Department of Electrical and Electronics Engineering

AC Machines
Laboratory Manual

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CERTIFICATE

This is to certify that this book is a bonafide record pratical work done in the AC Machines Laboratory in …….semester of……..year during the year………

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Experiment –1

O.C. Test, S.C. Test & Load Tests on a Single Phase Transformer.

Objective:

To determine the iron losses, copper losses and efficiency of a transformer at any load.

Apparatus:

0-2 Amps Ammeter	01
0-20 Amps Ammeter	01
0-300 Volts Voltmeter	01
0-200 Watts L.P.F. type Wattmeter	01
0-3.0 KW U.P.F. type Wattmeter	01

Transformer Ratings:

Power: 2 KVA, Primary/Secondary : 230/415Volts.
: 8.69/4.82 Amps.

Circuit Diagram:

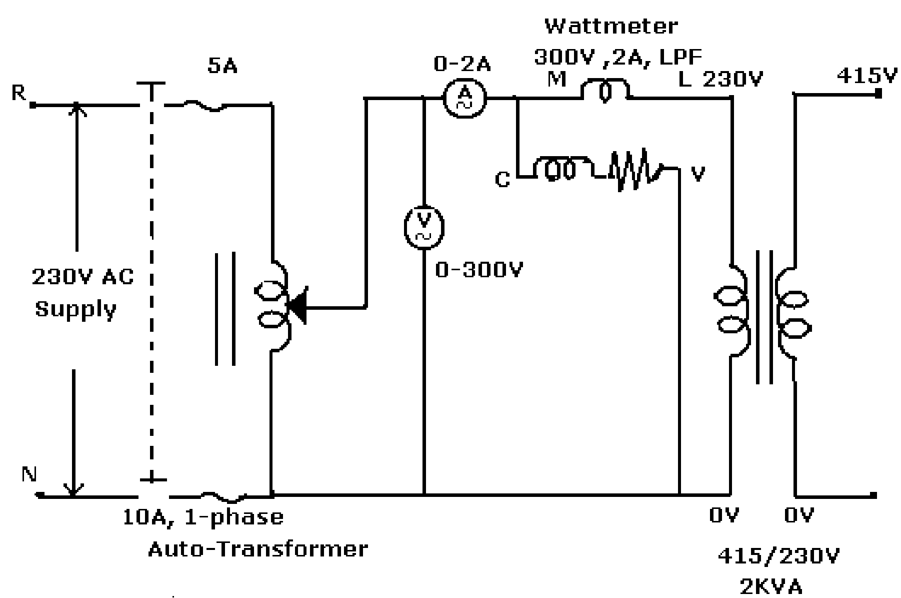


Fig.1.1: Open Circuit Test

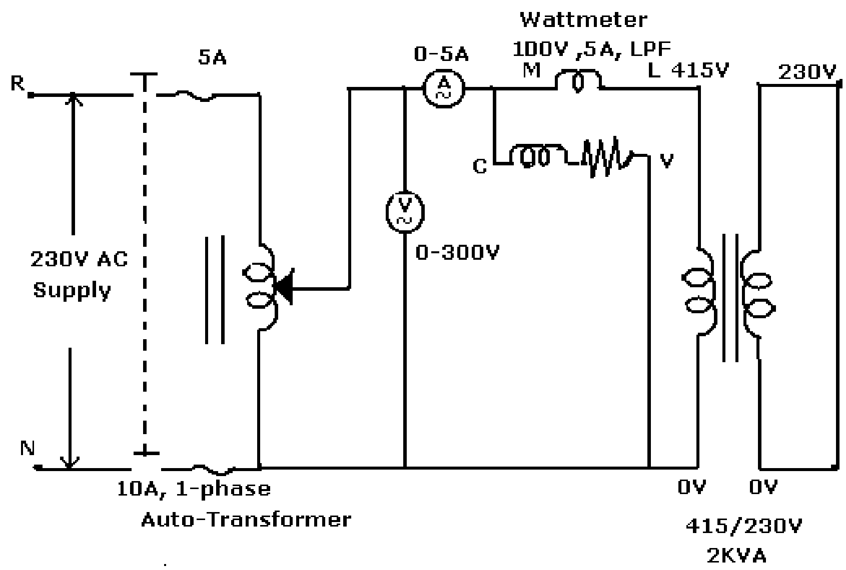


Fig.1.2:Short Circuit Test

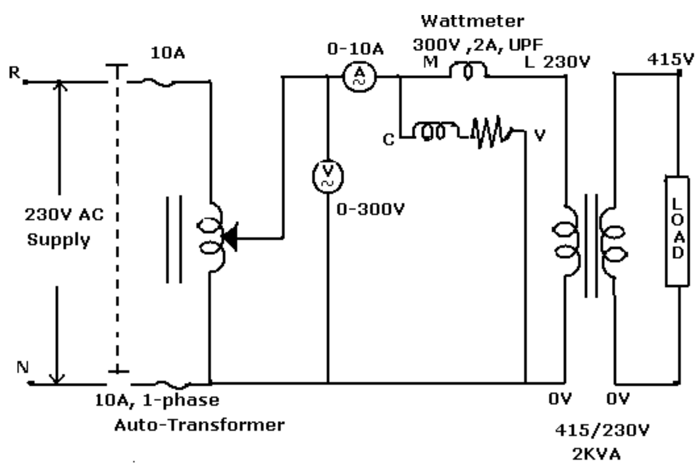


Fig.1.3: Load Test

Theory:

A transformer is a static device which transfers the electrical energy from one circuit to another circuit without any change in the frequency. The transformer works on the principle of electromagnetic induction between two windings placed on a common magnetic circuit. These two windings are electrically insulated from each other and also from the core.

The losses in a transformer are (i) magnetic losses or core losses (ii) ohmic losses or copper losses. The losses of a transformer, magnetic losses and ohmic losses can be determined by performing (a) open circuit test and (b) short circuit test. From the above tests, the efficiency and regulation of a

Given transformer can be predetermined at any given load. The power consumed during these tests is very less as compared to the load test. Ln this experiment LV side parameters are denoted by suffix 1 and FIV side parameters by suffix2.

Open Circuit Test:

In open circuit test, usually HV side is kept open and meters are connected on LV side as shown in the fig.1.1. When rated voltage is applied to the LV side, the ammeter reads the no-load current Io and watt meter reads the power input. The no load current I_{NL} is 2 to 5% of full load current. Hence, the copper losses at no-load are negligible. We represent the iron or core losses. Iron losses are the sum of hysteresis and eddy current losses.

$$W_o = V_{LV} I_O \cos\phi_0$$

Short Circuit Test:

This test is performed to determine the equivalent resistance and leakage reactance of the transformer and copper losses at full – load condition.

In this test usually LV side is shorted and meters are connected on HV side. A variable low voltage is applied to the HV winding with the help of an auto-transformer. This voltage is varied till the rated current flows in the HV side or LV side. The voltage applied is 5 to 10 percent of rated voltage, while the rated current flows in the windings. The wattmeter indicates the full load copper losses and core losses at V_{SC} But the iron, losses at this low voltage are negligible as compared to the iron losses at the rated voltage

Load Test:

This test is performed to determine the efficiency and regulation of a transformer at different load conditions. Usually, this test is performed for low, power, rating of transformers. This test gives accurate results as compared to the above tests. In this test, measurements are taken on HV side and LV side at different load conditions. W indicates the input power at LV side and W indicates the output power connected on secondary side (HV).

Procedure:

(a) O.C Test:

* Connect the circuit diagram as shown in the figure 1.1
* Gradually increase the voltage using the auto-transformer till the voltmeter reads 230V
* Record the voltmeter, ammeter and L.P.F. wattmeter readings.
* The ammeter indicates the no-load current and wattmeter indicates the iron losses
* Switch off the supply and set the auto-transformer at zero position.

(b) S.C Test:

* Connect the circuit diagram as shown in the figure I .2
* Gradually increase the voltage using the auto-transformer till the ammeter reads 4.82 amps, (the rated current of the transformer on HV side)
* Record the voltmeter, ammeter and U.PF. Wattmeter readings.
* The ammeter indicates Isc, voltmeter indicates Vsc and wattmeter indicates Wsc copper losses of the transformer at full load condition.
* Switch off the supply and set the auto-transformer at zero position.

(c) Load Test:

* Connect the circuit diagram such that the supply on LV side and load on HV side as shown in the fig. 1.3.
* Gradually increase the voltage using auto transformer till the voltmeter reads the rated voltage, 230v on LV side and also record the voltage on HV side.
* Maintain the voltage V to be constant for all loads.
* Switch on the load switches one by one and record the ammeter, voltmeter and wattmeter readings. (The load current should not be exceeding the rated current, 4.82A.)
* Switch off the supply and set the auto-transformer at zero position.

Calculations:

* Determine the R_{02} , X_{02}, Z_{02} ,R_{01} , X_{01} , Z_{01} , and R_0 , X_0 values on both sides of the transformer from O.C. test and S.C test.
* Tabulate the efficiency and regulation of the transformer at different load conditions by assuming load with different power factors.
* Draw the equivalent circuit diagram on both sides.

Observations:

O.C Test: Voc =230V; Ioc = 0.48A, Woc = 50w. (LV data)

S.C Test: Vsc = 25V; Isc =4.824, Wsc = 90W (HV data)

Equivalent Circuit Diagram of transformer:

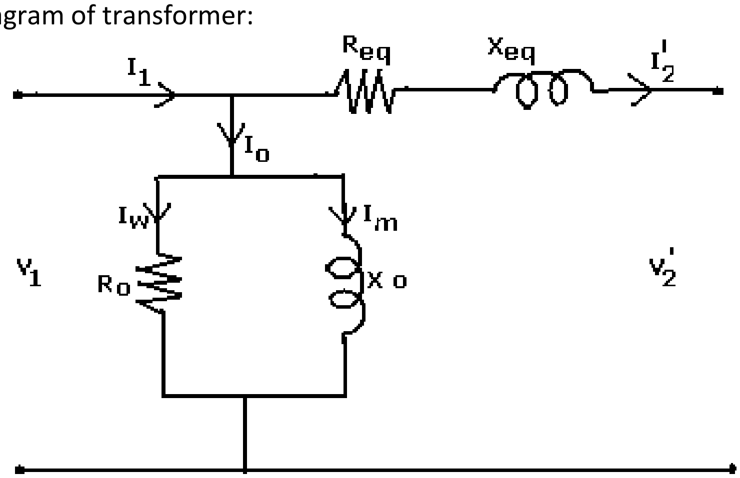


Fig.1.4: Equivalent Circuit

Sample Calculation

Calculation of Ro and Xo of equivalent circuit from o.c test

V_0 = 230V I_0 = 0.48A W_0 = 0.05

Iron losses = Wo = $V_1 I_0 \cos\phi_0$

Coso ϕ0 = $\frac{W0}{V1I0} = \frac{50}{230x0.48}$

$\phi_0 = 63.06^0$, $\sin\phi_0 = 0.8915$

$I = I_0 \cos\phi_0$ $I_w = I_0 \cos\phi_0$

= 0.48x0.8915 = 0.48 x 0.453

= 0.43A = 0.2174A

LVside

$$Ro = \frac{V1}{Iw} \qquad Xo = \frac{V1}{I}$$

$$= \frac{230}{0.217} \qquad = \frac{230}{0.45}$$

= 1058 Ω = 534.88 Ω

HV side R_0 : LVside R_0 x K^2 = 3444.5Ω

HV side X_0 : HV side X_0 x K^2 = 1740.7Ω

Where $K = \frac{V_{HV}}{V_{LV}} = \frac{415}{230}$ = 1.804

SC TEST:

Calculation of R_{01} and X_{01} for equivalent circuit

I_{sc} = 4.824 A V_{SC} = 25V W_{sc} = 0.09KW

Full load copper losses or variable losses = Wsc = $I^2_{sc} R_{02}$

$$\mathbf{R02} = \frac{\mathbf{WSC}}{\mathbf{ISC^2}} = \frac{\mathbf{90}}{(\mathbf{4.82})^2} = \mathbf{3.874\ \Omega}$$

$$\boldsymbol{Z02} = \frac{\boldsymbol{VSC}}{\boldsymbol{ISC}} = \frac{\mathbf{25}}{\mathbf{4.82}} = \mathbf{5.187}\ \boldsymbol{\Omega}$$

$$\mathbf{X}02 = \sqrt{(\mathbf{Z}02^2 - \mathbf{R02^2})} = \mathbf{3.45}\ \boldsymbol{\Omega}$$

$$\boldsymbol{R}\mathbf{01} = \frac{\boldsymbol{R02}}{\boldsymbol{K^2}} = \mathbf{1.19}\ \boldsymbol{\Omega}$$

$$\boldsymbol{X}\mathbf{01} = \frac{\boldsymbol{X02}}{\boldsymbol{K^2}} = \mathbf{1.06}\boldsymbol{\Omega}$$

Calculation of percent regulation from sc test

At full load current, I_2 = 4.82 A, V_2 = 4 I 5V, p.f = 0. 8 lag

Percent regulation

$$= \frac{\boldsymbol{I2}\ (\boldsymbol{R02\ Cos\emptyset} + \boldsymbol{X02\ Sin\emptyset})}{\boldsymbol{V2}} = \mathbf{6}\%$$

Efficiency Calculation from O.C and S.C tests

$$\%\eta = \frac{\textbf{Out put in KVA}*\textbf{p.f}*\textbf{100}}{\textbf{Output in KVA}*\textbf{p.f}+\textbf{Iron losses}+\textbf{x}^2\textbf{Full loadcopperlosses}}$$

At full load 0.8 power factor where x

$$\%\eta = \frac{2000 \times 0.8 \times 100}{2000 \times 0.8 + 50 + 90} = 92\% \qquad = \frac{\text{Actual load in KVA}}{\text{Rated load KVA}}$$

Sample Observations for Load Test:

V_1 = 230V **Load Test**

Primary		Secondary				
I_1(A)	W_1(kw)	V_2(V)	I_2(A)	W_2(kw)	$\%\eta = \frac{W_2}{W_1}$	$\%\text{reg} = \frac{V_{2NL} - V_2}{V_{2NL}}$
0.54	0.05	412	0.02	0	0	0
1.61	0.35	409	0.72	0.31	88.6	0.78
2.86	0.64	405	1.44	0.59	92	1.7
4.14	0.94	402	2.16	0.88	93.6	1.428
5.42	1.22	398	2.87	1.16	95.1	2
6.68	1.52	395	3.56	1.41	92.8	2.43

Observations:

Primary		Secondary			
I_1 (A)	W_1 (kw)	V_2 (V)	I_2 (A)	%η	%reg.

