Exam ID#001062-01 Course: ECE 261 Term: F03 Type: M Solutions: S

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Question 1:

The industrial plant shown in Figure 1 consists of two three-phase, star connected motors connected in parallel and fed from a feeder of capacity 250 A per phase and a negligible impedance. The first motor absorbs 240 KW ~~at~~ a lagging power factor of 0.8; the second motor absorbs 140 KVA at a lagging power factor of 0.85. The supply voltage is $680\sqrt{3}$ volt (line to line, *RMS*).

a) Determine the value of the system power factor, active, reactive and apparent powers.
b) If the plant is to expand by adding a new three-phase, star connected motor that absorbs 100 KVA at a lagging power factor of 0.8. Can this load be added without exceeding the feeder capacity?
c) What will be the capacitor cost for adding the new motor if the cost of the capacitor banks is \$150/KVAR?

[25 marks]

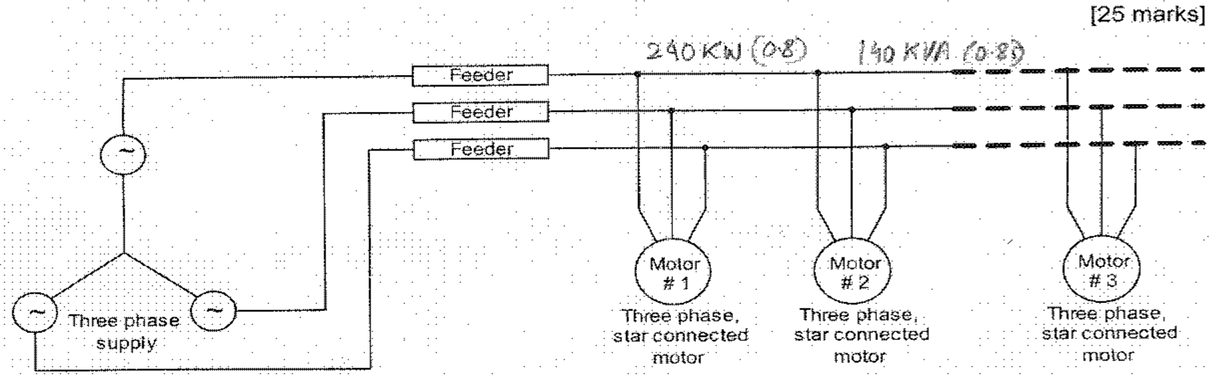


Figure (1)

Motor #1 | Motor #2

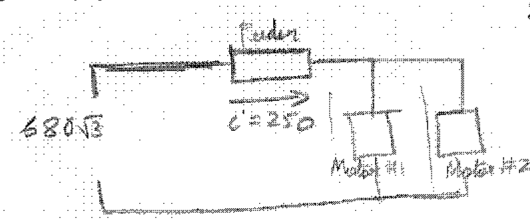
240 KW @0.8 | 140 KVA @0.85

a) P.F = $\cos(\theta_v - \theta_i)$

$P = \sqrt{3} V_L I_L \cos(\theta_v - \theta_i)$

$Q = \sqrt{3} V_L I_L \sin(\theta_v - \theta_i)$

$S = \sqrt{3} V_L I_L$



$V_L = 680\sqrt{3}$

$\therefore V_{ph} = \frac{V_L}{\sqrt{3}} = 680$

Since feeder has negligible Impedance

From motor #1

$P = 240 KW$ $\cos\theta = 0.8$ $\therefore \theta = 36.86°$

$Q \Rightarrow \tan 36.86 = \frac{Q}{P} \Rightarrow 0.75 \times 240 KW = 179,935.23$ or $180 KVAR$

