CMR INSTITUTE OF TECHNOLOGY

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Internal Assesment Test - II

Sub:	Transformers and Generators							Code:	17EE33
Date:	17/10/2018	Duration:	90 mins	Max Marks:	50	Sem:	3	Branch:	EEE - B
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1.a	Explain the working of transformer on load giving reasons for the increase in the current drawn by the primary with an increase in the load on the secondary.	[3]	CO1	L2
1.b	Draw the vector diagram of practical transformer for (i) unity pf, (ii) lagging pf and explain.	[7]	CO1	L3
2.	Develop the exact equivalent circuit of single phase transformer, from this derive the approximate and simplified equivalent circuits of transformer with respect to primary and secondary.	[10]	CO1	L3
3.a	Prove that for maximum efficiency, iron loss is equal to copper loss. Also mention the power at maximum efficiency.	[6]	CO1	L2
3.b	P1 and P2 are the iron and copper loss of the transformer on full load. Find the ratio of P1 and P2 such that maximum efficiency occurs at 75% of full load.	[4]	CO1	L3
4	Define voltage regulation and derive the expression for voltage. What is the condition for zero regulation?	[6] [5]	CO1	L3
5	The results obtained from open circuit and short circuit tests on 10 KVA, 450/120V, 50 Hz transformer are : O.C. test 120 V 4.2 A 80 W Instruments placed on Iv side. S.C. test 9.65 V 22.2 A 120 W With Iv winding short circuited.\ Compute : i) Equivalent circuit constants referred to primary ii) Efficiency at full load 0.8 pf lag iii) Efficiency at half full load and 0.8 lagging pf.		CO1	L1
6	Explain back to back test of similar transformers?			

7	Find the all-day efficiency of 500kVA distribution transformers whose copper and iron losses at full load are 4.5kW and 3.5kW respectively. During a day it is loaded as under: No. of hrs 6 6 4 4 Loading in kW 400 300 100 0 pf 0.8 0.75 0.8 -	[10]	CO2	L2

Cognitive level	KEYWORDS

Course Outcomes		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1:	Describe the construction, operation and performance of single phase and three phase transformers	**3**	**2**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO2:	Explain the need of operating transformers in parallel and the procedure to do it.	**3**	**3**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO3:	Illustrate the concept of auto transformer; tap changing transformer and tertiary winding.	**3**	**2**	**2**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO4:	Analyze armature reaction and commutation and their effects in a dc machine.	**3**	**3**	**2**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO5:	Describe the construction, operation, characteristics and applications of synchronous generators	**3**	**2**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO6:	Perform the analysis of synchronous machines by using different methods	**3**	**3**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

L1	List, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where, etc.
L2	summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
L3	Apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover.
L4	Analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer.
L5	Assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize.

PO1 **-** *Engineering knowledge*; PO2 **-** *Problem analysis*; PO3 **-** *Design/development of solutions*; PO4 **-** *Conduct investigations of complex problems*; PO5 **-** *Modern tool usage*; PO6 **-** *The Engineer and society*; PO7- *Environment and sustainability*; PO8 – *Ethics*; PO9 **-** *Individual and team work*; PO10 **-** *Communication*; PO11 **-** *Project management and finance*; PO12 **-** *Life-long learning*

SOLUTION

1. a)

· Transformer on load

~~Winding Resistance~~

* When a transformer is not ideal, then the resistance of coils used in the primary and Secondary ~~...~~ must be considered.

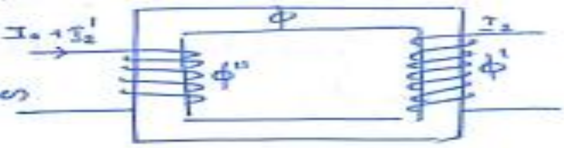
* Also it must also be considered that the flux linking the primary winding and secondary winding has two parts.
  (i) Mutual flux(ϕ) which links both the windings and is confined to the iron core, and the leakage fluxes ϕ_{L1} and ϕ_{L2} whose path is mostly in air.

This leakage fluxes induces voltages which is in the opposition of supply voltage in case of primary and induced 2° emf in case of secondary side. This effect can be represented as a leakage inductances or leakage reactances in the primary and secondary side.