Calculations

Experiment-2
Sumpner's Test

Objective:

To predetermine the efficiency, regulation and equivalent circuit of a given pair of identical single - phase transformers by conducting Sumpner's test.

Name plate details of the two identical transformers:

Primary voltage	: 230 Volts	Secondary voltage:	415 Volts
Primary current	: 69Amps.	Secondary current	4.82 Amps
Power (Burden)	: 2KVA	Frequency:	50 Hz.

Apparatus:

Digital voltmeter, 0 to 1000Volts	02
Digital ammeter, 0 to l0 Amps	02
Digital wattmeter, 0 to 300 Watts	02
Digital temperature indicator, 0 to 100 Degrees	01

Theory:

The efficiency of a transformer can be predetermined by conducting o.c. and S.C. tests. But the rise in temperature can be found only by conducting the actual load test. It is difficult io conduct the actual load test for large transformers. In case of Sumpner's test the efficiency, regulation and rise in temperature can be obtained with small amount of power consumption.

In Sumpner's test, the two primary windings of the identical transformers are connected in parallel across the supply and the two secondaries are connected in series with their polarities in opposition. One digital wattmeter (L.P.F. type), one voltmeter and one ammeter are connected At primary side. One digital wattmeter (U.P.F: type), one voltmeter and one ammeter are connected at secondary side. If primaries are energized then the voltage across the two secondaries will be zero since both the transformers are identical transformers.

The power input to the transformers at no-load is indicated by the wattmeter on the primary side. This power is, equal-to the iron losses of the two transformers. An auto-transformer is connected in series with the two secondaries. A small voltage is injected in the secondary circuit from a separate ac source. It will circulate a current in the secondary side since the secondary's are in opposition, the secondary current will cause primary current in opposite directions so that the reading of wattmeter on primary is not affected and it will indicate the iron losses of the two transformers. The auto-transformer is adjusted till the full load current flows in the secondary side of the transformer. At full load current the wattmeter on the secondary side indicates the full load copper losses of the two transformers.

Procedure:

* Make all the connections as per the circuit diagram shown in fig .Z.Z.
* Keep the switch 's' open on the secondary side of the transformer.
* Keep the auto-transformer at zero position and disconnect the supply To the auto transformer.
* Apply the normal voltage of 230Volts to the primary side.
* Check the voltmeter reading across the switch. If it reads zero, it means the secondaries are connected in opposition. If the voltmeter reads twice the secondary rated voltage then the connections should be reversed on the secondary side.
* lf voltmeter reads zero closes the switch .S'.

* Connect the supply to the auto-transformer and energize the secondary circuit and adjust the auto transformer till the ammeter on the secondary side reads the rated current (4.82A).
* Record the readings of the meters on both the primary and secondary
Sides.
* Calculate R_{eq} , x_{eq} , regulation and efficiency of the transformer 0.8 pf lag, 0.8pf lead and upf for full load and half load conditions.

Observations:

V_1 = 220 V I_1 = 0.86 A W_1 = 94.3 W
V_2 =50 V I_2 = 4.65 A W_2 = 185 W

Formulas for Calculations:

Core loss for each transformer = $W_0 = \frac{W1}{2} = \frac{94.3}{2}$ = 47.15 W

Full load copper loss for each transformer = $W_0 = \frac{W2}{2} = \frac{185}{2}$ = 92.5 W

$$\%\eta = \frac{\text{Out put in KVA}*\text{p.f}*100}{\text{Output in KVA}*\text{p.f}+\text{Iron losses}+x^2\text{Full loadcopperlosses}}$$

Where

$$x = \frac{\text{Actual load in KVA}}{\text{Rated load KVA}}$$

% Regulation of the transformer = $\frac{I2(Req\ Cos\emptyset + Xeq\ Sin\emptyset)}{V2}$

Where V_2 = Secondary voltage at no-load.

Calculations for R_{eq}, X_{eq} :

$I^2_{sc} R_{eq} = \frac{Wsc}{2}$ $Z_{eq} = \frac{Vsc}{Isc}$ $X_{eq} = \sqrt{(Zeq^2 - Req^2)}$

Diagram of Equivalent circuit of the transformer:

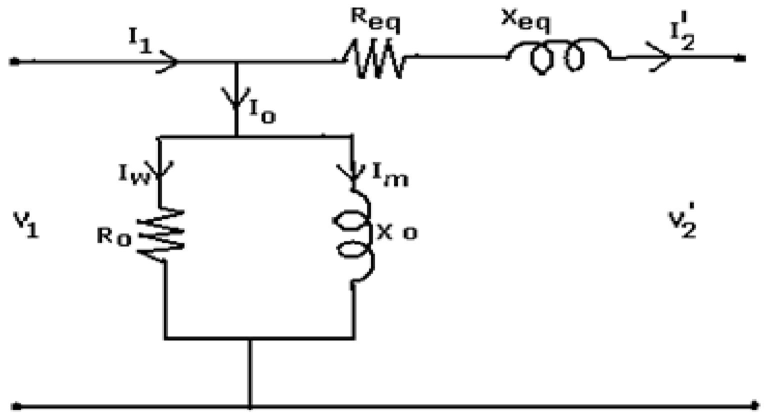


Fig 2.1 : Equivalent Circuit

Calculation for equivalent circuit of transformer:

$I_w = I_0 \cos\phi$ $\qquad$ $I_\mu = I_0 \sin\phi$

I_0 is the no load current on primary side

$R_0 = \frac{V_1}{I_w}$ $\qquad$ $X_0 = \frac{V_1}{I_\mu}$

Graphs: Plot the graph for output in KW Vs percent for 0.8p.f and u.p.f. at full and half loads.

Circuit Diagram:

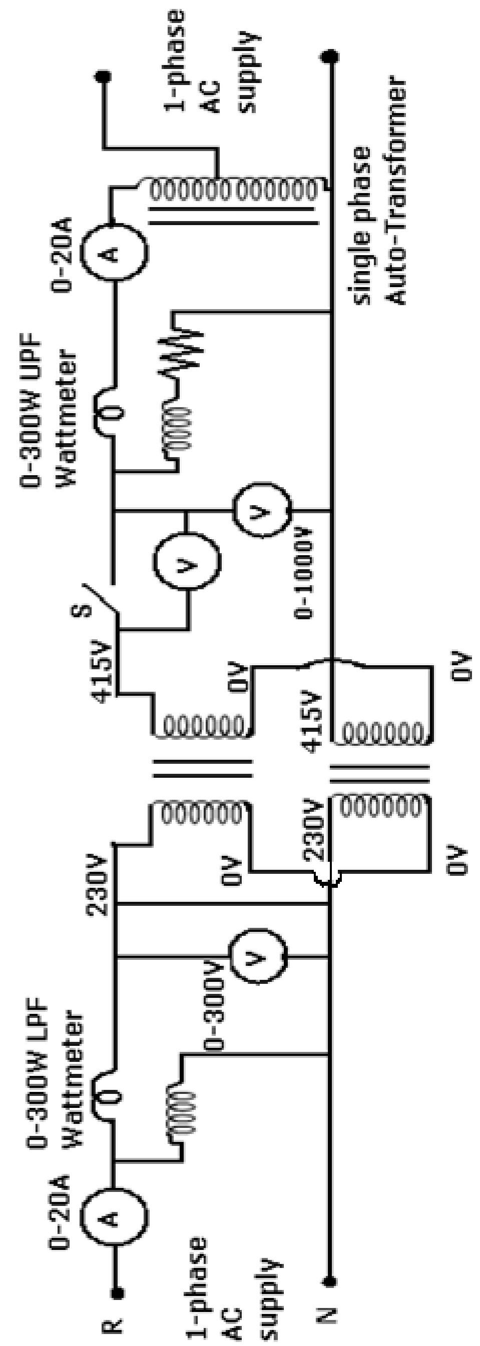


Fig. 2.2: Sumpner's test

Calculation for R_0 and X_0

$V_1 = 220$ V $I_1 = 0.86$ A $W_1 = 94.3$ W

$W_0 = \frac{94.3}{2} = 47.15W$ $I_0 = \frac{0.86}{2}A$

$Cos\phi_0 = \frac{W0}{V0\ I0} = \frac{47.15}{220 \times 0.43} = 0.498$

$I_w = I_0$ Cosϕ = 0.43 x 0.498 = 0.214A

$I_\mu = I_0$ Sinϕ = 0.43 x 0.866 = 0.372A

$R_0 = \frac{V1}{Iw} = 1028\Omega$, $X_0 = \frac{V1}{I\mu} = 591.4\ \Omega$

$W_{sc} = \frac{185}{2} = 92.5W$, $Vsc = \frac{50}{2} = 25V$, $I_{sc} = 4.65A$

HV $R_{02} = \frac{Wsc}{Isc^2} = 4.278\ \Omega$, $Z_{02} = \frac{Vsc}{Isc} = \frac{25}{4.65} = 5.376\ \Omega$.

$HVX_{02} = \sqrt{(5.376)^2 - (4.278)^2} = 3.26\Omega$

$K = \frac{415}{230} = 1.804$

$LVZ_{01} = \frac{Z02}{K^2} = \frac{5.376}{1.804^2} = 1.652\ \Omega$

LV $R_{01} = \frac{4.27}{1.804^2} = 1.314\Omega$

$LVX_{01} = \frac{X02}{K^2} = 1.0\ \Omega$

Total losses = $W_i + W_{cu}$ = 92.5 + 47.15 = 139.3W

Output = Rated power = 2KVA.

Calculation of efficiency at full load with 0.8 p.f. lag

$\%\eta = \frac{2000X0.8X100}{2000X0.8 + 139.3} = 92\%$

Calculation of regulation at full load with 0.8 p.f. lag

$\%\ reg = \frac{4.65}{415}\ [4.27X0.8 \pm 3.26X0.6]$

Where ‘+’ is for lagging and ‘-‘ is leading loads

Experiment-3
'V' and inverted 'V' curves of a 3 - Phase Synchronous Motor

Objective:

To draw the V and Λ curves of a 3-phase synchronous motor at no-load and load conditions.

Apparatus:

0-300V dc Voltmeter	01
0-300V ac Voltmeter	01
0-l0A dc Ammeter	01
0-2A dc Ammeter	01
0-3 KW wattmeter	01
Frequency meter	01
Phase sequence meter	01

Motor Specifications:

DC Motor:

Voltage : 220 V.
Current : 19 Amps
Speed : 1500 rpm

Synchronous Machine:

Voltage --- 220 V
Current --- 5 Amps
Speed --- 1500 rpm
Power --- 3.5 KVA

Theory:

Normal Excitation:-

If the field current is equal to the rated excitation, which is called the normal field excitation. The p.f. of the motor is unity at this excitation.

Under Excitation:-

A field current below the normal excitation is called unclear excitation. Here I increases and operating p.f. of motor decrease. The power factor is lagging when it is under excited (equivalent to inductive load).

Over Excitation:-

Field current above the normal excitation is called over excitation. Here Ia again increases and operating p.f. decreases, but it is leading here. Hence the motor draws leading current.

If the armature current is plotted against the field current of a synchronous motor at constant load, the curve appears as V . Hence the curve is known as V curve. The current drawn by the motor will be minimum when the current I_a is in phase with the voltage or the power factor of the motor is unity.

It is observed from the experiment that whenever the field current changes, the no-load armature current raises sharply on each side, of the unity power factor point. It is also observed that at full load, large changes in field current or excitation make relatively less difference in the armature current.

The input power = $\sqrt{3}$ VI cosϕ. Thus, if the power factor for constant output is plotted against the field current, out a constant load it will be as inversion of V curve. The V and inverted V curves of a synchronous motor can be obtained by performing the synchronization test. The v-curves of synchronous machine motor show how armature current varies with I_f , when motor input is kept constant. These curves are obtained by plotting as armature current against dc field current while motor input is kept constant.

The inverted v-curves of synchronization machine motor shows how pf varies with I_f , when motor input is kept constant, such that they change with power factor change.

The synchronization switch is closed when (1) frequency of voltage on both sides of the switch is same. (2) Line to neutral voltage on the supply side must be equal to corresponding line to neutral voltage on the synchronous machine side closing the synchronizing switch is called synchronization.

If the phase angle between V and I is less than 90^0 the power per phase delivered by ac supply source Vl cosϕ is positive. Machine is acting as a synchronous generator if the phase angle lies between 90^0 and 180^0, cosϕ is negative, then ac supply source actually now receives power. The synchronous machine acts as a generator.

Synchronous motor runs at a constant speed. If the load is kept constant the power output remains constant. As excitation varies its power factor varies where as the input also remains constant.

Thus the current drawn decreases in magnitude which the phase angle (of lag) also decreases and power factor increases. At a certain Stage, pf = 1, further increase in excitation pf decreases thus angle increases.

Now on load condition, if line to neutral voltage of the machine coincide with those of the supply the voltages of the lamps become zero all times lamps are dark. This time the synchronization switch is closed, if not the phase move away from synchronization. At one point the voltage across each lamp becomes twice a phasor voltage and lights reach maximum intensity. .The limit of stability depends on the excitation. The stronger the excitation the more stable is the machine.

The input power is constant at a constant load on the motor. The armature current and power factor changes with the change in the excitation.

Procedure:

* Connect the circuit as shown in the circuit diagram.
* Keep the dc motor (prime mover) potentiometers and synchronous machine field auto-transformer at zero position.
* Switch on S, switch.
* Push the start button and slowly increase the potentiometer till the motor attains the rated speed.
* Check the phase voltage, frequency and phase sequence of the A.P.S.E.B. supply at the synchronizing switch (contactor).
* Adjust the auto-transformer (to increase the excitation of the syn. machine) till the phase voltage of the synchronous machine is same as the A.PS.E.B. Supply at the synchronizing switch.
* Check the frequency and phase sequence of the the A.P.S.E.B. supply and the synchronous machine are same on both sides of the synchronizing switch. (Connect the frequency meter across the R-Phase, Neutral on the supply side and simultaneously check at the generate side. Adjust the prime mover (DC Motor) speed till the frequencies are equal.
* Check the lamps connected across the synchronization switch.
* If the lamps are not gradually becoming dark then adjust the dc motor speed very gently till the lamps become dark.
* Push the synchronizing ON button when all the lamps are dark.

