CMR
INSTITUTE OF
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Internal Assesment Test - I

Sub:	Transformers and Generators							Code:	17EE33
Date:	10/09/2018	Duration:	90 mins	Max Marks:	50	Sem:	3	Branch:	EEE
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1.a	Explain how the flux in the core of transformer remains constant, from no load to full load. Develop the phasor diagram of an actual transformer when it is inductively loaded.	[6]	CO1	L2
1.b	Show that for maximum efficiency, iron loss is equal to copper loss.	[4]	CO1	L3
2.a	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 LV side. S.C. test: 9.65 V 22.2 A 120 W With LV winding short circuited. Compute : i) Equivalent circuit constants. ii) Efficiency and voltage regulation at full load upf. iii) Efficiency at half full load and 0.8 lagging pf.	[10]	CO1	L3
3	Describe the test on two similar single phase transformers that give their ohmic losses and core losses.	[10]	CO1	L2
4.a	Show that open delta connection has a kVA rating of 58% of the rating of the normal delta delta connection. Also list the limitations of open delta connection.	[5]	CO1	L3
4.b	A delta-delta bank consisting of 3 single phase transformers, 20kVA, 2300/230V ratings supplies a load of 40kVA. If one of the transformer is removed, find for the resulting V - V connection, (i) kVA load carried by each transformer, (ii) Total kVA rating of the V-V bank, (iii) Ratio of the V-V bank to delta-delta bank transformer ratings	[5]	CO1	L3
5.a	State the advantages and disadvantages of three phase transformers over bank of 3 single phase transformers.	[5]	CO1	L1
5.b	Show that an auto -transformer will result in saving of copper instead of 2-winding transformer	[5]	CO2	L3
6	Explain the purpose of Tap changing transformers. With the help of sketches illustrate the working of on load tap changer	[10]	CO2	L2
7.a	Define All-day Efficiency	[2]	CO1	L1

7.b	A 2300/230V, 500kVA, 50Hz distribution transformer has core loss of 1600W at rated voltage and copper loss of 7.5 kW at phase load. During the day it is loaded as follows % Load 0% 20% 50% 80% 100% 125% pf - 0.7lag 0.8lag 0.9lag 1 0.85 lag Hours 2 4 4 5 7 2 Determine the all day efficiency of the transformer.	[8]	CO1	L3

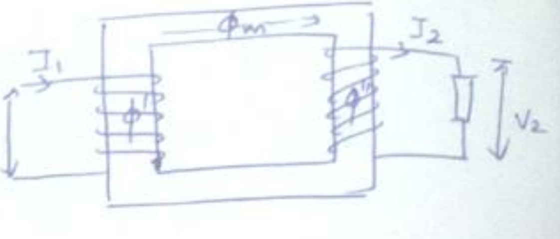
Course Outcomes		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1:	Describe the construction, operation and performance of single phase and three phase transformers	**3**	**2**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
CO2:	Explain the need of operating transformers in parallel 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**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Cognitive level	KEYWORDS
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*

17EE33 TRANSFORMERS AND GENERATORS
IAT 1 SOLUTION

1-a) 2 MARKS



- When a load is connected to the V_1 2° side of the x'er, a current I_2 will flow in the winding
- Under no load condition, the no-load current I_0 which develops a flux ϕ_m in the core.
- Due to current I_2 a flux ϕ' is developed in the 2° winding which is in opposite direction of ϕ_m.
- The increase in 2° current causes an increase in 1° current by I_2'. That is total 1° current $I_0 + I_2' = I_1$ flows in the 1° winding which creates an increase in flux in the primary by ϕ'' in the same direction as ϕ_m

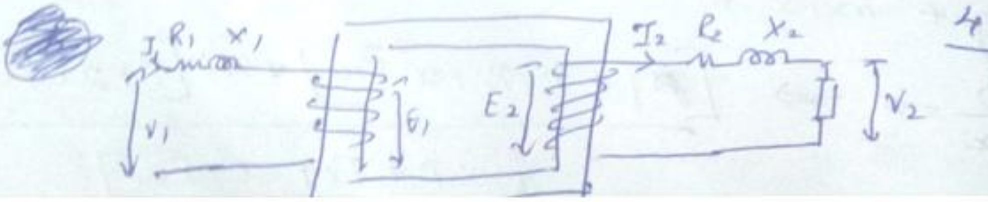
So Net flux in the core

$$= \phi_m + \phi' - \phi''$$

Now ϕ' and ϕ'' are result of I_2, so their magnitude is same and so cancels.