Under load condition,

As secondary is closed circuit, a current I_2 will flow through the secondary circuit. ~~As this~~ This current I_2, creates a flux ϕ' in the 2° coil.

The magnitude & direction ϕ' is such that it opposes the main flux ϕ.



Now, the load is supplied from the source only. So, the current I_2 must be supplied from the source side. So, total current in the 1° side will no load current I_0 + current proportional to load I_2' (transformed value)

ie; $I_1 = I_0 + I_2'$

We know the relation

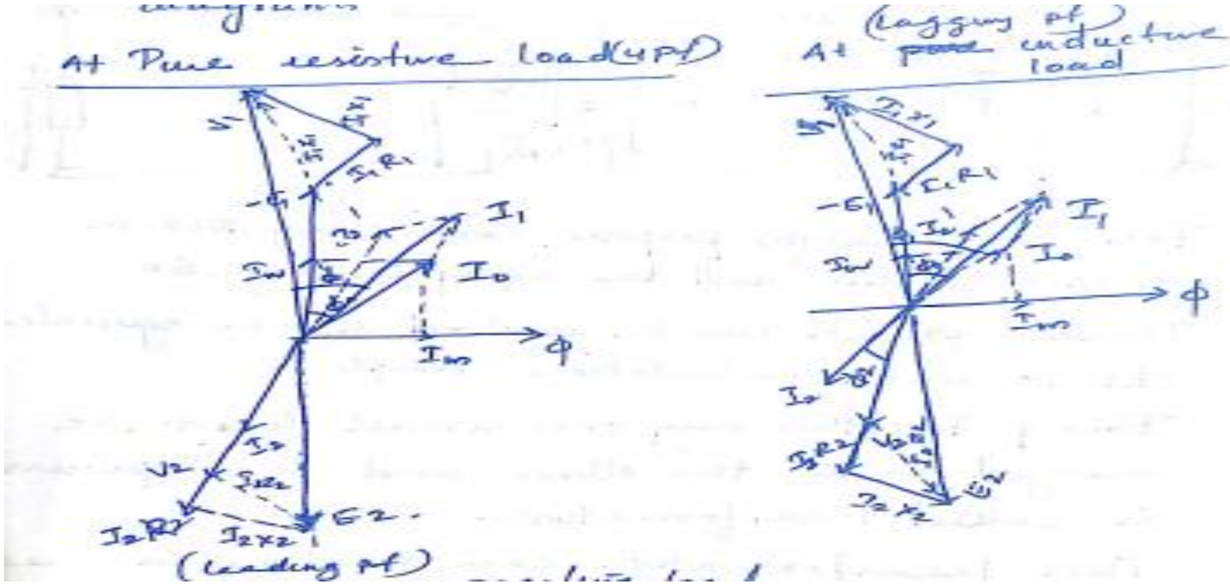
$$\frac{I_1}{I_2} = k \implies \frac{I_0 + I_2'}{I_2} = k$$

Assuming no load current is negligible

we get $\frac{I_2'}{I_2} = k$ or $I_2' = k I_2$.

ie $\implies$ $\boxed{I_1 = I_0 + k I_2}$

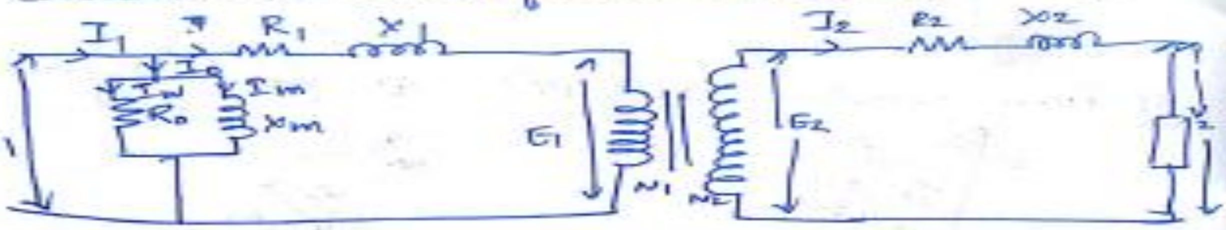
b)



2. ,.