Fig.3.1: Circuit Diagram:

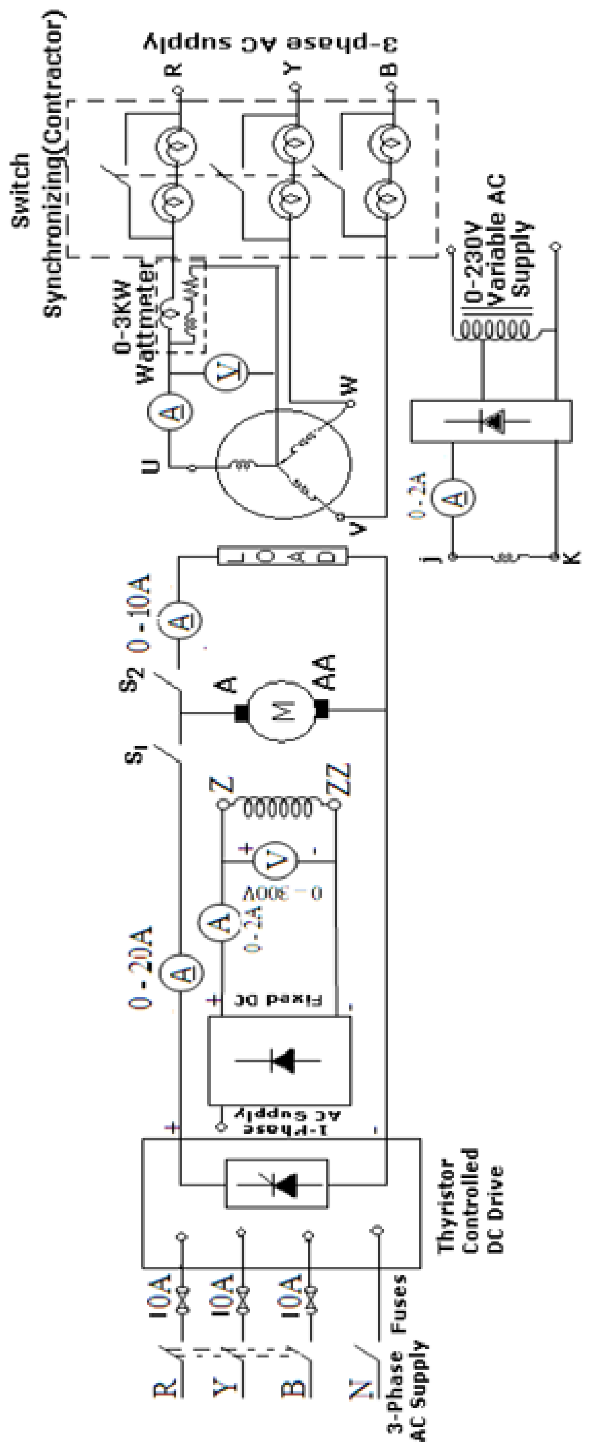


Fig. 3.1 : Circuit Diagram

V & Inverted V Curves

* Now, the syn. machine is parallel to the power supply and starts working as a synchronous motor. Switch – off the S_1 switch (to disconnect the supply to the DC motor.
* Gradually, decrease the excitation of the syn. motor by decreasing the auto- transformer position and record I. Ino and power per phase of the synchronous motor.
* Similarly, increase the excitation of the syn. Motor by increasing the auto - transformer position and record I_f, I_{ph} and power per phase of the synchronous motor. Do not exceed the field current more than 1.2 amps (rating of the field current).
* Switch - off the power supply contactor and set the auto – transformer and dc drive potentiometer to zero position. Synchronous machine contactor is also becomes off .
(Note: Do not touch the Synchronization switch OFF button)

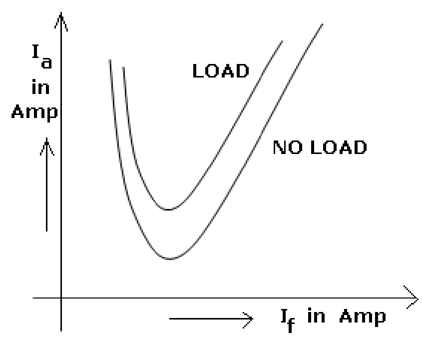
Sample Observation Table:

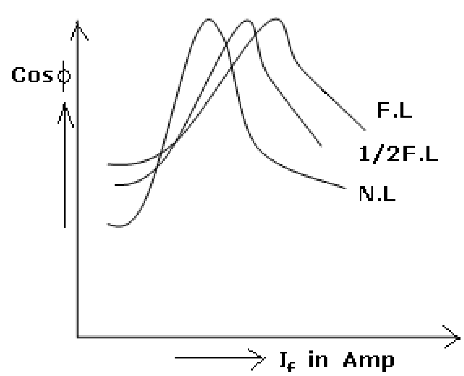
I_f	I_a	W	V	Pf
0.1	5.53	50	232	0.0389
0.2	4.79	60	232	0.054
0.3	4.1	70	231	0.074
0.4	2.93	100	232	0.147
0.5	2.4	120	233	0.215
0.61	1.54	110	230	0.3106
0.7	1.67	70	231	0.18
0.8	1.02	40	231	0.17
0.9	0.68	80	234	0.503
1.0	1.04	90	232	0.373
1.1	1.2	100	230	0.3623

Practical Observation Table:

I_f	I_a	W	V	Pf

Model Graphs:





Result: Thus, the test is carried out and 'V' and 'Λ' curves are drawn as no-load.

Experiment-4
Brake test on a Slip Ring Induction Motor

Objective:
To perform the brake test on a 3-ϕ slip ring induction motor and obtain its performance characteristics.

Nameplate details:
AC slip ring induction motor.

	Stator	**Rotor**
Voltage	415V	200v
Current	7.5A	11.0A
Winding	Star	Star
Power	5.0 h.p	
Speed	1440 r.p.m	

Apparatus:

Voltmeter 0-300V ac digital	01
Ammeter 0-10A ac digital	01
Wattmeter 0-5KW digital	01
Tachometer 0-9999rpm digital	01

Theory:
The slip ring induction motor consists of two main parts. They are stator and rotor.

Stator: It is a star connected 3- ϕ winding. Each phase winding is separated by 120^0 electrical. Il 3- ϕ supply is connected to the stator, it produces a rotating magnetic field in the stator core.

Rotor: It is also a star connected 3- ϕ winding and wound for the same number of poles as the stator. Its external terminals are short-circuited. Due to the relative speed between the rotating flux in the stator and the stationary flux in the rotor. The rotor rotates nearer to the synchronous speed maintaining a low slip.

The synchronous speed of the rotating flux in the stator $N_s = \frac{120f}{P}$

Where 'f is the supply frequency in Hz and 'P' is the number of poles.

Slip : It is the relative speed of the rotor with respect to synchronous speed of the rotating magnetic field.

Percent Slip = $\frac{(Ns - N)}{Ns} X100$

Torque $\tau = 9.81(\tau_1 - \tau_2)$. R, Where R is at the radius of the brake drum.

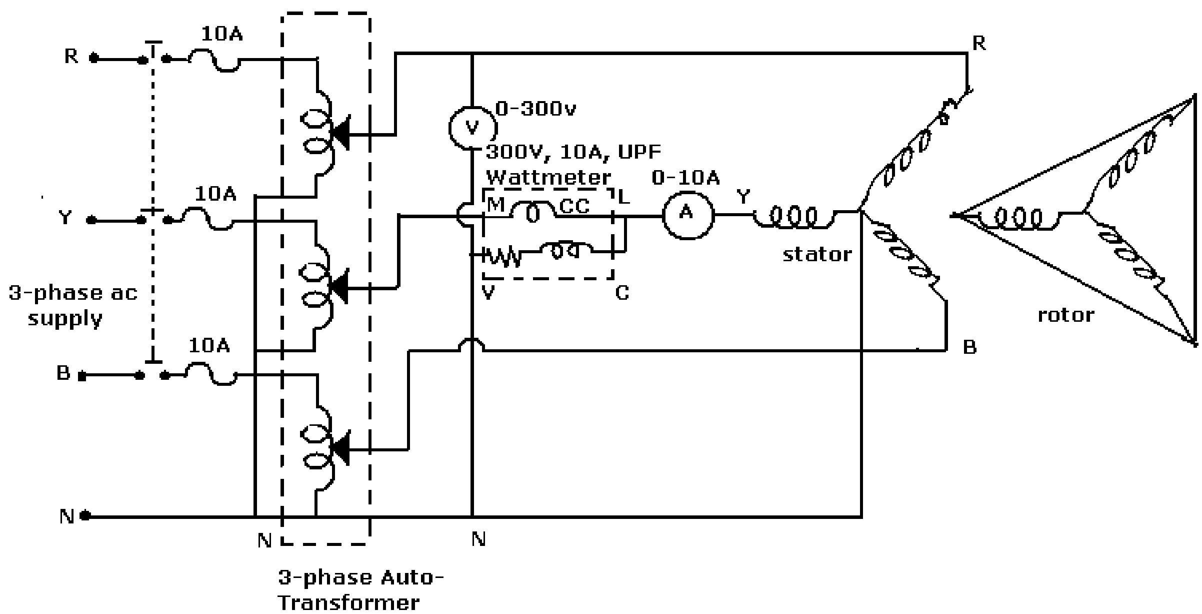
Output = $\frac{2\pi N\tau}{60} watts$

$\%\eta = \frac{output}{input} x100$

Power factor = $\cos\phi = \frac{Pph}{Vph.Iph}$

(Where 'P_{ph}' is the input power per phase)

Circuit Diagram:



Procedure:

* Connect the circuit diagram as shown in the fig 4.1
* Keep the 3-ϕ auto transformer at zero voltage position.
* Loosen the rope on the brake drum and set the tension meters at zero position.
* Switch - ON the motor and increase the auto - transformer gradually till the voltmeter reads the rated phase voltage 230V.
* Note down the readings of the voltmeter, ammeter, tachometer, spring balances and wattmeter readings at no-load.
* Now increase the load gradually by tightening the rope till the ammeter reads the rated current. Pour some water in side the break drum for cooling.
* Note down V_{ph}, I_{ph}, P_{ph}, T_1, T_2 and speed.
* Switch – OFF the supply and adjust the 3-ϕ auto - transformer at zero position.

Sample Observations : N_s = 1500 rpm

S.No.	V_{ph} (Volts)	I_{ph} (amp)	$P_{ph}=W_0$ (KW)	N (rpm)	T_1 (Kg)	T_2 (Kg)	P_{in}(kw) =3 P_{ph}
1	241	4.17	0.16	1409	0	0	0.48
2	241	4.27	0.26	1403	1.75	0	0.78
3	241	4.4	0.39	1391	3.2	0	1.17
4	241	4.5	0.46	1387	4.1	0	1.38
5	241	4.71	0.57	1381	5.8	0	1.71
6	241	4.9	0.64	1373	6.4	0	1.92
7	241	5.05	0.72	1367	7.4	0	2.16
8	241	5.66	0.90	1356	9.8	0	2.7
9	241	6.0	0.99	1356	10.8	0	2.97

Practical Observations :

S.No	V_{ph}(V)	I_{ph}(A)	$P_{ph}=W_o$(KW)	N(rpm)	T_1(Kg)	T_2(Kg)	P_{in}(Kw)=3P_{ph}

Sample Calculations:

$\tau = 1.5 \times (T_1 \sim T_2)$ (N-m)	$\omega = \frac{2\pi N}{60}$	$P_{out} = \tau \times \omega$ (K watts)	$\%\eta = \frac{P_{out}}{P_{in}} X100$	$Cos\phi = \frac{W_o}{VI}$
0	0	0	0	0.15921
2.625	147.55	0.387	49.615	0.25266
4.8	146.9	0.705	60.25	0.367786
6.15	145.66	0.8958	64.9	0.4242
8.7	145.25	1.2636	73.9	0.5022
9.6	144.62	1.388	72.33	0.542
11.1	143.152	1.588	73.51	0.592
14.7	141.99	2.087	77.3	0.6598
16.2	141.99	2.30	77.4	0.685

Practical Calculations:

$\tau = 1.5 \; x \; (T1 - T2)$ $(N-m)$	$\varpi = \frac{2\pi N}{60}$	$Pout = \tau \; x \; \varpi$ $(K \; watts)$	$\%\eta = \frac{Pout}{Pin} x100$	$Cos\phi = \frac{Wo}{VI}$

Graph :

Draw the graph for

(i). I_{ph} Vs τ (ii) I_{ph} Vs ŋ (iii) I_{ph} Vs N (iv) I_{ph} Vs slip

Conclusion:

The performance characteristics of the slip ring induction motor are drawn from the readings obtained form the brake test.

Experiment- 5
No load and Blocked rotor tests on a 3 phase – Squirrel Cage Induction Motor

Objective: To draw the circle diagram of a 3-phase squirrel cage Induction motor.

Apparatus :

0-300 V A.C. Voltmeter 0l
0-10 A A.C. Ammeter 0l
0-3.0 KW A.C. Wattmeter 0l
0-2000 rpm A.C. Tachometer 0l
3-phase 16 Amps Auto - Transformer 0l

Motor Ratings :

Power:3.7 KW
Voltage: 415 Volts
Current: 7.9 Amps
Speed: 1430 rpm
Connection: Star

Theory:

This test is used to determine the no load current Io, power factor, cosϕ, wind age & friction losses, core losses, no load resistance Ro and magnetizing reactance Xo.

The motor is uncoupled from its load and rated voltage is applied to the stator. Since there is no output, the power supplied to-the stator is the some of its copper losses, core losses and friction and wind-age losses.

The no load test is carried out with different values of applied voltage, at below and above the normal voltage. The power input is Measured by the two wattmeter, Io by an ammeter and V by a voltmeter. The total power input will be the difference of the two wattmeter reading W_1 and W_2. The readings of the total power input are WO, Io and voltage V is plotted. If we subtract loss corresponding to OA from Wo, then we get the no-load electrical and magnetic losses in the machine, because the no-load input Wo to the motor consists of (i) small stator Cu loss $3I_o^2 R_1$ (ii) Stator core loss $W_c = 3 G_o V_c^2$ (iii) Loss due to friction and windage.

Hence knowing the core loss W_c, G_o and B_o can be found.

$$\cos\phi_0 = \frac{Wo}{\sqrt{3}Vc\ Io}$$

Where V_c = Line voltage and W_0 is no-load stator input.