$\therefore$ Net flux $= \phi_m$ remains same.

4 MARKS



From the fig,

$$\vec{I_0} = \vec{I_m} + \vec{I_c}$$

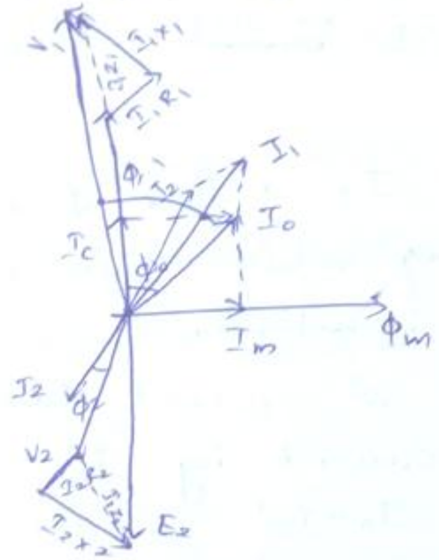
$$I_1 = \vec{I_0} + \vec{I_2'}$$

$$V_1 = E_1 + I_1 R_1 + j I_1 X_1$$

$$= E_1 + I_1 (R_1 + j X_1) = \underline{E_1 + I_1 Z_1}$$

$$E_2 = V_2 + I_2 R_2 + j I_2 X_2$$

$$= V_2 + I_2 (R_2 + j X_2) = \underline{V_2 + I_2 Z_2}.$$



Ans (b) Efficiency, $\eta = \dfrac{\text{Output power}}{\text{input power}} \times 100$

$$\eta = \frac{x\ kVA \cos\phi}{x\ kVA \cos\phi + P_c + x^2 P_{cu}} \times 100$$

Condition for Max η

$$\eta = \frac{xP}{xP + P_c + x^2 P_{cu}}.$$

To get max η

$$\frac{d\eta}{dx} = 0 \Rightarrow \frac{\left[P[xP + P_c + x^2 P_{cu}] - xP[P + 2x P_{cu}]\right]}{[xP + P_c + x^2 P_{cu}]^2} = 0$$

$x P^2 + P_c P + x^2$ ...

$\Rightarrow [xP + P_c + x^2 P_{cu} - xP - 2x^2 P_{cu}] = 0$

$\Rightarrow P_c - x^2 P_{cu} = 0$

$P_c = x^2 P_{cu}$

At full load $x = 1$

$\boxed{P_c = P_{cu}}$

2a) : OC Test

$W_0 = V_1 I_0 \cos\phi_0$

~~$\cos\phi_0 = \frac{80}{120 \times 1.2}$~~

$\cos\phi_0 = \frac{80}{120 \times 4.2} = 0.158$

$\sin\phi_0 = 0.987$

$I_c = I_0 \cos\phi_0 = 4.2 \times 0.158 = 0.664 A$

$I_m = I_0 \sin\phi_0 = 4.2 \times 0.987 = 4.146 A$.

$R_0 = \frac{V_0}{I_c} = \frac{120}{0.664} = 180.8 \Omega$

$X_m = \frac{V_0}{I_m} = \frac{120}{4.15} = 28.9 \Omega$

SC Test

$R_{eq} = \frac{W_{sc}}{I_{sc}^2} = \frac{120}{22.2} = 0.243 \Omega = R_{01}$

$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \frac{9.65}{22.2} = 0.434 \Omega = Z_{01}$