Equivalent Resistance and leakage (8) reactance of Practical xfr

Consider the transformer circuit as,



For the analysis purpose, considering xfer as a seperate ckts will be complicating. So

These circuits can be resolved into an equivalent ckt to make calculations simple.

~~This is~~ For this any one circuit has to be merged with the other and that process is called transformation.

This transformation can be done in two ways

(i) 2° to 1° transformation (ie: referred to 1°)

(ii) 1° to 2° " " (ie: referred to 2°)

(i) 2° to 1° transformation

Keeping 1° and reference circuit, transfer all the 2° parameters to the 1° circuit.

In order to solve the circuit, the transformed parameters must be defined.

We know the transformation ratio

$\frac{E_2}{E_1} = K$

Here in the new circuit $E_1 = E_2'$

$\therefore \frac{E_2}{E_2'} = K$ or $E_2' = E_2/K$.

Similarly $V_2' = V_2/K$.

We already know $I_2' = K I_2$.

Power loss in 1° and 2° ckt must be same (resistance is same)

~~$I_1^2 R_1 = I_2^2 R_2$~~

~~Now the new ckt~~

$I_1^2 R_2' = I_2^2 R_2$

$R_2' = \left(\frac{I_2}{I_1}\right)^2 R_2 = R_2/K^2$.

||ly

$X_2' = X_2/K^2$

$Z_L' = Z_L/K^2$,

$\therefore$

$E_2' = E_2/K$	$V_2' = V_2/K$	$I_2' = K I_2$
$R_2' = R_2/K^2$	$X_2' = X_2/K^2$.	
$Z_L' = Z_L/K^2$.		

- Net winding resistance in the circuit referred to 1°

$R_{01} = R_1 + R_2'$

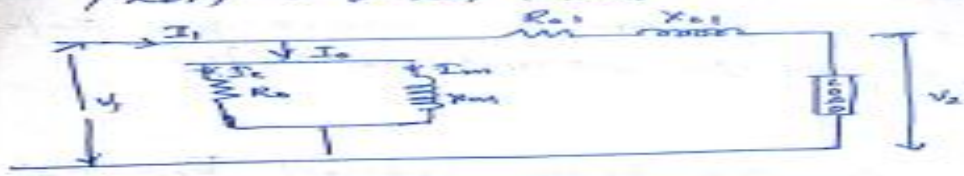
Net leakage reactance in the circuit referred to 1°

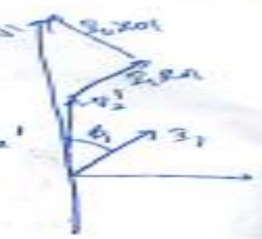
$X_{01} = X_1 + X_2'$

$\therefore$ Net impedance referred to 1° $Z_{01} = R_{01} + j X_{01}$

$|Z_{01}| = \sqrt{R_{01}^2 + X_{01}^2}$

(14)

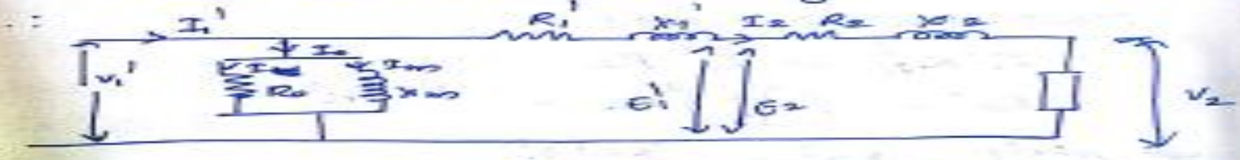




1° to 2° transformation

In 1° to 2° transformation or transformation referred to secondary, all the primary side parameters are transformed to 2° except the no load parameters as their values are constant and has no change on transferring.

$\therefore$



As did in the 2° to 1° transformation,

Here $R_1' = K^2 R_1$ $\quad V_1' = K V_1$ $\quad I_1' = I_1/K$

$X_1' = K^2 X_1$ $\quad E_1' = K E_1$

Total winding resistance w.r.t 2°

$R_{02} = R_1' + R_2 = K^2 R_1 + R_2$

Total leakage reactance w.r.t 2°

$X_{02} = X_1' + X_2 = K^2 X_1 + X_2$

Total impedance

$Z_{02} = R_{02} + j X_{02}$

$|Z_{02}| = \sqrt{R_{02}^2 + X_{02}^2}$.