Blocked rotor test:-

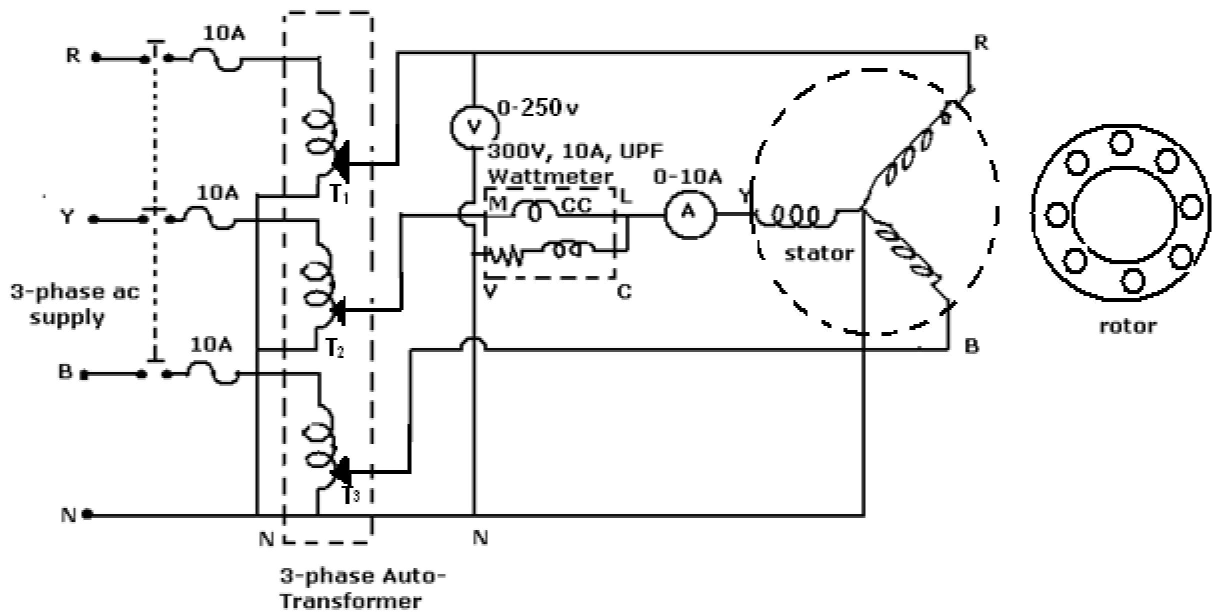
This test is also known as locked-rotor or short-circuit test. It is used to find out

(i) Short-circuit current with normal voltage applied to the stator.
(ii) Power factor at short-circuit condition.

Both these values are used for the construction of the circle diagram.

Circuit diagram:

3-Phase Induction Motor



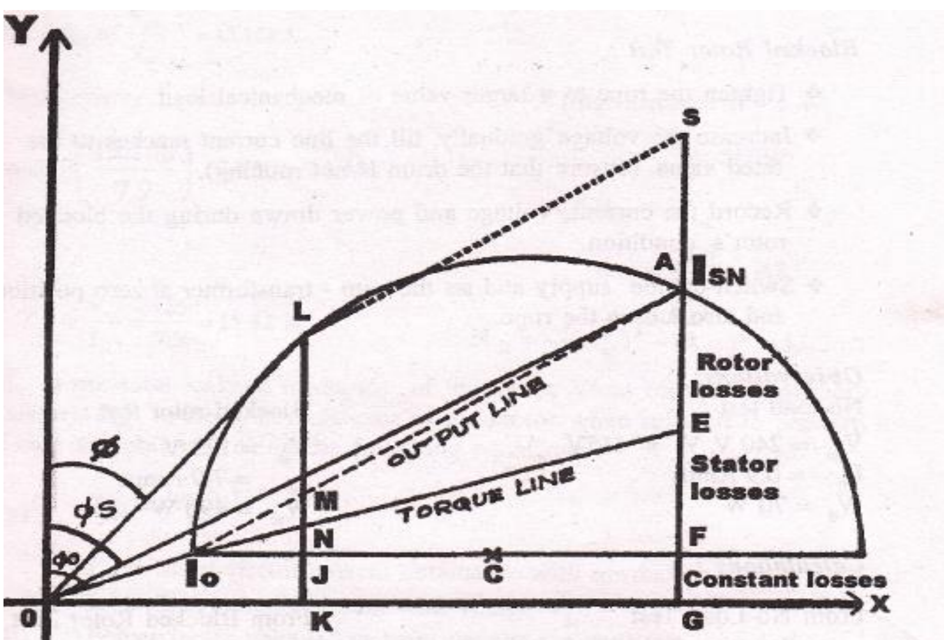


Fig. 5.2 : Circle Diagram

Procedure:

load Test:

- Connect the circuit as shown in the fig. 5.1.
- Set the 3-phase auto-transformer at zero position.
- Loosen the rope on the brake drum.
- Push the start button and increase the voltage till the voltmeter reads the phase voltage, 230 V.
- Record the No-load current, voltage, power drawn in each phase and speed.
- Slowly tighten the rope and record the T_1 &T_2 (readings of the Tension meters), line current, voltage, power drawn in each phase and rpm at different loads.
- Tight the rope (Increase the load) till the ammeter reads the rated current and record the current, voltage, power and speed.
- Switch-off the supply and set the auto-transformer at zero position.

Blocked Rotor Test:

- Tighten the rope to a larger value of mechanical load.
- Increase the voltage gradually, till the line current reaches to the rated value. (Ensure that the drum is not rotating).
- Record the current, voltage and power drawn, during the blocked rotor's condition.
- Switch off the supply and set the auto - transformer at zero position and also loosen the rope.

Observations:

No-load test:

V_{ph} =24OV, V_L= 415V

I_0 = 0.9 AmPs

W_0 =70w

Blocked Rotor Test

V_{sc} = 125V

I_{sc} =7.9A

W_{sc} = 490 W

Calculations:

From No-Load Test:

$W_0 = V_{ph}\, I_0 \cos\phi_0$

$\cos\phi_0 = \frac{W0}{Vph \text{ X } Iph} = \frac{70}{0.9 \text{ X } 240} = 0.324.$

$\phi_0 = 71.10$

$I_{SN} = I_{SC} \text{ X } \frac{Vph}{Vsc} = 15.168$ A

Total power Input

$=490(15.168/7.9)^2=1806.34$ W

$Z_{01} = V_{sc} / I_{sc} = 15.82\ \Omega.$

From Blocked Rotor Test:

$W_{sc} = I_{sc}\ V_{sc} \cos\phi_{sc}$

$\cos\phi_{sc} = \frac{490}{7.9 \text{ X } 125} = 0.496$

$\phi_{sc} = 60.25^0$

Total losses = $W_{sc} + W_0$

= 560W

$I_{sc}^2 R_{01} = W_{sc}$

$R_{01} = 560/7.9^2 = 8.972\ \Omega.$

$\therefore X_{01} = \sqrt{(Z01)^2 - (R01)^2} = 13.14\ \Omega$

X_{01} is the total leakage reactance of the motor when referred to primary (stator). R_{01} is the total resistance of the motor when referred to primary. These are obtained using the following equations: -

(a) $I_{SN} = \frac{IscXV}{Vsc}$

I_{SN} = Short-circuit current obtainable with normal V_1

I_{sc} = Short-circuit current with voltage V_{sc}

(b) Power factor calcularion from short circuit test is as follows:

$W_{sc} = I_{sc} V_{sc} \cos \phi_{sc}$

$\therefore \cos \phi_{sc} = \frac{Wsc}{Vsc \text{ X } Isc}$

Where W_{sc} = total power input at short-circuit condition

V_{sc} = line voltage at the short-circuit condition

I_{sc} = line current at short-circuit condition

(c) Total cu loss = $W_{sc} - W_0$

$3I_2^2 R_{01} = W_{sc} - W_0$, $R_{01} = \frac{Wsc - W0}{3I2^2}$

$Z_{01} = V_{sc}/I_{sc}$, $X_{01} = \sqrt{(Z01)^2 - (R01)^2}$

Conclusions:

Thus, the no-load and blocked rotor tests are conducted on a 3-Phase squirrel cage induction motor and then the circle diagram is drawn.

Experiment-6
Equivalent circuit of a 1-phase Induction Motor

Objective:

Draw the equivalent circuit of the single phase Induction motor by conducting (a) No-load test (b) Blocked rotor test.

Apparatus:

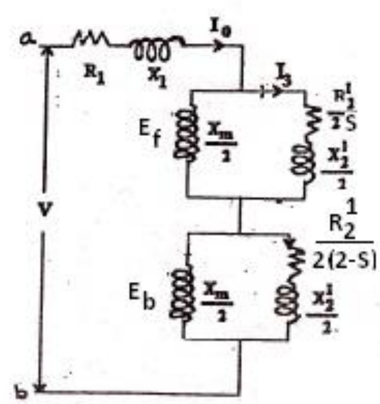
230 V, 10 Amps auto - transformer	0l
0 - 300 V A.C. voltmeter	01
0 - 10 Amps A.C. ammeter	01
0 - 3.0 KW A.C. wattmeter	01
0 - 2000 rpm tachometer	0l

Name Plate Details:

Supply:	1- Phase, 50Hz, 220/230 V
Current:	7.6 Amps
Power:	750W (1 HP)
Speed:	1425 rpm

Starting capacitor: 120 μF, 275 v.

Theory:



Equivalent circuit of 1-ϕ induction motor

A 1-ϕ induction motor is not a self starting motor. For such machines an initial start by hand or in either direction a torque to be provided so that the motor accelerates to ifs final speed.

It may be considered as if there are two motors which have a common stator winding but their respective rotors revolve in opposite directions. Equivalent circuit of such motors is based on double field revolving theory. Here1 -ϕ motor is imagined to have, (i) stator winding (ii) two imaginary rotors. Since iron losses are neglected the exciting branch shown consists of exciting reactance only.

$T_f = I_3^2 r^2/ S$ is forward torque and $T_b = I_5^2 r^2/ (2\text{-}S)$ is backward torque

Core losses can be represented by an equivalent resistance which may be connected either in parallel or in series with the magnetizing reactance core loss current I_W= coreloss. No-load and blocked rotor tests are performed on single phase induction motor to determine its parameters of equivalent circuit. Equivalent circuit in figure is drawn on the basis of double field revolving theory in which the iron loss component has been neglected. The motor consists of stator winding, represented by its resistance

R_1 and leakage reactance X_1 and two imaginary rotors, generally called as forward and backward rotors. Each rotor has been assigned to the actual rotor values in terms of stator. Exciting branch has been shown with exciting reactance only with one-half of the total magnetizing reactance assigned to each rotor. If the forward rotor operates at a slip S, then the backward rotor has a slip of (2-S). The complete parameters of equivalent circuit can be calculated the following steps.

Measurement of AC resistance of stator main winding:

The DC resistance of main winding of stator i.e, R_{dc} is measured by multimeter. The effective value of resistance is taken 1.3 times R_{dc}.

Magnetising reactance x_m from no Load test:

At no load $\cos\phi_0 = \frac{Wo}{Vo\ X\ Io}$

$$Z_0 = (r_1+\frac{r_2'}{4}) + j(x_1 + \frac{x_m}{2}+\frac{x_2'}{2})$$

Parameters from No Load and Blocked rotor tests:

No load Test:

Rated Voltage =220V .

Current I_0 = 5.15 A

Power W_0 =220W

Blocked Rotor Test:

V_{sc}= 6.8V

L_{sc}= 7.6A

W_{sc}= 360W

Main Winding Resistance R_1 =2.6x1.5 = 3.9 Ω.

Starting Winding= 9.9 Ω.

Calculations:

$W_{sc} = I_{sc}^2(R_1+R_2')$

$360= (7.6)^2 (3.9 + R_2')$

R_2'=2.33 Ω

$\cos P_{sc} = \frac{360}{70X7.6} = 0.676$

$P_{sc} = 47.5^0$

determining $(X_1 + X_2')$

$$\cos P_{sc} = \frac{R_1+R_2'}{\sqrt{(R_1+R_2')^2+(X_1+X_2')^2}}$$

$$0.676= \frac{(3.9+3.33)}{\sqrt{(3.9+3.33)^2+(X_1+X_2')^2}}$$

$(X_1 + X_2')$ = 6.79

$X_1 = X_2'$= 6.79/2 = 3.395 Ω.

$Z_e= \frac{Vsc}{Isc}$, $R_e = \frac{Wsc}{Isc^2}$

$X_e = \sqrt{Z_e^2 - R_e^2} = X_1 + X_2'$

Moreover X_1 can be taken equal to X_2'

.i.e, $X_1 = X_2' = \frac{X_e}{2}$

Thus, $X_{2f} = X_{2b} = \frac{X_2'}{2}$

Similarly $R_{2f} = R_{2b} = \frac{R_2'}{2}$

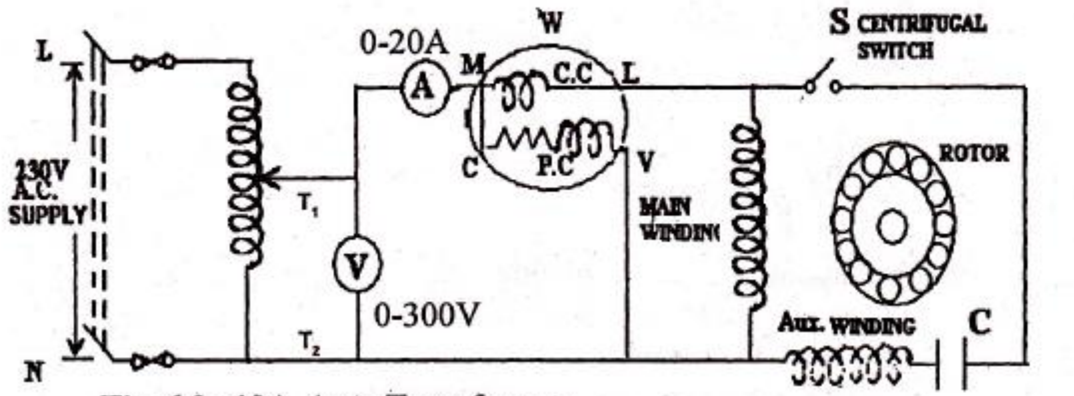


Fig. 6.2 : 10A, Auto Transformer

Calculation for efficiency:

$$(i)\ Z_f = R_f + JX_f = \frac{J.\frac{X_m}{2}\left[\frac{R_2^1}{2S} + J\frac{X_2^1}{2}\right]}{\frac{R_2^1}{2S} + \left[\frac{X_2^1}{2} + \frac{X_m}{2}\right]} = ...ohms$$

where Z_f = Forward Impedance

$$(ii)\ Z_b = R_b + JX_b = \frac{J.\frac{X_m}{2}\left[\frac{R_2^1}{2(2-S)} + J\frac{X_2^1}{2}\right]}{\frac{R_2^1}{2(2-S)} + \left[J\frac{X_2^1}{2} + \frac{X_m}{2}\right]} = ...ohms$$

where Z_b – backward Impedance

(iii) $Z_T = Z_f + Z_b + Z_1\ [\text{where } Z_1 = R_1 + JX_1] = ...ohms$

(vi) Current drawn by the motor at above slip = I_1 = V/Zt = ………….Amps

(v) $\text{Cos P} = \frac{R_1}{Z_1}$

(vi) Voltage across forward rotor = $E_f = I_1 \times Z_f$ = ……….Volts

$$(vii)\ \text{Impedance of the rotor} = Z_3 = \left[\left(\frac{R_2^1}{2s}\right)^2 + \left(\frac{X_2^1}{2}\right)^2\right]^{1/2} = \text{ohms}$$

$$I_3 = \frac{E_f}{Z_4} = ...\text{Amps}$$

$$\tau = I_3^2\left[\frac{R_2^1}{2s}\right] \text{in syn - watts}$$

(viii) Voltage across the backward rotor = E_b = **$I_1 \times Z_b$ = ………….V**

$$Z_5 = \left[\left(\frac{R_2^1}{2(2-s)}\right)^2 + \left(\frac{X_2^1}{2}\right)^2\right]^{1/2} = ...\text{volts}$$

$$I_s = \frac{E_b}{2s}; \tau_b = I_2^2\left[\frac{R_2^1}{2(2-s)}\right] = \text{Syn-watts}$$