$X_{eq} = X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = 0.36\ \Omega$

At full load upf $x = 1$ $\cos\phi = 1$

(ii) $$\eta = \frac{x\ kVA\ \cos\phi}{x\ kVA\ \cos\phi + P_i + x^2 P_{cu}} \times 100$$

$$= \frac{1 \times 10 \times 10^3 \times 1}{1 \times 10 \times 10^3 \times 1 + 80 + 1^2 \times 120} = 98.03\ \%$$

$$\%R = \frac{x\,(I_1 R_{01} \cos\phi_1 \pm I_1 X_{01} \sin\phi_1)}{V_1} \times 100$$

$$I_1 = \frac{P}{V_1} = \frac{10{,}000}{450} = 22.22\,A$$

$$\%R = \frac{22.22 \times 0.243 \times 1}{450} \times 100 = 1.19\ \%$$

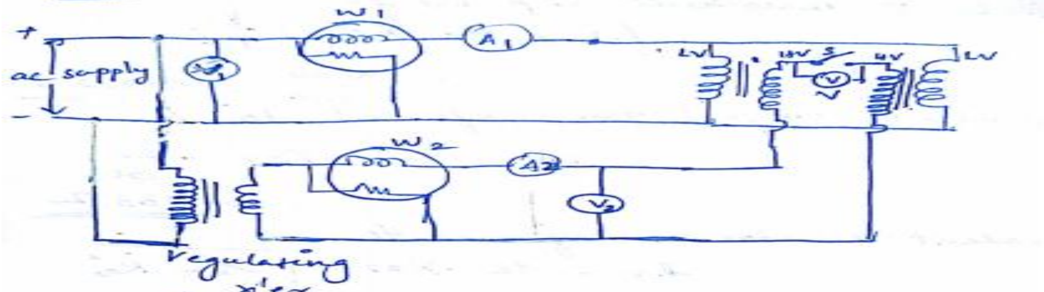
(iii) η at $x = 0.5$
$\cos\phi = 0.8$.

$$\eta = \frac{0.5 \times 10 \times 10^3 \times 0.8}{(0.5 \times 10 \times 10^3 \times 0.8) + 80 + (0.5)^2 \times 120} \times 100$$

$$= 97.32\ \%$$

3

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 wherein 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 (series) opposition as shown in figure. For the secondaries to be in phase opposition, voltage in the voltmeter connected across 2 term 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 the 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 loss of each transformer).

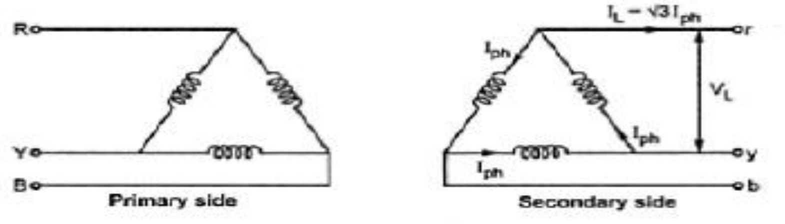
As secondaries are in phase opposition current I_2 will not create any effect on the primary side as 1° induced currents will cancel out.

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.

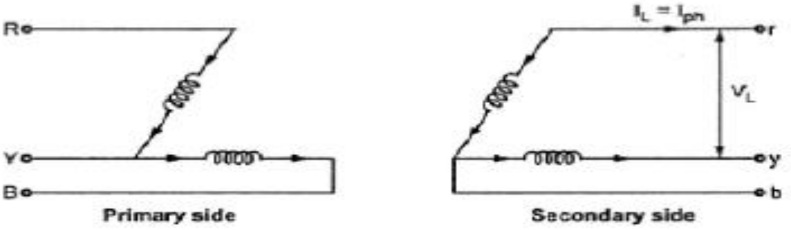
4. a If one of the transformers fails in Δ - Δ bank and if it is required to continue the supply eventhough at reduced capacity until the transformer which is removed from the bank is repaired or a new one is installed then this type of connection is most suitable.

When it is anticipated that in future the load will increase, then it requires closing of open delta. In such cases open delta connection is preferred.

Key Point: *It can be noted here that the removal of one of the transformers will not give the total load carried by V - V bank as two third of the capacity of Δ - Δ bank.*



Δ - Δ connection



V - V connection

$$\Delta - \Delta \text{ capacity} = \sqrt{3}\, V_L\, I_L = \sqrt{3}\, V_L\, (\sqrt{3}\, I_{ph})$$

$$\Delta - \Delta \text{ capacity} = 3 V_L I_{ph} \quad \text{... (i)}$$

$$V - V \text{ capacity} = \sqrt{3} V_L I_L = \sqrt{3} V_L I_{ph} \quad \text{... (ii)}$$

Dividing equation (ii) by equation (i)

$$\frac{V - V \text{ capacity}}{\Delta - \Delta \text{ capacity}} = \frac{\sqrt{3} V_L I_{ph}}{3 V_L I_{ph}} = \frac{1}{\sqrt{3}} = 0.557 = 58 \%$$

Thus the three phase load that can be carried without exceeding the ratings of the transformers is 57.7 percent of the original load.

