = 4.44 \; \phi_m (50)(182)$

$\phi_m = 0.0495 \; Wb$

$125 \times 10^3 = V_2 I_2$

$I_2 = \frac{125 \times 10^3}{439.56} = 284.4 A$

$$\frac{I_2}{I_1} = \frac{V_1}{V_2}$$

$I_1 = I_2 \frac{V_2}{V_1} = 284.4 \times \frac{439.56}{2000}$

$I_1 = 62.5 A$

Q5. Find no. of turns of primary and secondary of a 415/240 V, 50Hz transformer if area of the core is 50 sq. cm and max. value of flux density in the core is 1.3 Wb/sq. m

Sol. $N_1 = ?$ $\quad N_2 = ?$ $\quad \underset{V_1}{415} / \underset{V_2}{240}$

$V_1 = 4.44 \; \phi_m f N_1$

$415 = 4.44 \times 1.3 \times 50 \times 10^{-4} \times N_1$

$N_1 = 288$ turns

$N_2 = N_1 \times \frac{V_2}{V_1} = \frac{288 \times 240}{415} = 167$ turns

Q6. The primary winding of a single phase transformer is connected to 240V, 50Hz. The secondary winding has 1500 turns. If the maximum value of the core flux is 0.002 wb. Determine : a) no. of turns on primary windings
b) secondary induced voltage
c) net cross sectional core area if the max. flux density is 0.465 T. [4M]

Sol. ~~240 = 240~~

$V_1 = 4.44\ \phi_m f N_1$

$240 = 4.44\,(0.002)\,(50)\,N_1$

$N_1 = 541$

$N_1 = 541$ turns

$V_2 = 666$ V

$A = 4.8 \times 10^{-3}\ m^2$

$\frac{N_2}{N_1} = \frac{V_2}{V_1} \Rightarrow V_2 = \frac{1500}{541} \times 240 = 666\ V$

~~240 = 4.44~~

$\phi_m = B_m A$

$A = \frac{\phi_m}{B_m} = 0.0043\ m^2$

Q7. A 3000/300 V, 50Hz single phase transformer has an emf per turn of 15V and the maximum flux density of 1.5 T. Find no. primary and secondary turns and cross sectional area of the core.

Sol. $V_1 = 3000$

$V_2 = 300$

~~3000 = 4.44 (1.5) (50) N1~~

$3000 = N_1 (V)$

$\frac{3000}{15} = N_1$

$N_1 = 200$

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$$N_2 = N_1 \times \frac{V_2}{V_1} = 20$$

$$V_1 = 4.44\,(B_m A)\, f N_1 \qquad A = 0.045\ m^2$$

Q. A 100 kVA, 6000/400V, 50Hz, 1-ϕ transformer has 100 turns in secondary. Calculate the rated primary and secondary currents, the no. of primary turns and max. value of flux in core.

$V_1 = 6000$

$V_2 = 400$

$$P = V \times I$$

$$100 \times 10^3 = 6000 \times I_1$$

$$I_1 = 16.67\ A$$

$$100 \times 10^3 = 400 \times I_2$$

$$I_2 = 250\ A$$

$$N_1 = N_2 \times \frac{V_1}{V_2} = 1500$$

$$V_1 = 4.44\, \phi_m f N_1$$

$$\phi_m = \frac{6000}{4.44 \times 50 \times 1500} = 0.018\ Wb$$

3rd June, 2023

Energy Calculation

1 kWhr = 1 unit

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q1. Find the total no. of units consumed in a month for the following consumption tables assuming 30 days a month with a sanction load of 5kW

	Name	wattage	avg consumption hours per day	units consumed per day
1.	Greyser	2000 W	1 hour	2000 x 1 = 2000 Whs = 2kWhs = 2 units
2.	T.V	50 W	6 hours	300 Whs = 0.3 units
3.	4 LED	20W each bulb	6 hours each bulb	4x20x6 = 480 Whs = 0.48 units
4.	3 Fan	75W each fan	8 hours each bulb	3x75x8 = 1800 Whs = 1.8 units
5.	Fridge	100 W	24 hours	2.4 units
6.	water pump	1500W	20 mins	0.5 units