(ix) Net Torque $(\tau = \tau_f - \tau_b$ Syn-watts.

$$\text{Mechanical output} = P_m = \frac{2\pi N\tau}{60}$$

$$\text{percent } \eta = \left(\frac{P_m}{VI\cos\phi}\right)X100.$$

No-Load Test:

$$\cos\phi_0 = \frac{W_0}{V_0 I_0} = \frac{200}{216X4.5} = 0.205$$

$$\cos\phi_0 = \frac{R_1 + R_2^1}{\sqrt{(R_1 + \frac{R_2^1}{4})^2 + (X_1 + \frac{X_m}{4} + \frac{X_2^1}{4})^2}}$$

$$0.205 = \frac{3.9 + 3.33}{\sqrt{(3.9 + \frac{3.33}{4})^2 + (3.39 + \frac{3.39}{4} + \frac{X_m}{2})^2}}$$

$X_m = 49.94\ \Omega$

Calculation:

Let S = 0.01

Total $Z_t = Z_1 + Z_f + Z_b$

$I_f = V/Z_t$

$Z_1 = R_1 + jX_1 = 3.9 + j3.99\ \Omega$

$$Z_b = \left(\frac{R_2^1}{2(2-S)} + j\frac{X_2^1}{2}\right) \Big\| \ j\frac{X_M}{2}$$

$$= \left(\frac{2.23}{2(2-S)} + j\frac{3.39}{2}\right) \Big\| \ j\frac{49.94}{2}$$

$$= 1.67\angle 72.9^0\ \Omega$$

$$Z_t = 3.9 + j3.39 + 5.1 + j23.81 + 0.49 + j1.6$$

$$= 9.49 + j28.8 = 30.32\angle 71.8^0\Omega$$

$$I_t = \frac{216}{Z_t} = \frac{9.49}{30.32} = 0.313A$$

Using current division

$$I_3 = I_1 \frac{j\frac{X_m}{2}}{j\frac{X_m}{2} + \frac{R_2^1}{2S} + j\frac{X_2^1}{2}} = 1.49\angle 5.3$$

$$\rightarrow I_s = \frac{I_1 \times j\frac{X_m}{2}}{j\frac{X_m}{2} + \frac{R_2^1}{2(2-3)} + j\frac{X_2^1}{2}} = 6.67\angle -70.5^0 A$$

Therefore Forward Torque

$$T_f = I_3^2 \frac{\frac{R_2^1}{2s}}{\frac{2\Pi N}{60}} = 1.734\ \text{N-mt}$$

Backward Torque

$$T_b = I_3^2 \frac{\frac{R_2^1}{2(2-S)}}{\frac{2\Pi N}{60}}$$

Net torque $T = T_f - T_b$

Mechanical output $P_m = \frac{2\Pi NT}{60}$

Percent $\eta = \frac{P_m}{VI_1 \cos\phi} \times 100$

Circuit Diagram:

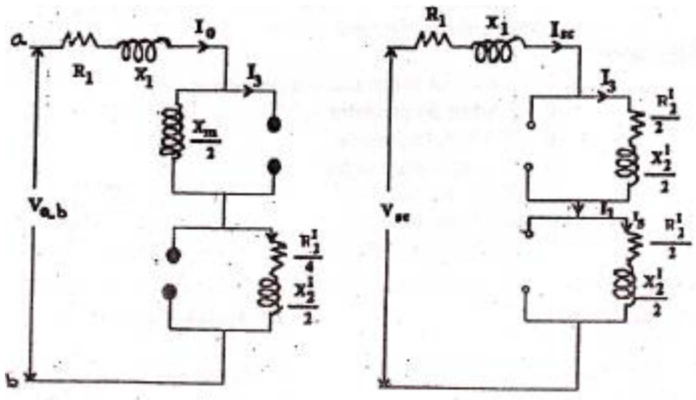


Fig. 6.3 : Equivalent circuits for no-load and blocked rotor

Procedure:

* Connect the circuit as shown in the circuit diagram for O.C test.
* Keep the auto transformer at zero position.
* Increase the voltage slowly to the rated voltage.
* Record the no-load current, voltage, power consumed and speed.
* Switch off the supply and bring back the auto-transformer zero position.
* Connect the circuit as shown in the circuit diagram of blocked rotor test.
* Increase the voltage slowly till the current in the main winding is equal to 7.64A.
* Record the load current voltage and power consumed.

Conclusion:

Equivalent circuit of a 1- ϕ Induction motor is obtained and performance is predicted.

Experiment-7
SLIPTEST

Objective:

To determine the X_d & X_q of the salient pole type Synchronous Machine.

Apparatus:

3 - ϕ, 16 amps auto - transformer	- 01
0 - 2 Amps dc ammeter	- 01
0 - 300 V dc voltmeter	- 01
0 - 20 Amps ammeter	- 01
0 – 300 V ac voltmeter	- 01
0 - 600 V ac voltmeter	- 01
0 - 2000 rpm tachometer	- 01

Motor Ratings:

DC Motor	**AC Generator**
P = 5.2KW	KVA=5
N = 1500 rpm	N = 1500 rpm
V=180V	V=415V
I = 3.4A	I=7A
Winding = shunt	" Y" connected
Excitation Voltage = 180 V	Excitation voltage = 180 V
Current = 1.5 A	Current =1.8A
	p.f=0.8, f=50Hz

Theory:

Direct axis synchronous reactance, X_d :

Direct axis synchronous reactance ofsynchronous machine in per unit is equal to the ratio of field current, I_{fsc} at rated armature current from the short circuit test, to the field current , I_{fo} at the rated voltage from open circuit test. Therefore direc t axis synchronous reactance is given by,

$$X_d = I_{fsc} / I_{fo} \text{ per unit}$$

Thus X_d can be determined by performing o.c & s.c test on an alternator.

Quadrature axis synchronous reactance, X_q:

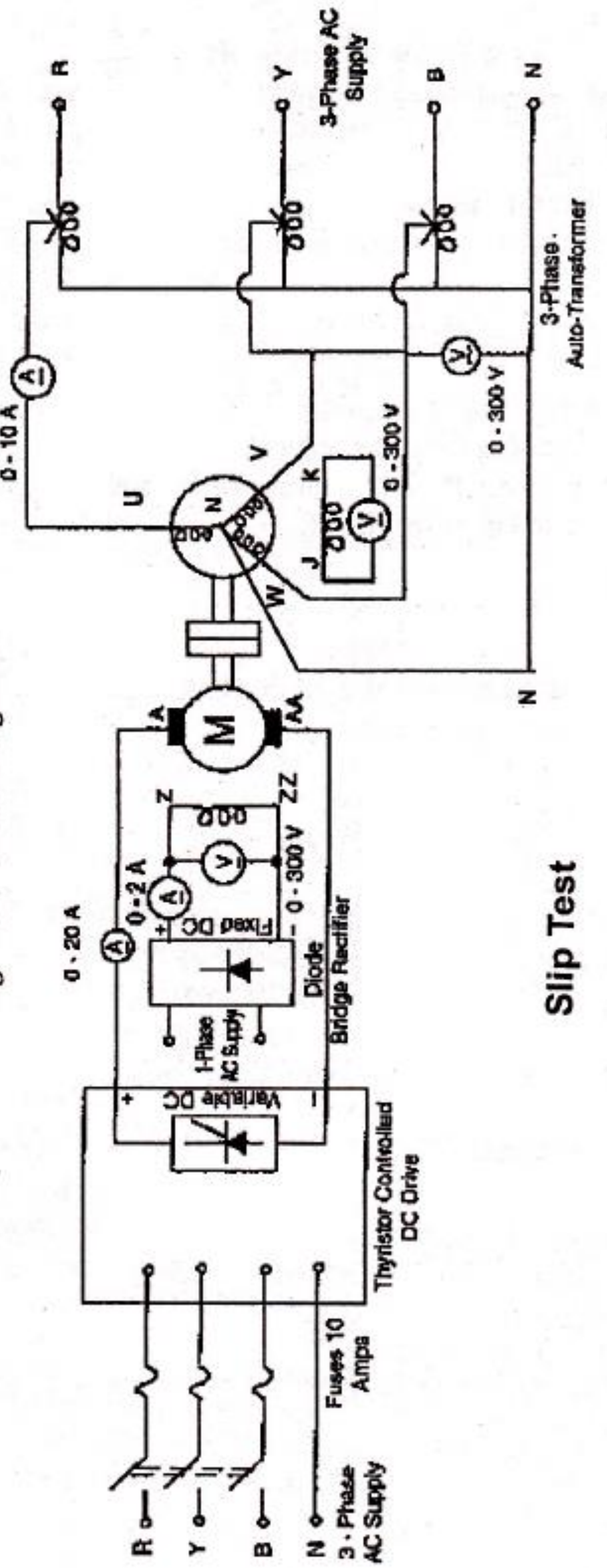
For slip test, the machine should be driven at a speed, slightly less than synchronous speed, with its field circuit open. Three phase balanced reduced voltage at rated frequency is applied to the armature terminals of the alternator. This voltage is to be adjusted so that the current drawn the stator winding is full load current , under these conditions of operation , the variation of current drawn by the stator winding and no voltage across the field winding. These wave forms clearly indicate that these are changing between minimum and maximum values. When the crest of the stator mmf wave Coincides with the direct axis of the rotating field, the induced emf in the open field is zero, the voltage across the stator terminals is maximum and the current drawn by the stator winding is minimum. Thus the approximate value of the direct-axis synchronous reactance X_{ds} is given by

$$X_{ds} = E_{max}/I_{min}$$

When the crest of the stator mmf wave coincides with the quadrature axis of the rotating field, the induced emf in the open circuit field is maximum, voltage across the stator terminals is minimum and current drawn by the stator winding is maximum.

$$X_{qs} = E_{min}/I_{max}$$

Fig. 7.1 : Circuit Diagram:



Slip Test

The most accurate value of quadrature axis synchronous reactance X_q is given by

$$X_q = \left(\frac{X_{qs}}{X_{ds}}\right) \text{ x } X_d$$

$$= \left(\frac{E_{min}}{I_{max}}\right) \text{ x } \left(\frac{I_{min}}{E_{max}}\right) \text{ x } X_d.$$

Where X_d , is measured from OC and SC tests.

Observations:

V_{max} = 327 V $\qquad$ V_{min}= 306V

I_{ph} = 9.67A $\qquad$ $I_{ph(min)}$ = 9.40 A

$X_d = \frac{V_{max}}{I_{min}}$= 34.98 Ω. $\qquad$ $X_q = \frac{V_{min}}{I_{max}}$ = 31.64 Ω.

Procedure:

- Connect the circuit as shown in the circuit diagram.\
- Set the DC drive potentiometer, 3 - Phase auto - transformer at zero position and DC motor field auto - transformer at the maximum position as marked on the panel.
- Switch on the supply and set the dc motor field auto transformer such that the field current is 1.2 Amps.
- Slowly increase the motor till it reaches slightly above or below the synchronous speed by potentiometers.
- Adjust the 3-phase auto - transformer till the alternator phase current reaches 7.0 amps.
- Record the minimum and maximum values of the induced AC voltage across the field of the alternator and also min. and max. Phase currents of the alternator.
- Switch off the supply and set the potentiometers and 3-phase auto- transformer at zero position.

Conclusions:

The values of X_d and X_q of salient pole machine are determined from slip test.

Experiment-8

0. C and S.C. Test of a 3-phase Alternator

Objective:

To pre determine the regulation of an alternator at full load at different power factors using synchronous impedance and MMF methods.

Apparatus:

0 - 300 V dc Voltmeter - 01
0 - 10 amps dc Ammeter - 01
0 - 2 amps dc Ammeter - 02
0 - 300 V ac Voltmeter - 0l
0 - 10 amps ac Ammeter - 0l
0 - 2000 rpm Tachometer - 01

Motor Ratings:

DC Motor

Voltage: 220V
Current: 19 Amps
Power: 3.7 KW

Alternator

Voltage: 415 V
current: 5 Amps
Power: 3.5 KVA
Speed: 1500 rpm

Theory:

Voltage Regulation:

The voltage regulation of an alternator is defined as " the rise in voltage from full-load to no-load and (field excitation and speed remaining the same) divided by the rated terminal voltage".

Percent regulation 'up'= $\frac{E_0 - V}{V}$ X 100.