Limitations

This overload can be carried temporarily if provision is made to reduce the load otherwise overheating and breakdown of the remaining two transformers would take place.

It can be noted here that the removal of one of the transformers will not give the total load carried by V - V bank as two third of the capacity of Δ - Δ bank.

4b.

(i) $\frac{\text{Total kVA load in V-V bank}}{\text{kVA / xler}} = \sqrt{3}$

kVA load by each transformer = $\frac{\text{Total kVA load in V-V}}{\sqrt{3}}$

$= \frac{40}{\sqrt{3}} = 23.1$ kVA

(ii) Total kVA rating of the V-V bank

$= 0.58 \times (3 \times 20) = 34.8$ kVA.

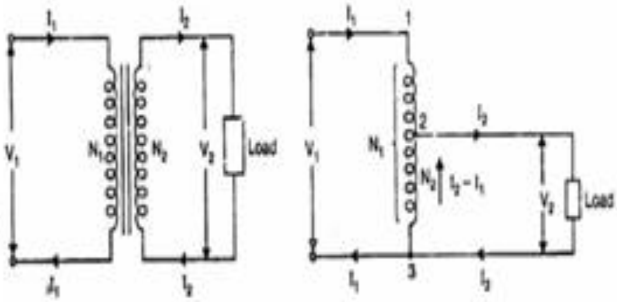
(iii) Ratio of V-V bank to Δ-Δ bank xler ratings.

$\frac{P_{V-V}}{P_{\Delta-\Delta}} = \frac{34.8}{60} = .58 = 58\%$

5. a

Three single-phase units	One 3-phase unit
• Three single phase units are more flexible, • they can be rated individually to meet unbalanced loads, • in the case of a phase failure: only one unit need be replaced • But is heavier • But is require more external wiring	• A phase failure requires the replacement of a complete unit, • lighter (15% less weight for the same rating) • Cheaper • Requires less external wiring

5. b



Winding transformer

$$\text{Weight of Cu required} \propto (I_1N_1 + I_2N_2)$$

Autotransformer

$$\text{Weight of Cu required in section 1-2} \propto I_1(N_1 - N_2)$$

$$\text{Weight of Cu required in section 2-3} \propto (I_2 - I_1)N_2$$

$$\therefore \text{ Total weight of Cu required} \propto I_1(N_1 - N_2) + (I_2 - I_1)N_2$$

$$\frac{\text{Weight of Cu in autotransformer}}{\text{Weight of Cu in ordinary transformer}} = \frac{I_1(N_1 - N_2) + (I_2 - I_1)N_2}{I_1N_1 + I_2N_2}$$

$$= \frac{N_1I_1 - N_2I_1 + N_2I_2 - N_2I_1}{N_1I_1 + N_2I_2}$$

$$= \frac{N_1I_1 + N_2I_2 - 2N_2I_1}{N_1I_1 + N_2I_2}$$

$$= 1 - \frac{2N_2I_1}{N_1I_1 + N_2I_2}$$

$$= 1 - \frac{2N_2I_1}{2N_1I_1} \qquad (\because N_2I_2 = N_1I_1)$$

$$= 1 - \frac{N_2}{N_1} = 1 - K$$

$\therefore$ Wt. of Cu in autotransformer (W_a)