3. a)

Efficiency of transformers

The efficiency of a transformer is given by

$$\text{Efficiency} = \frac{\text{o/p power}}{\text{o/p power} + \text{Losses}} = \frac{\text{o/p power}}{\text{i/p power}}$$

$$= \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_c + P_{cu}}$$

For any load x

$$\text{Efficiency} = \frac{x(\text{o/p power})}{x(\text{o/p power}) + P_i + x^2 P_{cu} \text{ losses}}$$

$$= \frac{x V_2 I_2 \cos\phi_2}{x V_2 I_2 \cos\phi_2 + P_c + x^2 P_{cu}}.$$

Condition for Maximum Efficiency of a Transformer

Let $\eta = \dfrac{xP}{xP + P_c + x^2 P_{cu}}$

The efficiency is maximum when $\dfrac{d\eta_x}{dx} = 0$

$$= \frac{(xP + P_c + x^2 P_{cu})P - xP(P + 2x P_{cu})}{(xP + P_c + x^2 P_{cu})^2} = 0$$ (29)

$\therefore xP + P_c + x^2 P_c = x(P + 2x P_c) = 0$

$\cancel{xP} + P_c + \cancel{x^2 P_{cu}} = \cancel{xP} + \cancel{2} x^2 P_{cu} = 0$

$\therefore \quad P_c = x^2 P_c$ —— (1)

ie:- when the transformer efficiency is maximum at load when its copper losses equal to the iron loss.

~~All day Efficiency of a Transformer~~

~~This efficiency is considered on energy basis~~

From equation (1)

$$x = \sqrt{\frac{P_c}{P_{cu}}}$$

$\therefore$ Output kVA corresponding to maximum efficiency $= x \times$ rated kVA.

$$= \sqrt{\frac{P_c}{P_{cu}}} \times \text{rated kVA}.$$

Also at full load

$$P_c = P_{cu}$$

$$\text{ie; } P_c = I_2^2 R_{02}$$

$$I_2 = \sqrt{\frac{P_c}{R_{02}}}$$

b)

2) If P_1 and P_2 be the iron and copper losses of a transformer on full load, find the ratio of P_1 & P_2 such that maximum efficiency occurs at 75 % of full load.

Iron loss $P_C = P_1$

Full load cu loss $P_{cu} = P_2$

Cu loss at 75% load $= (0.75)^2 P_2$.

For maximum efficiency at full load

$P_c = P_{cu}$

To get maximum efficiency at 75 % load

$P_1 = x^2 P_{cu}$

$P_1 = (0.75)^2 P_2$

$\frac{P_1}{P_2} = \frac{9}{16} = 0.5625$.

4. .,

Voltage Regulation

The way in which the 2° terminal voltage varies with the load depends on the load current, the internal impedance and the load power factor. The change in secondary terminal voltage from no load to full load at any particular load is termed as regulation. It is usually expressed as a percentage or a fraction of the rated no-load terminal voltage.

ie :- percentage regulation

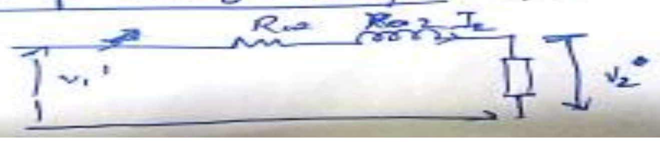
$$= \frac{\text{Terminal voltage on no load} - \text{terminal voltage on full load}}{\text{Terminal voltage on no load}} \times 100$$

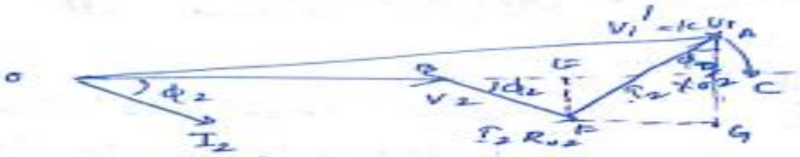
$$= \frac{\text{voltage drop in transformer at load}}{\text{No-load rated voltage } (2°)} \times 100$$

$$= \frac{I_2 R_{02} \cos\phi_2 \pm I_2 X_{02} \sin\phi}{\text{No-load rated voltage } (2°)} \times 100$$

$$\% R = \frac{I_2 R_{02} \cos\phi \pm I_2 X_{02} \sin\phi}{V_2} \times 100 .$$

Calculation of voltage drop in T/F





From fig $V_1' = OA = OC$.
$V_2 = OB$.