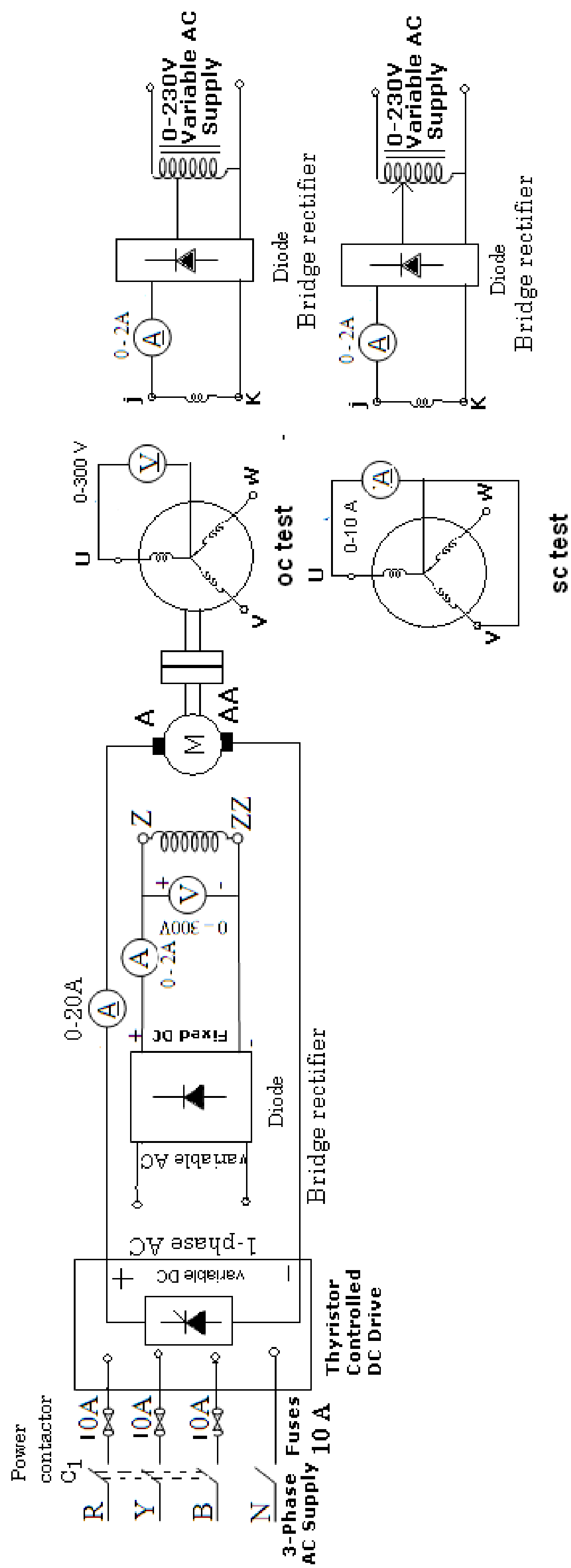
Where E_0 and V are respectively the no Load voltage and full load voltage.

Regulation of an alternator by synchronous impedance method:

R_a per Phase: It is obtained from direct voltmeter and ammeter method by applying DC supply or by using multimeter to the stator winding. The effective value of R_a is increased due to skin effect,

R_a=1.3 x R_a(DC)

O.C.C: O.C.C is plotted from the given data as shown in Fig8.1 as in D.C Machines, this is plotted by running the machine on no-load and by noting the values of induced voltage and field excitation current. It is just like a B-H curve.


0-230V
Variable AC
Supply
Diode
Bridge rectifier
0-2A
j
K
0-300 V
U
V
W
oc test
0-10 A
sc test
A
AA
M
Z
ZZ
0-300V
0-2A
0-20A
Fixed DC
variable AC
1-phase AC
variable DC
Thyristor
Controlled
DC Drive
Power
contactor
C_1
10A
R
Y
B
N
Fuses
10 A
3-Phase
AC Supply

S.C.C: S.C.C is drawn from the data given by the short-circuit test as shown in Fig.

It is obtained by short circuiting the armature (i.e. Stator) windings through a low resistance ammeter. The excitation is so adjusted as to give the rated full load current. Both these curves are drawn on a common field - current base. At rated field current I, of the alternator, draw a horizontal line which intersects the S.C.C. at a point. Now draw a perpendicular on to the X - axis from this point which gives the necessary field current for O.C. voltage E_1 . It may be assumed that the whole of this voltage E_1 is being used to circulate the armature short circuit current I_1 against the synchronous impedance Z_s.

$$\therefore Z_s = \frac{E_{1(oc)}}{I_{1(sc)}}$$

$$E_1 = I_1 Z_s$$

Since R_a can be found as discussed earlier, the synchronous reactance X_s is given by

$$X_s = (Z_s^2 - R_a^2)$$

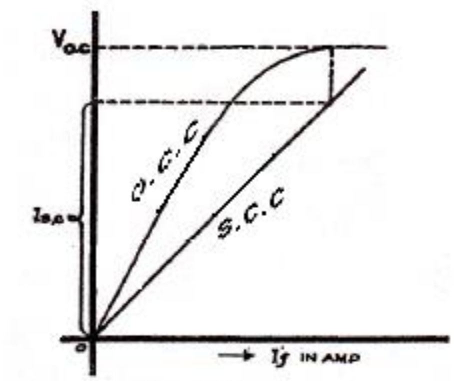
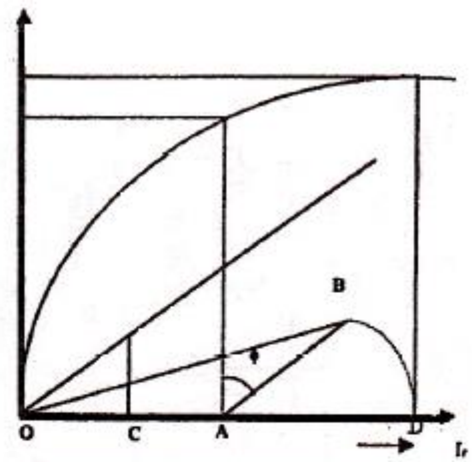


Fig. 8.2



Characteristics for MMF method

Fig. 8.3

0. C. and S.C characteristics of alternator

Knowing R_a and X_s Phasor diagram can be drawn for any load.

No load voltage E_0 is given by

$$E_0 = ((v\cos\phi + IR_a)^2 + (V\sin\phi \pm IX_s)^2)^{0.5}$$

When V is the rated terminal voltage per phase and I is rated load current

Per phase cosϕ is power factor.

Regulation by mmf method: This method also utilizes o.c. and S.C. test data and the armature leakage reactance is treated as an additional armature reaction. In other words it is assumed that the change in the terminal potential difference on load is due to entirely armature reaction and due to ohmic resistance drop which in most cases is negligible.

Now field AT required to produce a voltage of V on full load is the vector sum of the following.

- Field AT required to produce a voltage of V (or R_a is to be taken into account, then $V+IR_a \cos\phi$) on no load.
- Field AT required overcoming the demagnetizing effect of armature reaction on full load. This value is found from SC test. In other-words the demagnetizing armature AT on full load are equal and opposite to the field AT, required to produce a full load current on short circuit.

From the complete diagram of O.C and S.C characteristics, OA represents I_f for normal voltage V. OC represents I_f required for producing full load current on S.C vector AB=OC is drawn at an angle of (90+ϕ) to OA. (If the p.f is lagging and 90-ϕ if pf is leading). The total field current is OB for which the corresponding O.C voltage is E_0.

:. Percentage regulation= $\frac{E_0 - V}{V}$ X 100.

Observation Table:

OC Test

E_{oc}	I_f
83	0.153
102	0.193
133	0.257
156	0.31
184	0.387
201	0.443
222	0.534
230	0.59
240	0.664
250	0.74

Practical Observations:

I_f	E_{oc}

SC Test

V_{sc} = 21 V I_{sc} = 5A I_f = 0.564 A

Calculations:

$Z_s = E_1/I_1$ = 226/5 = 45.2 Ω.

R_a = 8.8 Ω.

$X_s = \sqrt{Z_s^2 - R_a^2}$ = 44.3 Ω.

V= 240 V

$E_0 = \sqrt{(V\cos\emptyset + IR_a)^2 (V\sin\emptyset + IX_s)}$

=443.2 Volts.

% Regulation = $\frac{E_0 - V}{V}$ X 100= 84.3%

Procedure:

- Connect the circuit as shown in the fig. 8.1 for O.C. Test.
- Keep the dc drive potentiometers and auto - transformer of the alternator field at zero position.
- Switch - on the supply and slowly increase, the dc motor speed, (prime mover) to its rated speed.
- After attaining the rated speed, gradually increase the auto -transformer and record the field current and phase voltage of the alternator.
- When the phase voltage is reached to the rated value 230V, switch - off the supply and keep the potentiometers and auto - transformer at zero position.
- Connect the circuit as shown in the circuit diagram for S.C. Test.
- Switch - on the supply and slowly increase the dc motor speed to its rated speed.
- After attaining the rated speed, gradually increase the auto - transformer and record the field current and phase current of the alternator.
- Switch ofsf the supply when the phase current is reached the rated value, (5A).
- Switch - off the supply and keep the potentiometers and auto - transformer back to zero position.

Experiment-9
Hysteresis loss determination

1. Objective

To record the hysteresis loop of the core of an iron cored transformer and to find the hysteresis losses (the power converted to heat due to hysteresis) in the iron core of the transformer.

2. Hysteresis loop of the core of an iron cored transformer:

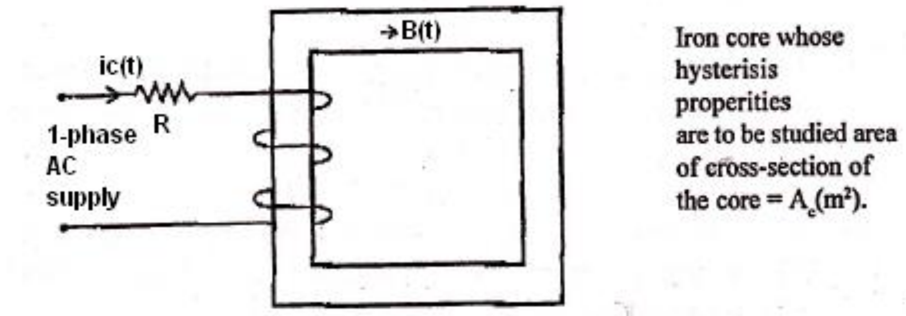


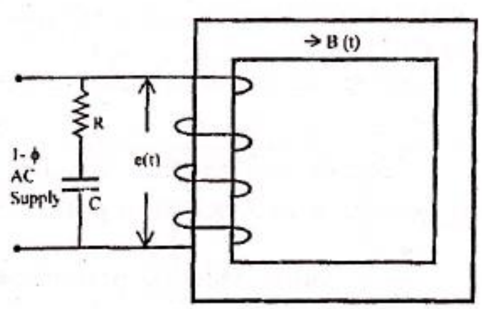
Fig. 9.1

In fig.9.1, the voltage v (t) applied to winding 1 of the transformer equals the induced emf e (t) in the winding (neglecting the winding resistance). But from Faraday's law, e (f) = $[N_{,}A_c]\frac{dB(t)}{dt}$ where B (t) is the flux density in the core. (N_1 is the number of turns of the winding, and Ac the area of cross-section of the core is constants). Hence v (t) = $[N_{,}A_c]\frac{dB(t)}{dt}$ Assuming the flux density to vary sinusoidally with time, let B (t) =B_{max} sin wt. Then v (t) = N_1 A_c B_{max} sin (Ct+TM/2). We see that v (t) is also sinusoidal, at the same frequency as B (t), but leading B (t) by 90^0. If we can correct this phase shift, we can use v (t) as a signal representing B (t).

The current io (t) flowing through the winding 1 produces and mmf of N_i I_0 (t) amp-turns. The corresponding H is N_1 and I_c is the circumferential length of the core. N_i and I_c are constants and so H is proportional to I_0 (t). We can use I_0 (t) as a signal representing H (t).

A plot of B-H where both B and H vary between a positive maximum and a, negative maximum is called the hysteresis loop of the core. We can use v (after correcting the phase shift) to represent B i_0 to represent H. If we give these two signals to a CRO, we can observe the hysteresis loop of the transformer on the screen.

9.2 Obtaining a signal corresponding to B (t) (which lags v (t) by90^0):



$$V = V\angle 0^0$$

$$I = \frac{V}{R} = \frac{V}{R}\angle 0^0$$

$$V_c = I(-jx_c) = \frac{V}{R}X_c\angle -\frac{\Pi}{2}$$

Fig. 9.2

Voltage v (t), which is applied to the winding, is also applied to the resistance R in series with the capacitance c. If the resistance is large compared to the capacitive reactance, the current I through the R-C branch is nearly in phase with the voltage V. V_c, the voltage across the capacitance lags this current, and hence the voltage v, by 90^0. V and V_c are the phasor representations of the instantaneous quantities v (t) and v_c(t), Since V_c lags V by 90^0, V_c(t) also lags v (t) by same amount. Thus, v_c (t), as well as B (t) lags v (t) by 90^0, and so they both are in phaase. We can use v_c (t) to represent B (t).

9.3. Obtaining a signal corresponding to H (t) which is proportional to I_0(t):

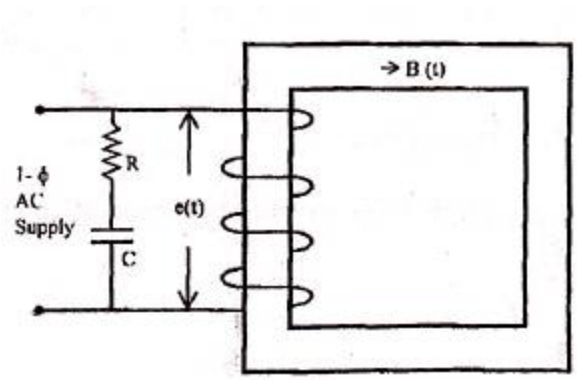


Fig. 9.3

From fig. 9.3, we see that the current i_0(t) flows through R_0. Hence the voltage across R_0 is $i_0(t)R_0$ which is proportional to, and which represents H(t). Note that R_0 is in series with the transformer reduces the voltage across the transformer. Hence, the current i_0(t) reduces. For this change to be small, R_0 must be chosen small-as possible.

9.4. Obtaining the hysteresis losses from the hysteresis loop seen on the CRO:

Consider the circuit of fig-9.4. Mmf=$N_1 i_0$ (t).

$$H(t) = \frac{\text{mmf}}{\text{circumfential length of the core}} = N_1 \frac{i_0\,(t).}{I_c}$$

Signal applied to the X-deflection plates of the CRO = $i_0(t)\,R_0$ volts =H (t) $I_c \frac{R_0}{N_1}$ volts, which is proportional to H (t). With an X-deflection scale of x volts/cm, a given value H_1 of H, corresponds to ($H_1\, I_c \frac{R_0}{N_1} x$) cms on the screen.