$\therefore S \Rightarrow \sqrt{P^2 + Q^2} = 300 KVA$ or $299,961.14 VA$

P.F. = 0.8

From motor #2

S = 140 KVA @0.85

$\cos\theta$ = P.F. = 0.85 $\therefore \theta$ = 31.7

P = cos 31.7 × 140 = 119 KW = 119,113.5 W

Q = sin 31.7 × 140 = 73.56 KVAR = 73,566 VAR

∴ The system uses ——

$P_T = P_{motor_1} + P_{motor_2} = 240+119 = \underline{359\,KW}$

$Q_T = Q_{motor_1} + Q_{motor_2} = 180 + 73.56$

$= \underline{253.56\,KVAR}$

$\therefore S_{Total} = \sqrt{P_T^2 + Q_T^2}$

$= \underline{439.5\,KVA}$

$\therefore$ P.F. $\Rightarrow \cos\theta = P/S = 0.82$

10

$= \underline{35.2^\circ}$

adding new motor → 100KVA @ P.F. 0.8

Current drawn by

$V_{line} = \sqrt{3}\,V_{ph}$

$\sqrt{3}\,680 = \sqrt{3}\,V_{ph}$

Motor #1 ⇒ $P = 3V_{ph}I_{ph}\cos\theta = \sqrt{3}V_LI_L\cos\theta$

$240Kw = \frac{680\sqrt{3}}{\sqrt{3}} \times I \times 0.8$

$\underline{I = 147.0\,A}$

Current drawn by Motor #2 ⇒ $S = 3\,V_{ph}\,I_{ph}$

$\frac{140\,000}{680\times3} = I_{ph}$

$= \underline{68.6\,A}$

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Current drawn by motor #3

$S = 100KVA$

$S = 3V_{ph}I_{ph}$

$\therefore \frac{100\,000}{3\times680} = I_{ph}$

$= \underline{49\,A}$

$\sqrt{3}V_{ph}$ I_L

Total current absorbed by all motors = 264 Amp which is > supplied 250A ∴ No new motor can be

Capacitor Banks
\$150/KVAR

$\therefore$ Total cost = $Q \times 150$ ...

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Question 2:

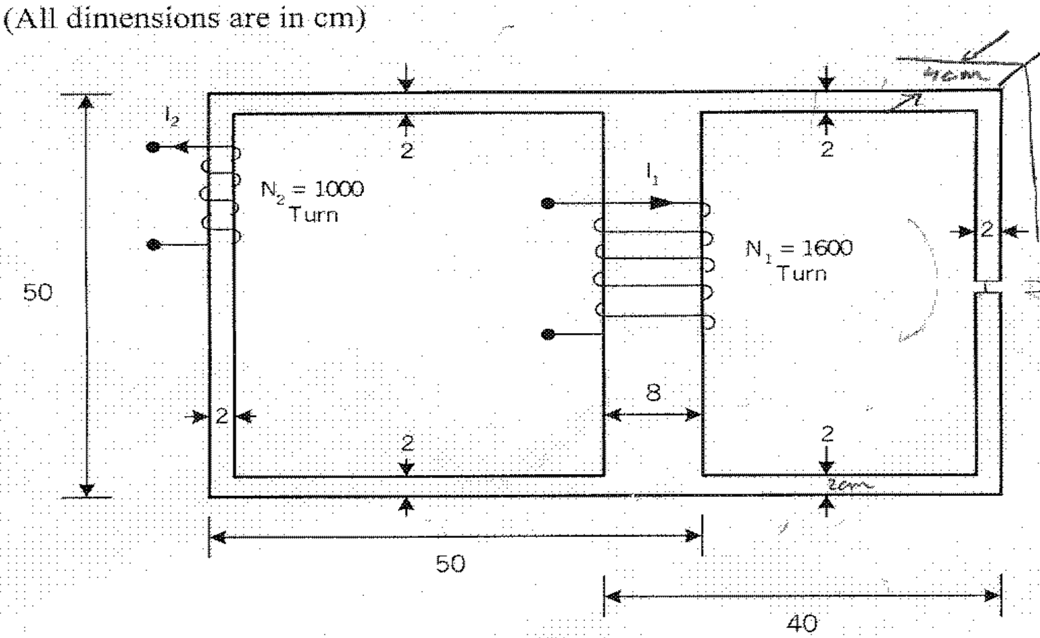
A magnetic circuit is shown in Figure 2. The air gap has a length of 1 cm and the core relative permeability is (μ_r = 2000). The thickness of all parts of the magnetic circuits is 4 cm. Two coils are connected as illustrated in the figure. The number of turns of Coil 1 is 1600 while coil 2 has 1000 turns.