Total units consumed per day = 7.48 units

Total units consumed per month = 224.4 units

Units	Rs
0-50	4.15
51-100	5.6
101-200	7.15
200>	8.2

FAC → NIL

Tax → 9%

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Date: / /

Type of charges | Charges

	Type of charges	Charges
1.	Fixed charges for sanctioned load per month	$100 \times 1 + 110 \times 4 = ₹540$
2.	Energy consumption charges	$50 \times 4.15 + 50 \times 5.56 + 100 \times 7.15 + 24.4 \times 8.2 = Rs\ 1399.3$
3.	Fuel adjustment charges	NIL
4.	Tax	Rs 125.937 $1399.3 \times \frac{9}{100}$

Monthly Bill = Rs 2065.237

6th June, 2023

Q2. A list of loads and avg. consumption per day is given below. Considering 30 days a month determine:

i) Total no. of units consumed in a month

ii) Monthly Bill for above consumption considering domestic connection of 3 kW sanctioned load with the tarrif details listed in table. 2

Table 1

	Appliance	Wattage	avg. consumption per day	units (kWh)
1.	4 bulbs	60 W/bulb	10 hr each	2.4
2.	4 fans	75 W/bulb	12 hr each	3.6
3.	Geyser	1kW	1 hr	1
4.	Fridge	100 W	16 hr	1.6
5.	T.V	50 W	10 hr	0.5
6.	Mixer	750 W	1 hr	0.75
				9.85

Consider Tax 7.3%

Table 2.

	Type of charge	Tarrif	
1.	Fixed charge for same load	Rs. 50 for 1st kW Rs. 60 for every additional	
2.	Energy consumption	units	Rs
		0 - 30	3.50
		31 - 100	4.95
		101 - 200	6.5
		201 - 300	7.55
		301 - 400	7.6
		401 & above	7.65

Sol. units consumed / day = 9.85 units

units consumed in a month = 295.5 units

$$F\ C = 1(50) + 2(60) = 170 \text{ Rs}$$

$$E\ C = 30(3.5) + 70(4.95) + 100(6.5) + 95.5(7.55)$$

$$= 1822.55 \text{ Rs}$$

$$\text{Tax} = 1822.55 \times \frac{7}{100}$$

$$= 133.04$$

$$\text{Total Bill} = 170 + 1822.55 + 133.04$$

$$= \text{Rs } 2125.59$$

Q3) Following table gives typical consumption for household

Date: / /

T1.

1.	4 LED bulbs	20W/bulb	8hr each	0.64
2.	TV	60W	6hr	0.36
3.	AC	2000W	2hr	4
4.	Fridge	100W	24hr	2.4
5.	Water pump	750W	30min	0.375
6.	3 Fans	75W/Fan	10hr each	2.250
				10.025

Considering 30 days a month Find :

i) Total no. of units consumed in a month 300.75

ii) Monthly Bill considering 5kW sanc load

T2.

1.	FC	Rs 70 for first kW Rs 80 for next kW	
2.	EC	0-30 units	Rs 4
		31-100	5.45
		101-200	7
		201 & above	8.05
3.	FAC	8 paise/unit	
4.	Tax only on EC	9%	

Sol.

FC = 1(70) + 4(80) = 390

EC = 30(4) + 70(5.45) + 100(7) + 100.75(8.05) = 2012.54

FAC = 24.06

Tax = 181.1286

Monthly Bill = Rs 2607.7286

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7th June, 2023 Date: / /

Q4.

1.	AC	2000 W	1 hr	2
2.	TV	50 W	8 hrs	0.4
3.	3 LEDs	20 W each	6 hrs each	0.36
4.	3 Fans	75 W each	8 hrs each	1.2
5.	Fridge	100 W	24 hrs	2.4
6.	Water pump	750 W	30 mins	0.375
				6.735

Considering 30 days a month

i) Total no. of units consumed in a month

ii) Monthly Bill for the above consumption considering a domestic connection of 5kW sanc. load with tariff details as given below

1. Fixed charge for sanc. load — Rs 85 for first kW, Rs 95 for every additional kW

2. Energy consumption charges

0 - 50	Rs 4.1 per unit
51 - 100	Rs 5.55 per unit
101 - 200	Rs 7.1 per unit
above 200	Rs 8.15 per unit

3. Fuel adjustment charges — 14 paise per unit energy consumed

Consider overall tax 9% on energy consumption charges

Sol. no. of units / day = 6.735 units

Total no. of units consumed in a month = 202.05 = 202 units

sanc. load = 5kW

FC = 1(85) + 4(95) = 465

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$EC = 50(4.1) + 50(5.55) + 100(7.1) + 2(8.15)$
$= Rs\ 1209.20$