Let B (t), the flux density through the core (assumed sinusoidal), be B (t) – B_m sin wt N/A-m. The signal applied to the Y-deflection plates of the, CRO = $v_c(t)$ ϕ volts. The relation between B (t) and v_c (t) can be derived as follows:

$V(t) = N_1 \frac{d}{dt} = N_1\, t \frac{d\{B(t)A_c}{dt}$, {(t) the flux through the core, equals the flux density B (t) multiplied by the area of cross-section of the core A_c}

$\frac{dB(t)}{dt} = B_m$ cost. So, v (t) = $N_1\, A_c\, B_m$cost,

And V= ($N_1\, A_c B_m c/2$) <0^0.

I is in phase with V (approximately) since R is selected to be much larger than X_c.

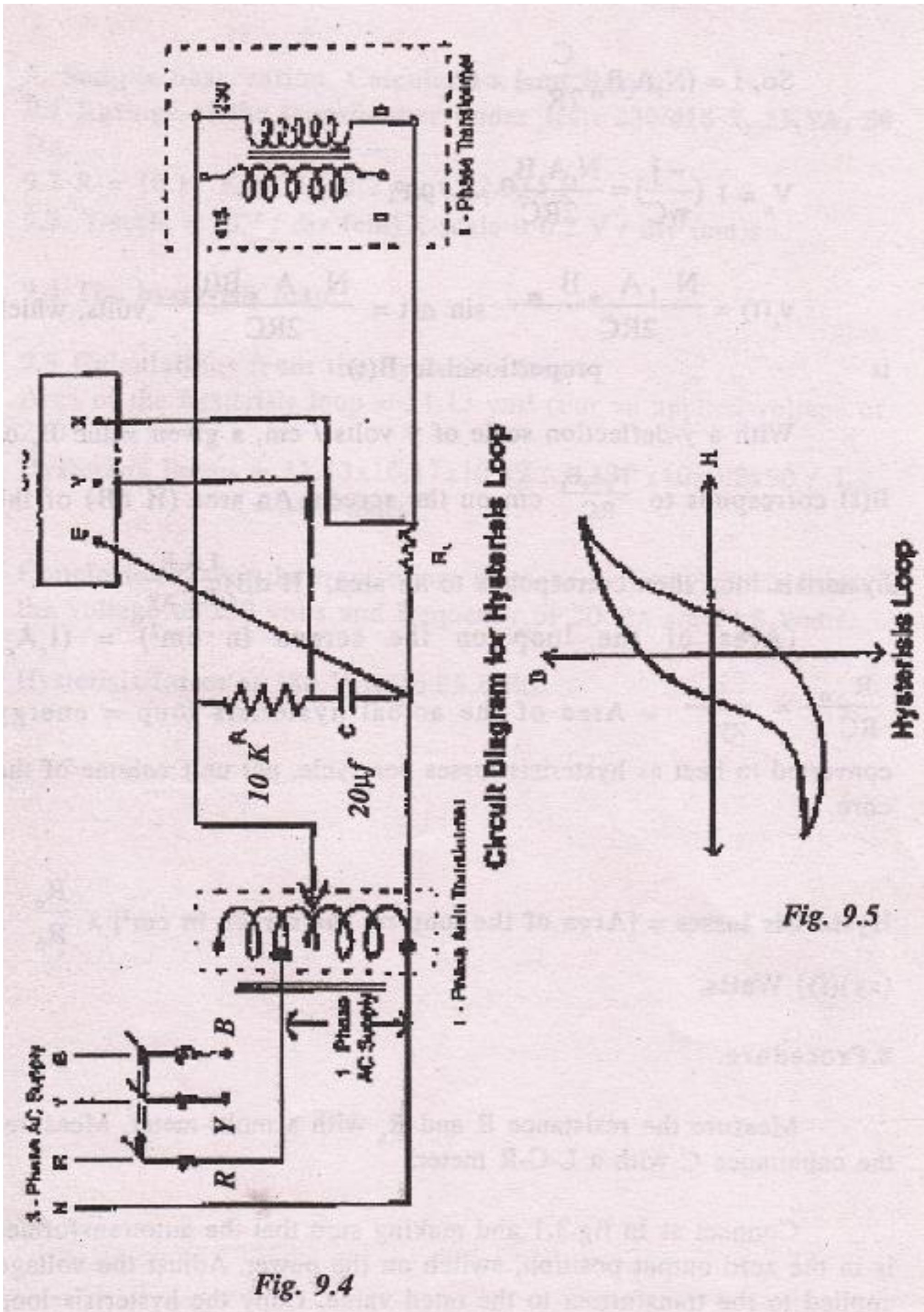

1 - Phase Transformer
10 K
20μf
1 Phase AC Supply
R
Y
B
Circuit Diagram for Hysterisis Loop
Hysterisis Loop
H
B

Fig. 9.4

Fig. 9.5

So, I= $(N_1 A_c B_m \frac{c}{2R}) < 0^0$,

V_c = i $(\frac{-j}{wc}) = \frac{N1\ AcBm}{2RC}$ < $-90^{0.}$

V_C (t) = $\frac{N1\ AcBm}{2RC}$ $\sin\omega t$ = $\frac{N1\ AcBm}{2RC}$ Volts, which is proportional to B (t).

With a y-deflection scale of y volts I cm, a given value B, of $\frac{N1\ AcB1}{RCy}$ cm on the screen. An area (H dB) of the hysteresis loop then corresponds to an area, (H dB) $\frac{Ic\ AcR0}{RCxy}$

(Area of the loop on the screen in cm^2) = $(I_c\ A_c) \frac{Ro}{RC} X \frac{i}{xy}$ = Area of actual hysteresis loop = energy converted to heat as hysteresis losses per cycle, per unit volume of the core.

.

Hysteresis losses = [Area of the loop on the screen in cm²] x$\frac{RC}{Ro}$ (xy) (f)] Watts.

4. Procedure.

Measure the resistance R and Ro with a multi-meter. Measure the capacitance C with an L-C-R meter.

Connect as in fig.3.1 and making sure that the autotransformer is in the zero output position, switch on the power. Adjust the voltage applied to the transformer to the rated value. Copy the hysteresis loop on the screen on a graph sheet. Also note the x-deflection scale and they y-deflection scale.

9. Sample observation, Calculation and Results:

9.1 Ratings of the transformer under test: 230/415 V, 2KVA, 50Hz.

9.2 R = 10.17 KΩ, R_0=1.2Ω, C=2.635µF

9.3. Y-scale=10V/div (cm) X-scale=0.2 V/div (cm) s.

9.4 The hysteresis loop:

9.5 Calculations from the hysteresis loop:

Area of the hysteresis loop = 11.13 cm², (For an applied voltage of 230 volts).

Hysteresis losses = $11.13 x 10.I7 x 10^3 x 2.63 x 10^{-6}$ x10x0.2x50 / 1.2

= 24.8 watts.

Conclusions: For the transformer under test, the hysteresis losses at the voltage of 230 volts and frequency of 50 Hz are 24.8 Watts.

Hysteresis losses at 180 V are 16.85 watts.

Experiment-10
SCOTT CONNECTION

Objective:-

To study the Scott Connection of transformers and to verify different types of connections of Three-Phase Transformers.

Apparatus:-

Name Plate Details:-

P=2KVA	V_{HV}= 415V	V_{LV}= 230V
	I_{HV}=4.82A	I_{LV} = 8.696A

Theory:

Scott Connection:-

Three Phases: Consider three lines R, Y and B. let ac voltages V_{RY}, V_{YB} and V_{BR} exist between these lines. These three voltages constitute a set of three-phase line voltages. If the magnitudes of three Voltage phasor are the same, and if there is a phase angle of 120^0 between any pair of voltages, then the set of voltages constitute a three-phase balanced set.

Two-phases: consider 4 lines I, 2, 3 and4 as in the fig.10. Let ac voltages V_{12} and V_{34} exist between lines I and 2, and lines 3 and 4 respectively. V_{12} and V_{34} constitute a set of two phase voltages.

If the magnitudes of the two voltage phasor are the same, and if there is a phase difference of 90^0 between them they constitute a two-phase balanced set. Suppose lines 2 and3 are joined. Then the Voltage between I and 4 is the sum of the voltages V_{12}, & V_{34}. If the two-phase supply is balanced, these voltages are equal in magnitude and 90^0 out of phase. So their sum has a magnitude 1.414 times the magnitude of the individual voltages. This is one means of checking a two-phase balanced supply. Another way is to observe the wave forms in the CRO.

Conversion:

We can convert three-Phase to two phases and vice-versa using two transformers .We can show two-phase voltages between lines I and 2, and lines 3 and 4, we will get balanced three phase voltages between R,Y and B.

Stare-Star Connection: This test is most economical for small high voltage transformer because the no of turns per phase and the amount of insulation required is minimum. The ratio of line voltages on the primary and secondary sides is same as the transformation ratio of each transformer. Angular displacement between primary and secondary voltages is zero. By stabilizing primary neutral we can avoid distortion in the secondary phase voltages. This connection works satisfactorily only if the load is balanced. As the frequency of this component is thrice the frequency of the circuit, at any given it tends to flow either towards or away from the neutral point in all the three transformers. The advantage of this connection is that insulation is stressed only to the extent of line to neutral voltage i.e 58% of the line voltage.

Delta-Delta connection: This connection is economical for large, low-voltage transformer in which insulation problem is not so urgent, because it increases the number of turns/phase. The ratio of transformation between primary and secondary line voltage is exactly the same as that of each transformer. No difficulty is experienced from unbalanced load as the case ofY-Y connection. The three phase voltages remain practically constant regard less of load imbalance. An advantage of this connection is that one transformer becomes disabled; the system can continue to operate in open-delta or in V-V although with reduced available capacity. The reduced capacity is 58% and not 66.7% of the normal value.

Star-Delta Connection: The main use of this connection is at the sub-station end of the transmission line where the voltage is star connected with grounded neutral. The ratio between the secondary and primary line voltage is 1/3 times the, transformation ratio of each transformer. There are 30^0 shifts between the primary and secondary line voltages which mean that a Y-Y transformer bank cannot be paralleled with either Y-Y or a Delta-Delta bank. Also, third harmonic currents flow in the Delta to provide a sinusoidal flux.

Delta - Star connection: This connection is generally employed where it is necessary to step up the voltages. The neutral of the secondary is grounded for providing 3-phase 4-wire service. In recent years, this connection has gained considerable popularity because it can be used to serve both the 3-phase power equipment and single phase lightening circuits. The ratio of primary of secondary is 1/3 times the transformation ratio of each transformer.

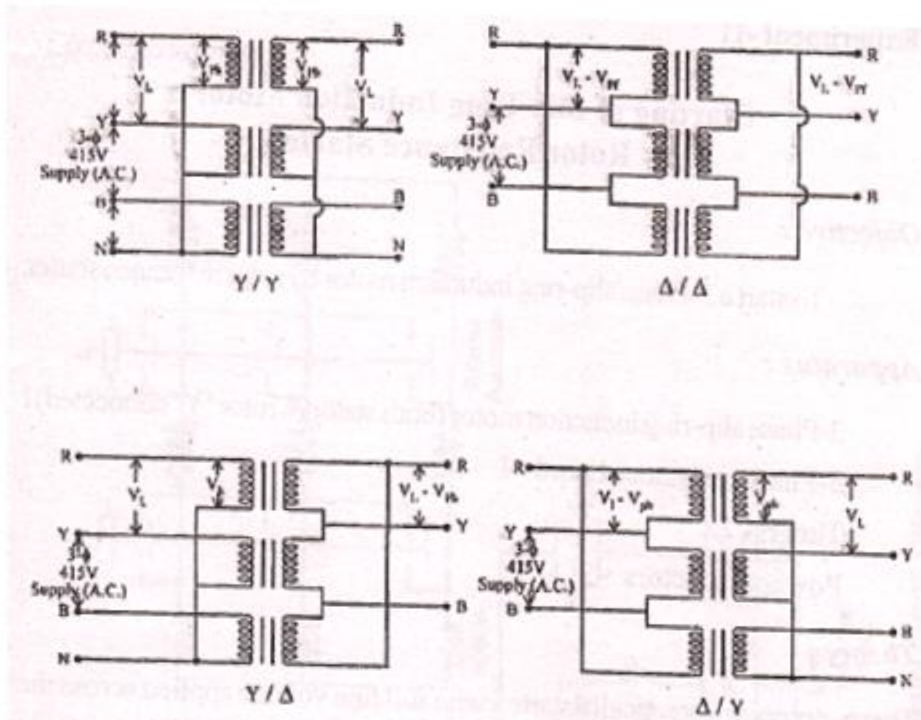
Procedure:

- Make the connections as shown in the circuit diagram.
- Measure the following voltages; V_{RY}, V_{YB}, V_{BR}, V_{12} and $V_{34.}$
- Instead of connecting the line R at the 86-6% point on the transformer T_1, connect it at the 415V point, the rest of the connections being the same V_{12} and V_{34} are unequal.

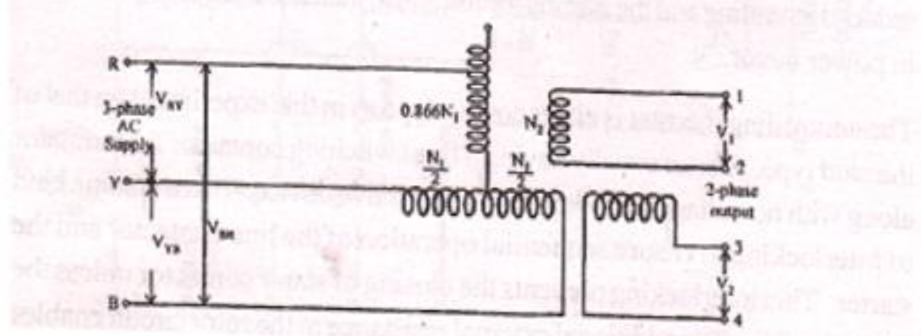
Star-star connection

Primary side	**secondary side**
V_{RY} =374V	V_{RY}= V_{YB}= V_{BR} =203V
V_{YB} = 374V	
V_{BR}= 374V	
Delta to Delta	**Star to Delta**
V_{RY}= V_{YB}= V_{BR} =368V	V_{RY}= V_{YB}= V_{BR} =368V
V_{RY}= V_{YB}= V_{BR} =203V	V_{RY}= V_{YB}= V_{BR} =117V
Delta to Star	**Scott Connection**
V_{RY}= V_{YB}= V_{BR} =368V	V_{RY}= V_{YB}= V_{BR} =368V
V_{RY}= V_{YB}= V_{BR} =356V	V_1= V_2=210V

Circuit Diagram:



Circuit Diagram for Scott Connection



Conclusion:

The voltages for different types of three phase transformers and Scott connection are verified.