a) If $I_2 = 0$:
   i. What must be the current in coil 1 (I_1) to set up a flux density of 0.1T in the air gap.
   ii- Calculate the flux in each section.
   iii- Calculate the self inductance of coil 1.

b) If I_1 has the value calculated in part a); what must be the current in coil 2 (I_2) so that the air gap flux is equal to zero.

(All dimensions are in cm)

[21 marks]



1cm = 0.01m

μ_r = 2000

Width = 4cm = 0.04m

Coil 1 N = 1600

Coil 2 N = 1000

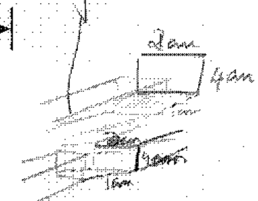


Figure (2)

a) $I_2 = 0$ ∴ $NI_2 = 0$

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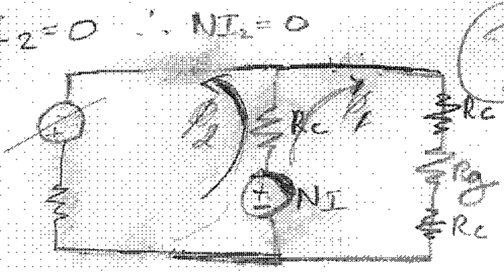
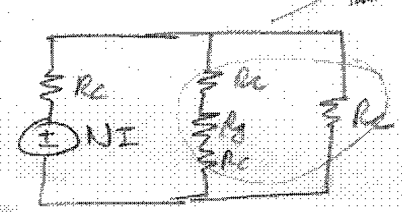


=> Redrawn



Supply → $NI_1 = 1600 \times I_1$

$R_T = (R_c // R_c\ R_g\ R_c) + R_c$

$B = \frac{\phi}{A}$ $B = 0.1\,T$

3

$\phi = \frac{NI}{R_T}$ $R_g = \frac{l}{\mu_0 A} = \frac{0.01}{4\pi \times 10^{-7} \times 0.02 \times 0.04} = 9{,}952{,}22\ 9.299$

$R_c = \frac{l}{\mu_0 \mu_r A} = \frac{0.4}{\mu_0 \mu_r \times 0.04}$ =

∴ $BA = \frac{NI}{R_T}$ ∴ $I = \frac{BA \times R_T}{N}$ =

Flux in each section

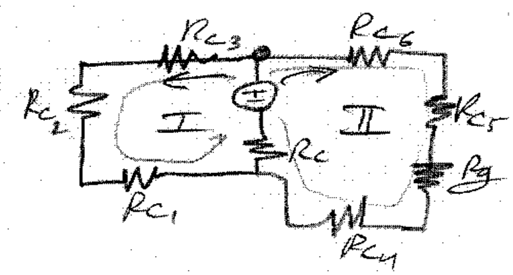
Fluxes => equivalent of I in that

ϕ in I = $\frac{NI}{R_T}$

ϕ in II = $\frac{NI}{R_T}$

1

I



$R_c = \frac{l}{\mu_0 \mu_r A}$

~~$R_{c4} = R_{c6}$~~
~~$R_{c3} = R_{c1} - R_c$~~
~~$R_g = R_{c5}$~~
R_{c5}
R_g = calculated in (