Exact voltage drop $V_1' - V_2 = OC - OB$
$= BC$

If from fig CD is neglected BD will be approx voltage drop.

$BD = BE + ED$
$= BE + FG$.
$= I_2 R_{02} \cos\phi_2 + I_2 X_{02} \sin\phi_2$.

This equation can be generalised as:

$V_1' - V_2 = I_2 R_{02} \cos\phi_2 \pm I_2 X_{02} \sin\phi_2$.

where '+' lagging pf '−' for leading pf.

$$\therefore \%R = \frac{I_2 R_{02}\cos\phi_2 \pm I_2 X_{02}\sin\phi_2}{V_2} \times 100$$

Regulation at any load

$$\%R = \frac{x I_2 (R_{02}\cos\phi_2 \pm I_2 X_{02}\sin\phi_2)}{V_2} \times 100$$

(38)

Condition for zero regulation

$$\text{Regulation} = \frac{I_2 R_{02}\cos\phi_2 \pm I_2 X_{02}\sin\phi_2}{V_2}.$$

For zero regulation,

$$I_2 R_{02}\cos\phi_2 + I_2 X_{02}\sin\phi_2 = 0$$

$$R_{02}\cos\phi_2 = -X_{02}\sin\phi_2$$

$$\frac{\sin\phi_2}{\cos\phi_2} = \frac{-R_{02}}{X_{02}}.$$

$$\boxed{\tan\phi = \frac{-R_{02}}{X_{02}}}$$

which means
−ve sign indicates that zero regulation occurs at a leading pf.

5) (i) Equivalent circuit parameters

OC test

$\cos\phi_0 = \frac{W_0}{V_1 I_0} = \frac{80}{120 \times 4.2} = 0.1587$

$I_m = I_0 \sin\phi_0 = 4.15\ A$ //

$I_c = I_0 \cos\phi_0 = .67\ A$

$R_0 = \frac{V_1}{I_c}$ $\quad X_m = \frac{V_1}{I_m}$

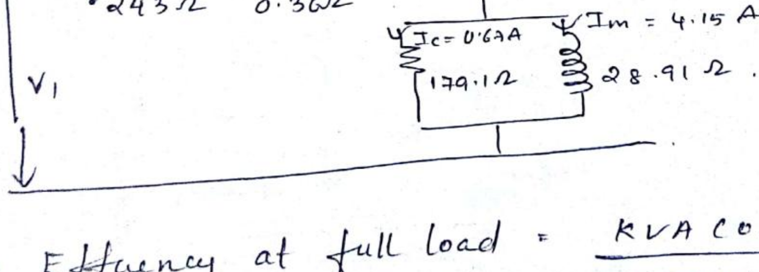
$= 179.1\ \Omega$ $\quad 28.91\ \Omega$

SC test (HV side is 1° — parameters referred to 1°)

$R_{01} = \frac{W_{sc}}{I_{sc}^2} = 0.243\ \Omega$

$Z_{01} = \frac{V_{sc}}{I_{sc}} = 0.4347\ \Omega$

$X_{01} = \sqrt{0.4347^2 - 0.243^2} = 0.36\ \Omega$ //



(ii) Efficiency at full load $x = 1$ $= \frac{KVA \cos\phi}{KVA \cos\phi + P_i + P_{cu}} \times 100$