$FAC = 202 \times 0.14$
$= Rs\ 28.28$

$Tax = 1209.2 \times \frac{9}{100} = 108.8$

$Total\ Bill = 465 + 1209.2 + 28.28 + 108.8$
$= Rs\ 181\blacksquare.28$

q5

1.	3 LEDs	15W per bulb	10 hours each	0.45
2.	2 Fans	75W per fan	8 hours each	1.2
3.	water pump	750W	1 hour	0.75
4.	Fridge	100W	24 hours	2.4
5.	T.V	50W	10 hours	0.5
6.	Geyser	1kWh	1 hour	1
				6.3

Considering 30 days a month
i) Total no. of units consumed in a month 189 units
ii) Monthly Bill, 3kW sanc load

1. Fixed charge for sanc. load — Rs 50 for first kW, Rs 60 for every additional kW
$FC = 1(50) + 2(60) = 170$

2. Energy consumption charges

0 - 30	Rs 3.50 per unit
31 - 100	4.55
101 - 200	6.50
201 - 300	7.55

$EC = 30(3.5) + 70(4.95) + 89(6.5)$
$= 1030$

8% on total charge
$= (170 + 1030)(0.08) = 96$

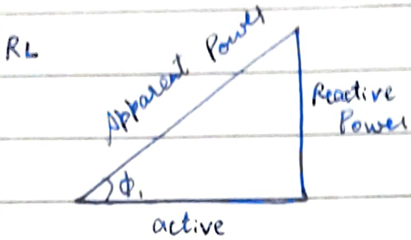
$Total\ bill = 170 + 1030 + 96 = 1296$

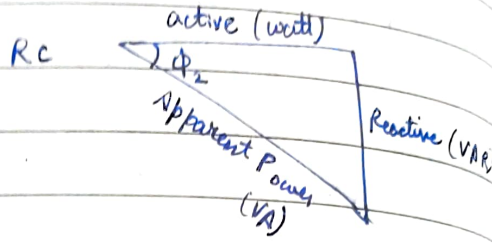
ans: 1296

8th June, 2023

Power Factor Improvement

Power Δ





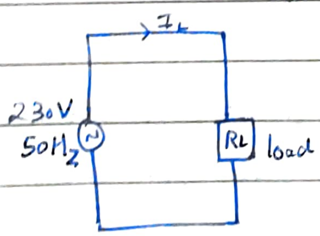
* Add a capacitor in parallel to improve power factor
when ϕ goes near 0, p.f improves

q: The power consumed in the inductive load is 5kW at 0.6 lagging power factor. The input voltage is 230V, 50Hz. Find the value of the capacitor C that must be placed in parallel, such that the resultant p.f of input current improves to 0.9 lagging. [4M]

Sol. $P = 5kW$

Case 1: $p.f = 0.6$

$\cos^{-1}(0.6) = 53.13^\circ$

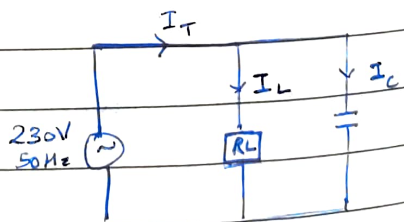


$5 \times 10^3 = 230\, I_L (0.6)$

$I_L = 36.23 \angle -53.13^\circ$ A

Case 2: $pf = 0.9$

$\cos^{-1}(0.9) = 25.8$



$5 \times 10^3 = 230\, I_T (0.9)$

$I_T = 24.15 \angle -25.8$ A

$\vec{I_T} = \vec{I_L} + \vec{I_C}$

$4.65 \times 10^{-3} + 18.473i = iI_c$

$24.15\angle{-25.8} = 36.23\angle{-53.13} + I_c\angle{90^\circ}$

$I_c = 18.47\angle{90^\circ}$, $V = 230V$

$X_c = 12.44\Omega$

$C = 255.87\ \mu F$

$4.65 \times 10^{-3} + 18.473i = iI_c$

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$24.15\angle{-25.8} = 36.23\angle{-53.13} + I_c\angle{90^\circ}$

$I_c = 18.47\angle{90^\circ}$, $V = 230V$

$X_c = 12.44\,\Omega$

$C = 265.87\ \mu F$

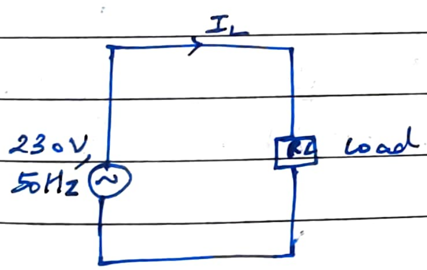
9th June, 2023

Q2. The power consumed in inductive load is 5kW at 0.6 lagging p.f. The input voltage is 230V, 50Hz (single phase). Find the value of capacitor C which must be placed in parallel such that resultant p.f of input current will be 0.95 lagging.