$R_{c4} = \frac{.4}{\mu_0 \mu_r \times 0.04 \times 0.02}$

=

$R_{c1} = \frac{.8}{\mu_0 \mu_r \times 0.04 \times 0.02}$

=

$R_{c3} = \frac{.49}{\mu_0 \mu_r 0.04 \times 0.002}$

=

Self inductance of coil 1 is

$L_{11} = \frac{N_1 \phi_1}{I_1}$

$= \frac{\lambda_1}{I_1}$ 1

=

b) $I_2 \Rightarrow \quad mmf = N I_2$

Using

$B = \cancel{\phi}/A$

where $\cancel{\phi}_{avg} = \dfrac{NI}{R_T}$

1

If $R_T = R_g = 0$ $\quad BA = \dfrac{NI\,0}{\cancel{R_g} = 0}$

$\therefore I_2$ should be $\underline{0}$

20

Question 3:

A 50 KVA, 600/2400 V, 60 Hz, single-phase transformer has open circuit and short circuit test data as follows:

Srated V_1 V_2 ω

	Volt [V]	Current [A]	Power [W]
Open circuit test	600	3.34	484
Short circuit test	76.4	15.0	392.0

rated V_1

High voltage side ∴ V_2 side

Not ... because ... I_{rated} =

Determine:

a. The approximate equivalent circuit referred to the primary and referred to the secondary.

b. Draw the transformer phasor diagram referred to the primary (use the approximate equivalent circuit)

c. The efficiency and voltage regulation at half load and 84% power factor leading.

0.5

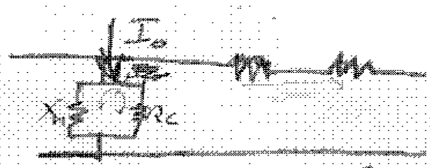
d. The necessary load to be added in parallel to the original load to obtain maximum efficiency while making the system power factor equals to 0.9 lagging.

$a = \frac{N_1}{N_2} = \frac{V_1}{V_2} = 0.25 = \frac{600}{2400}$

[12+6+10+12=40 marks]

a)

O.C.



$P = VI\cos\theta$

$484 = 600 \times 3.34 \times \cos\theta$

$\therefore \cos\theta = 0.24$

$\theta = 76°$

$\therefore R_c = V/I_o\cos\theta$

$= 600 \times 3.34 \times \cos 76$

$= 742.5\,\Omega$

$X_m = V/I_o\sin\theta$

$= 185.14\,\Omega$

4

to primary

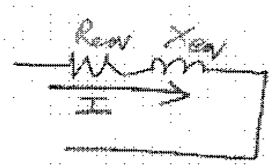
Ref to secondary $\Rightarrow$ $\div a^2$

$R_c' = R_c/a^2 = 11,880\,\Omega$

$X_m' = X_m/a^2$ 8

$= 2962.24\,\Omega$

S.C



$I = 15\,A$

$I_{rated} = \frac{S}{V} = \frac{50000}{2400} = 20.8\,A$

$P = I^2 R_{eq}$

$P = 392$ Using $P_{copper\,FL}$

$= V^2/R_{eq}$

$= (76.4)^2/R_{eq}$

$\therefore R_{eq} = 14.8\,\Omega$

$V^2/R_{eq} = 756.1$ $\therefore R_{eq} = 7.7$

$x = I_{given}/I_{rated} = \frac{15}{20.8} = 0.72$

$x^2 = \frac{P_{sc}}{P_{FCu}}$ $P_{FCu} = \frac{P_{sc}}{x^2} = \frac{392}{...} = 756$

$|Z| = \frac{V}{I}$ @ $I_{rated} \rightarrow \frac{V}{20.8} = 3.67$

$= \frac{76.4}{15}$

$= 5.09\,\Omega$

$\therefore X_{eq} = \sqrt{Z^2 - R_{eq}^2}$

$(5.09)^2 - (14.8)^2$

$= 13.85\,\Omega$

2

Ref to primary

$R_{eq}' = R_{eq} \times a^2$

$X_{eq}' = X_{eq} \times a^2$

$\therefore R_{eq}' = 7.7 \times (0.25)^2$

$\therefore X_{eq}' = 6.7 \times (0.25)^2$

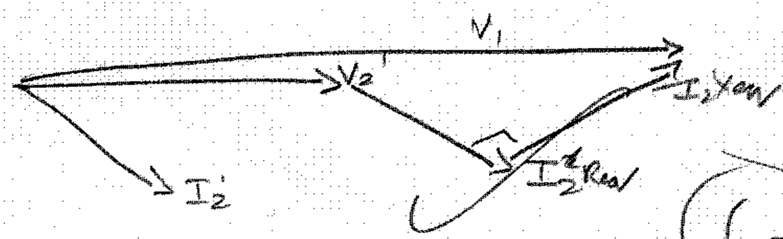
From I_{rated}

$3.67^2 - 7.7$

$= 6.7\,\Omega$

?