$$= (1 - K) \times \text{Wt. in ordinary transformer } (W_o)$$

$$W_a = (1 - K) \times W_o$$

$\therefore$ Saving in Cu $= W_o - W_a = W_o - (1 - K)W_o = K\,W_o$

Saving in Cu $= K \times$ Wt. of Cu in ordinary transformer

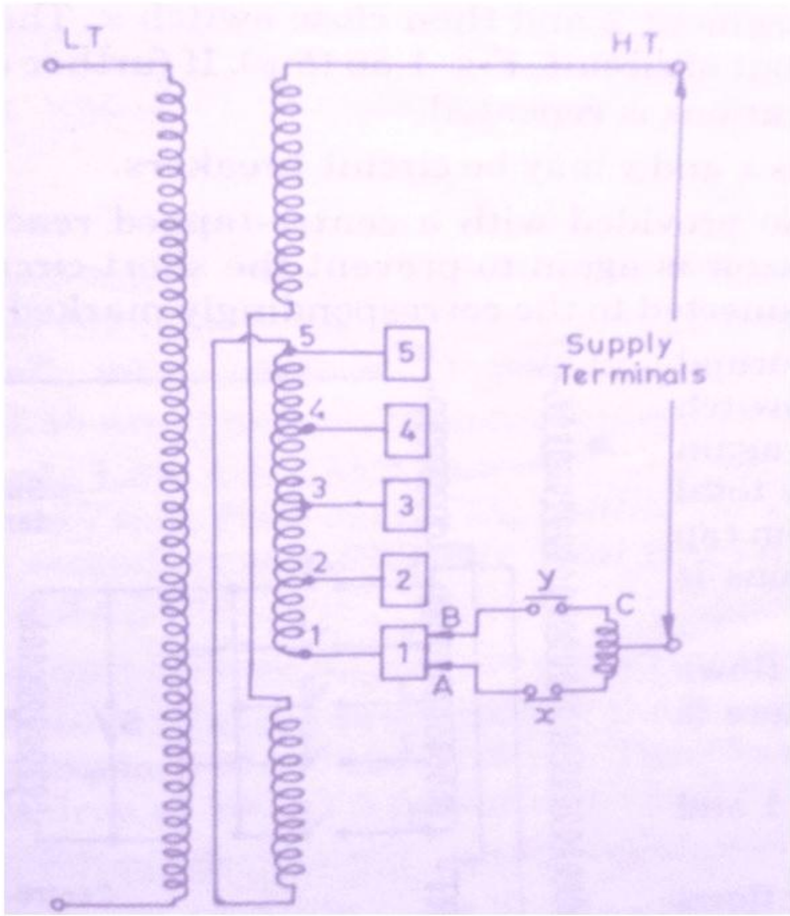
Thus if K = 0.1, the saving of Cu is only 10% but if K = 0.9, saving of Cu is 90%. Therefore, the nearer the value of K of autotransformer is to 1, the greater is the saving of Cu.

6. TAP CHANGING TRANSFORMERS

The modern loads are designed to operate at satisfactorily at one voltage level. It is therefore of great importance to keep the consumers terminal voltage within a prescribed limits. The Transformers output voltage and hence the terminal voltage of the consumer can be controlled by using tap either on primary or secondary side of Transformer.

Taps are connections to the, usually high-voltage winding of a transformer which enables changes to the turns ratio to be made in order to make changes to the secondary voltage to compensate, where necessary, to a fall in terminal voltage below the regulatory allowance.

Principle of On Load Tap Changer



A tap changer designed to operate while the Transformer is charged is called On Load Tap Changer (OLTC). On Load Tap Changer, OLTC is Make Before Break type which ensures that no sparking will take place while operating OLTC. On Load Tap Changer (OLTC) is used for short period or daily voltage regulation.

- The center tapped Reactor C prevents the tapped winding from getting short circuited.
- The Transformer tappings are connected to the segments 1 to 5. Two fingers A and B are movable and connected with the Centre Tapped Reactor through switches x and y and make contact with any one of the segment 1 to 5 under normal operation.
- The fingers A and B are connected with segment 1 and switches x and y are closed, thereby whole winding is in circuit.
- As both the fingers are connected with the segment 1, half of the current will flow from the lower part of the Center tapped Reactor C and half of the current will flow from upper part.
- As the Reactor is wound in the same direction, therefore mmf because of upper half of the current and lower half of the current will cancel out in Reactor.
- Therefore Reactor will be behave like non inductive and will not offer any impedance. Therefore, the voltage drop in the center tapped Reactor will be very small.

The steps to be taken for changing the tap are shown in figure below.