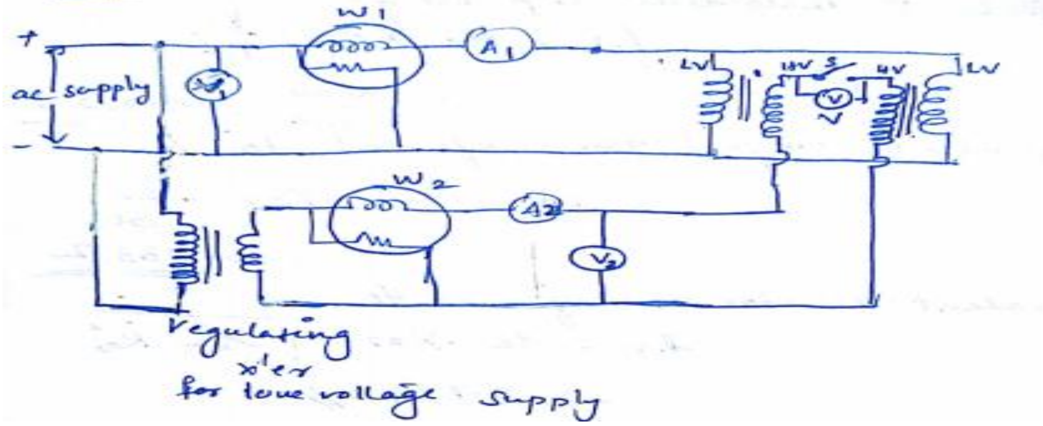
$= \frac{10 \times 10^3 \times 0.8}{10 \times 10^3 \times 0.8 + 80 + 120} \times 100 = 97.56\%$

(iii) Efficiency at half load $x = 1/2$ $= \frac{x\ KVA \cos\phi}{x\ KVA \cos\phi + P_i + x^2 P_{cu}} \times 100$

$= \frac{1/2 \times 10 \times 10^3 \times 0.8}{1/2\ 10 \times 10^3 \times 0.8 + 80 + (1/2)^2\ 120} \times 100 = 97.323$

6.

Sumpner's Test (Back to Back test)



while oc and sc tests on a transformer yield its equivalent circuit parameters, these cannot be used for the 'heat run' test where in the purpose is to determine the steady temperature rise if the transformer was fully loaded continuously. This is so because under each of these tests the power loss to which the transformer is subjected is either core loss or copper loss but not both. The way to get best results is by conducting an actual loading test which is the Sumpner's test which can only be conducted simultaneously on two identical transformers.

In conducting the Sumpner's test the Primaries of the two transformers are connected in parallel across the rated voltage supply (V_1), while the two secondaries are connected in phase opposition as shown in figure. For the secondaries to be in phase opposition, voltage in the voltmeter connected across 2 series terminals of 2's must be zero when switch 'S' is in open position, otherwise it will be double the rated 2' voltage in which case the polarity of one of the secondaries must be reversed.

Rated current (I_2) of the secondary side is injected in to the secondary side at a low voltage V_2.

when switch S is in open position, the two transformers appear in open circuit to the source V_1 and as their secondaries are in phase opposition and therefore no current can flow in them. Then current drawn from the source V_1 is $2I_0$ (twice no load current of each transformer) and power is $2P_0$ ($= 2P_c$ twice the core loss of each transformer)

when Switch 'S' is closed, the 2's of the transformers are series connected across V_2. V_2 is adjusted to circulate full load current in I_2, the power fed
in is $2P_{cu}$ (twice the full load copper
7. loss of each transformer).

As secondaries are in phase opposition current I_2 will not create any effect on the primary

Thus in the Sumpner's test while the transformers are not supplying any load, full iron-loss occurs in their cores and full copper loss occurs in their windings; net power input to the transformers being $(2P_c + 2P_{cu})$. The heat run test could, therefore, be conducted on the two transformers, while only losses are being supplied.

7)

				Assume
6	6	4	4	4
400	300	100	0	0
0.8	0.75	0.8	0.	0

Core loss in kwhr = $3.5 \times 24 = 84$ kwhr.

O/p power in kwhr.

hr	KW	kwhr
6	400	2400
6	300	1800
4	100	400
4+4	0	0.

= 4600 kwhr.

Copper loss in kwhr

x	$x^2 P_{cu}$	hr	Copper loss in kwhr
$\frac{400/0.8}{500} = 1$	$4.5 \times 1 = 4.5$	6	27
$\frac{300/0.75}{500} = 0.8$	$4.5 \times 0.8^2 = 2.88$	6	17.28.
$\frac{100/0.8}{500} = 0.25$	0.281	4	1.124
0	0	4+4	
			45.404 kwhr

$$\eta = \frac{4600}{4600 + 84 + 45.404} \times 100. = 97.26\%$$