b)



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c) $\epsilon = \dfrac{|V_1| - |V_2'|}{|V_2'|}$ Ref to primary

η

$$\eta = \frac{x\,S}{x\,S + P_{core} + x^2 P_{copper\,Full\,load}}$$

half load $\rightarrow x = 0.5$

$S \rightarrow$ half load

$\therefore S_{given} = 50$

half load $= 25$

$$= \frac{0.72 \times 25 \times .84}{0.72 \times 25 \times 0.84 + 484 + \underbrace{(0.72)^2 \times P_{copper\,FL}}_{392}} \times 100\%$$

2

$x = \dfrac{I_{given}}{I_{rated}} = \dfrac{15}{20.8} = 0.72$

$= 0.94 \times 100 = 94\%$

this is NOT $P_{cop}|_{F.L}$

$\dfrac{P_{copper\,given}}{P_{copper\,FL}} = x^2$

ϵ

$V_1 = V_2' + I_2' (R_{eq} + X_{eq})$

$I_2' = I_2 / a$ I_2 rated $= 20.8A$

$V_2' = V_2 \times a$

$= 2400 \times$

$= 600$

??

$\therefore V_1 = 600 + I_2' (R_{eq} + X_{eq})$

$= 613$

2

$\therefore \epsilon = \dfrac{|613| - |600|}{|600|}$

$= 0.0216$

Question 4:

Chose the correct answer:

[1] Two three-phase circuits connected in delta and star, respectively are connected to the same supply. They will consume the same power if:

a. $Z_\Delta = \sqrt{3} Z_y$
b. $Z_\Delta = 3 Z_y$
c. $Z_\Delta = \frac{1}{3} Z_y$
d. $Z_\Delta = Z_y$

[2] Three-wattmeter method can be used for measuring the power in:

a. Only star balance loads.
b. Only delta balanced loads.
c. Balanced star or delta loads.
d. Balanced or unbalanced loads.

[3] Eddy current losses are reduced by:

a. Reducing the magnetic circuit resistance.
b. Reducing the magnetic circuit reluctance.
c. Laminating the iron core.
d. Reducing the transformer voltage.

[4] The leakage flux in transformers is reduced by:

a. Increasing the core reluctance.
b. Utilizing soft magnetic material.
c. Primary and secondary windings being coaxial.
d. Reducing the separation between the primary and secondary windings.

[5] The voltage per turn in the transformer windings:

a. Is the same in both primary and secondary.
b. Is dependant on the windings voltage ratings.
c. Is larger in the primary than the secondary.
d. Is larger in the secondary than the primary.

[6] The transformer output voltage might be higher than the input voltage if:

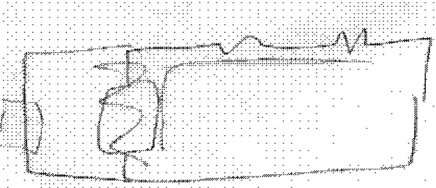
a. The load is highly inductive
b. The load is pure resistance
c. The secondary is open circuit
d. The load is highly capacitive

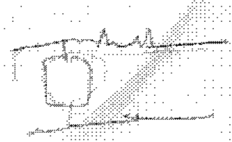
600 /2400

[7] The short circuit test in transformers should be conducted:

a. In high voltage side while low voltage is shorted.
b. In high voltage side while low voltage is loaded.
c. In low voltage side while high voltage is shorted.
d. In low voltage side while high voltage is loaded.

[14 marks]





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