Step1: Open Switch y

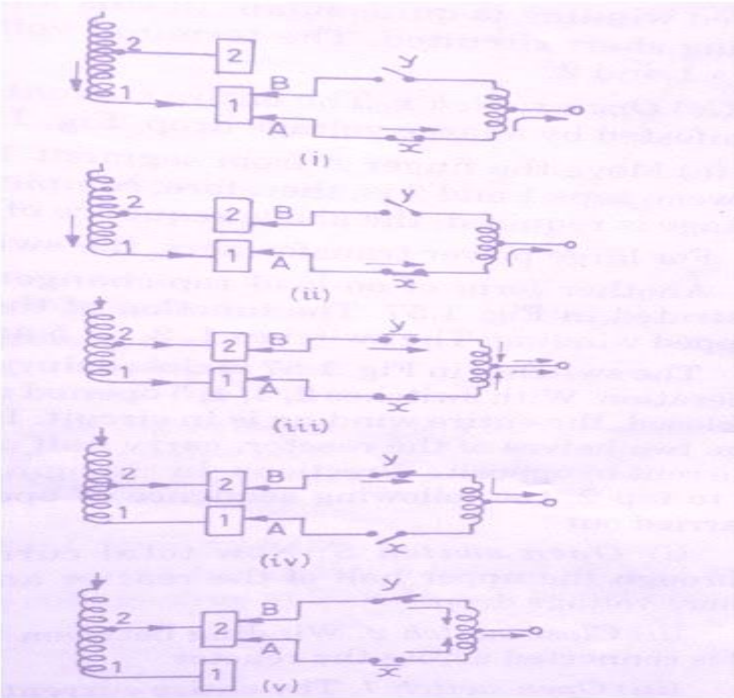
The entire current now will flow through switch x and lower half of the Reactor C. It therefore becomes highly inductive and there will be a large voltage drop across it. Reactor C shall be designed to withstand full load current momentarily.

Step2: Move Finger B

As the Switch y is open therefore finger B is not carrying any current and can be moved to segment 2 without any sparking.

Step3: Close Switch y

Now close Switch y. Now the Transformer winding between tap 1 and 2 get connected through the Reactor C. As the impedance offered by the Reactor is high for current flowing only in one direction, the circulating current through the Reactor, finger A and finger B will be very less. In this manner the Reactor prevents the tapped winding from getting short circuited.



Step4: Open Switch x

Now the entire current will flow from the upper half portion of the Reactor causing a high voltage drop across it.

Step5: Move Finger A

As the Switch x is open therefore finger A is not carrying any current and can be moved to segment 2 without any sparking.

In this way, the winding between segment 1 and 2 is completely cut out. If further change in voltage is required, above sequence of operation is repeated.

7.

A 2300/230V, 500kVA, 50 Hz distribution Xer has core loss of 1600W at rated voltage and Copper loss of 7.5 kW at full load. During the day it is loaded as follows

% Load	0 %	20 %	50 %	80 %	100 %	125 %
pf	—	0.7 lag	0.8 lag	0.9 lag	1	0.85 lag
hrs	2	4	4	5	7	2

Determine the all-day efficiency of the Xer?

Energy output = kVA × cos φ × hours kwh.

% rated load	pf	kVA cos φ	kW	hrs	o/p energy (kwh)
0	—	0	0	2	0
20	0.7	0.2 × 500 × 0.7	70	4	280
50	0.8	0.5 × 500 × 0.8	200	4	800
80	0.9	0.8 × 500 × 0.9	360	5	1800
100	1	1 × 500 × 1	500	7	3500
125	0.85	1.25 × 500 × 0.85	531.25	2	1062.5

Total energy o/p. 7442.5 kwh

Total energy loss in the core in 24 hrs

$$W_i = P_i \times t = \frac{1600}{1000} \times 24 = 38.4 \text{ kwh}$$

Copper loss at any load

% rated load	x	Copper loss $x^2 P_{cu}$	hrs	Energy loss in kwh
0	0	$0^2 \times 7500$	2	0
20	0.2	$0.2^2 \times 7500$	4	1.2
50	0.5	$0.5^2 \times 7500$	4	7.5
80	0.8	$0.8^2 \times 7500$	5	24
100	1	$1^2 \times 7500$	7	52.5
125	1.25	$1.25^2 \times 7500$	2	23.44

Total energy loss in cu = 108.64 kwh

$$\eta = \frac{\text{o/p energy in kwh}}{\text{o/p energy in kwh} + W_c + W_{cu}}$$

$$= \frac{7442.5}{7442.5 + 38.4 + 108.64} \times 100$$

$= 98.06\%$