Sol. $P = 5kW$

Case 1: $p.f = \cos\phi_1 = 0.6$ lag , $\phi_1 = 53.13^\circ$

$V = 230V$, $50Hz$

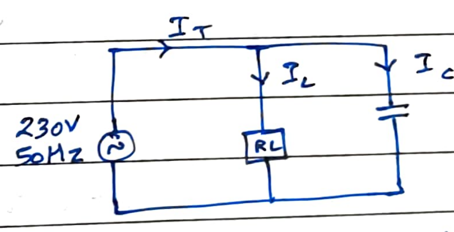


$5\times10^3 = 230\, I_L\,(0.6)$

$I_L = 36.23\angle{-53.13^\circ}\ A$

Case 2: $p.f = 0.95$

$\cos^{-1}(0.95) = 18.19^\circ$



$5\times10^3 = 230\, I_T\,(0.95)$

$I_T = 22.88\angle{-18.19}$

$\vec{I_T} = \vec{I_L} + \vec{I_c}$

$22.88\angle{-18.19} = 36.23\angle{-55.13} + I_c$

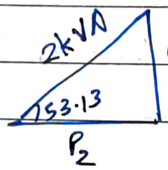
$21.74 + j(-7.14) = 20.71 + j(-29.72) + I_c$

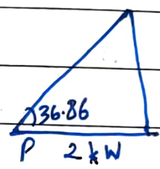
q3. The load connected accross a single phase AC supply consists of a heating load of 1.5 kW, a motor load of 2 kVA at a power factor 0.6 lag and a load of 2 kW at a power factor 0.8. Calculate the total power drawn from the supply in kW & kVA and overall power factor of the system.
What must be the kVAR rating of a capacitor to bring the power factor of above system to unity.

Sol. L_1 L_2 L_3

$P_1 = 1.5\,kW$ $P_3 = 2\,kW$, 0.8 lag

$kVAR_1 = 0$ 2 kVA, 0.6 lag



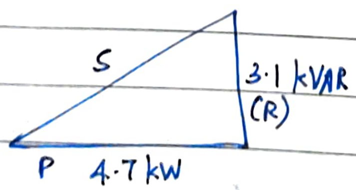


$P_2 = 2\cos(53.13) = 1.2\,kW$ $S_3 = 2.5\,kVA$

$Q_2 = 2\sin(53.13) = 1.6\,kVAR$ $Q_3 = 1.5\,kVAR$

Total real Power $= 1.5 + 1.2 + 2 = 4.7\,kW$ (P)

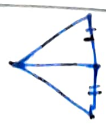
Total reactive Power $= 0 + 1.6 + 1.5 = 3.1\,kVAR$



$\cos\phi = \frac{P}{S} = 0.83$

Total apparent power (S) $= \sqrt{4.7^2 + 3.1^2} = 5.63\,kVA$

3.1 kVA capacitor rating needs to be added in parallel to make p.f 1



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q4. Three loads are connected across a single phase AC supply with particulars as:

Load 1: Heating load of 5kW

Load 2: Inductive load of 5kVA at 0.8 lagging p.f

Load 3: Inductive load of 3kW at 0.6 lagging p.f

Determine:

i) Total active Power and Reactive Power

ii) Total apparent Power

iii) Overall p.f

What must be kVAR rating of capacitor to be connected in // to make p.f unity.

Sol.

L_1	L_2	L_3
$P_1 = 5kW$	$S_2 = 5kVA$	$P_3 = 3kW$
	$pf = 0.8 \Rightarrow \phi = 36.86$	$p.f = 0.6 \Rightarrow \phi = 53.13$
	$P_2 = 4kW, \; Q_2 = 3kVAR$	$P = S(\cos\phi)$
		$S_3 = 5\ kVA$
		$Q_3 = 4kVAR$

Total active power $= 5 + 4 + 3 = 12\ kW$

Total apparent power (Q) $=$ 7

$$S = \sqrt{12^2 + 7^2} = 13.89$$

$$\phi = \cos^{-1}(P/S) = 30.23$$