Experiment-11

Starting of Slip-Ring Induction Motor by Rotor Resistance Starter

Objective:

To start a 3-Phase slip ring induction motor by rotor resistance starter.

Apparatus:

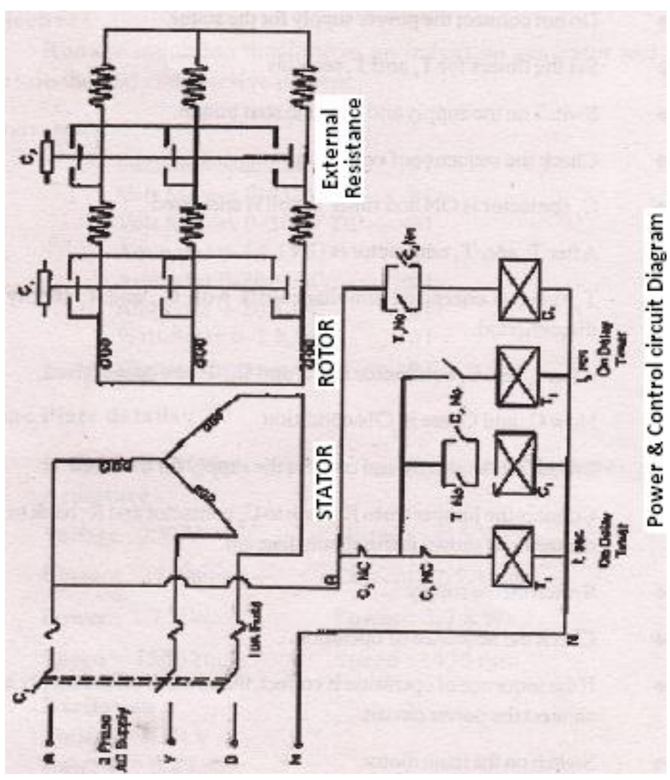
3-Phase slip-ring induction motor (both stator & rotor 'Y' connected) 1
3-Phase resistance board - 1
Timers-2
Power contactors - 3.

Theory:

These motors are practically started with full line voltage applied across the stator terminals. Starting current is adjusted by introducing a variable resistance or rheostat in the rotor circuit. The rheostat connected in star & the resistance being gradually cut out of the rotor circuit equally in each phase as motor picks up the speed. By increasing the rotor resistance, is the rotor current is reduced at starting and the starting torque is also increased due to improvement in power factor.

The controlling rheostat is either contact type as in this experiment on that of the stud type. Starter usually having a line switching contactor for the stator along with no voltage and order current protective device. There is some kind of interlocking to ensure sequential operation of the line contactor and the starter. This interlocking prevents the closing of stator contactor unless the starter is all in. The additional external resistance in the rotor circuit enables a slip ring motor to develop a high starting torque with moderate starting current. Additional resistance cuts as the motor gains speed

Circuit Diagram:



Procedure for rotor resistance starter:

* Connect the circuit as shown in the control circuit diagram fig.
* Do not connect the power supply for the stator
* Set the timers for T_1 and T_2 seconds
* Switch on the supply and push the start button.
* Check the sequence of operation
* C_1 contactor is ON and timer T_2 coil is energized
* After T_1 sec. T_2 contactor is ON
* T_2 timer is energized simultaneously with C_2 and T_1 supply is disconnected.
* After t_2 sec, C_3 contractor is ON and C_2 ,T_2 are de-energized.
* Now C_1 and C_2 are in ON condition.
* Switch off the supply and connect the supply for the stator
* Connect the jumper from R_1 bank to C_2 contactor and R_2 bank to C_3 contactor as shown in the circuit diagram.
* Switch on the supply.
* Check the sequence of operation.
* If the sequence of operation is correct, then switch off the supply and connect the Power circuit.
* Switch on the main motor.

Conclusions:

By connecting the control circuit the rotor resistance of starting method on a 3-Phase slip - ring induction motor can be performed.

Experiment-12
Induction Generator

Objective:
Run the induction machine as an induction generator and measure the real and reactive powers.

Apparatus:

Induction Machine	01
Volt Meters 0-750V AC	01
Volt Meters 0-300V DC	01
Ammeter 0-2A DC	01
Ammeter 0-204. AC	01
Ammeter 0-204 DC	01
Wattmeter 0-3 KW	01
Digital Tachometer	01

Name Plate details:

D.C. Shunt Motor	Induction Machine
Armature:	
Voltage: 220V	Voltage: 415 V
Current: 21 Amps	Current: 7.5 Amps
Power: 3.7 KVI	Power: 3.7 KW
Speed: 1500 rmp	Speed: 1430 rpm
Excitation:	
Voltage: 180 V	
Current: 0.85 A	

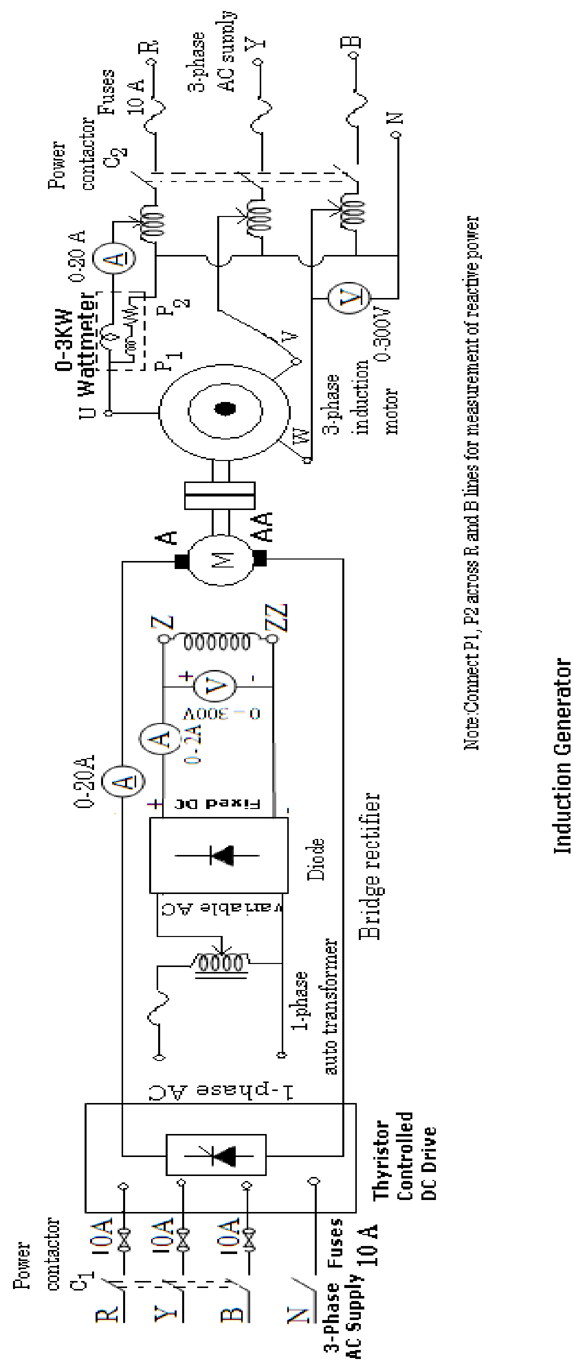
Theory:
An Induction motor runs at a speed less than the synchronous speed when it is connected to a constant voltage at constant frequency. If the rotor is driven by another machine at synchronous speed in the same direction of its rotation, the relative speed between the flux and the rotor becomes zero, hence the rotor emf, current and torque produced by the motor becomes zero. If the rotor is driven above the synchronous speed, the slip becomes negative. The direction of rotor emf, current is reversed, hence the stator component I_2 , sign changes i.e. the mechanical power and torque becomes negative. Therefore, at super synchronous speeds the rotor does not supply the mechanical power, to the shaft but absorbs mechanical power from the shaft. Consequently, the machine operates as an induction Generator drawing its excitation current from the supply mains. Hence, considerable amount of lagging KVAR is supplied from the mains. The equivalent circuit and all characteristic equations of the induction Motor is also applied to the induction generator with a negative sign for the slip.

Since, the induction generator run at super synchronous speeds, they are also called asynchronous generators.

Procedure:
* Connect the DC motor circuit as shown in the figure.
* Keep the course & fine potentiometers of the drive at zero position.
* Keep the field control auto-transformer at maximum position.
* Switch on the supply and adjust the field current to the rated value.
* Gradually raise the armature supply and observe the D.C. motor rotation.
* Switch off the supply and disconnect the connections for the motor.
* Connect the circuit of the 3-phase Induction motor as shown in the circuit diagram.

* Switch on the induction motor and observe the direction.
* The direction o the induction motor must be the same as the D.C. motor, if not, change the sequence of the connections.

Circuit Diagram:



* Switch off the supply.

* Connect the circuit as per diagram for the DC motor and induction motor.
* Switch on the dc motor and gradually increase the speed up to 1430 rpm. (Nearer to the rated rpm of the Induction motor).
* Switch on the induction motor and then, increase the dc motor speed above 1500 rpm up to 1600 rpm in steps by field weakening procedure.

(Note: Do not exceed the current ratings of D.C. Motor Induction Motor.)

* Measure the active power and reactive power at super synchronous speed.
* Stop the induction motor followed by the D.C motor.

Sample Observation Table:

S.No.	Speed	DC Motor			Induction Generator		Active Power P_{Ph}	Reactive Power Q_{ph}
		I_f	V_a	I_a	V	I		
1.	1493	1A	159	.65	252	1.18	50	-230
2.	1502	1A	162	4.3	251	1.26	-40	-230
3.	1505	.98A	163	5.6	252	1.5	-50	-240
4.	1512	.98A	165	8.5	252	1.94	-130	-260
5.	1530	.99A	169	12.16	252	3.2	-250	-320

Practical Observations:

S.No	Speed	DC Motor			Induction Generator		Active Power	Reactive Power
		I_f	V_a	I_a	V	I	P_{ph}	Q_{ph}

Conclusions:

The real and reactive power of and induction machine as induction generator is measured.

Experiment-13
Heat Run Test

Objective: To measure the rise in temperature inside the winding of a 3- phase transformer using Heat-Run test.

Apparatus:

Name of the Apparatus	
2KVA, 415/230V transformers	01
0-4 Amps auto-transformer	01
0-300W L.P.F. Wattmeter	01
0-3 KW U.P.F. Wattmeter	01
0-20Amps Ammeters	01
0-750V Voltmeters	01
0-300^0 C Temperature Indicator	01

Procedure:

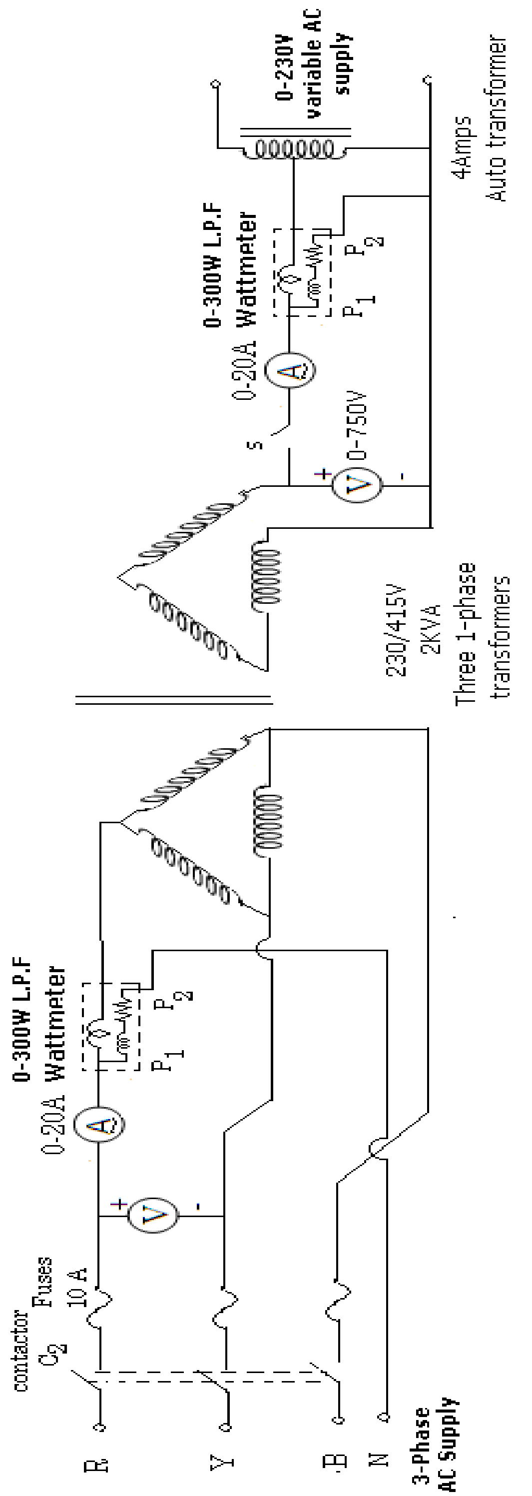
1. Connect the circuit as shown in the figure
2. Connect the voltmeter across R_1 & B_2 on LV Side
3. Keep the switch in the off position.
4. Switch on the 3-phase power supply.
5. Record the Ammeter, Voltmeter readings on the primary side and observe the reading on the secondary side, which is connected between R_1 & B_2.
6. If the voltmeter indicates high value then conduct the polarity test and connect them as per the dot convention.
7. If this voltmeter indicates zero, then switch ON S_{w1} and slowly increase the auto transformer till the ammeter indicates the rated current of the secondary winding 8.2 Amps.

Theory:

Heat-Run test on a 3-phase transformer is similar to the sumpner's test conducted on two single phase transformers. In this test the LV Winding is excited at normal voltage and frequency. The wattmeter indicates the core losses in one limb. (Since only one wattmeter is used for power measurement. If 2-wattmeter method is used then the total core loss is W_1+W_2. The total core loss is obtained by multiplying the above reading with 3. If the voltmeter connected on open-delta side indicates zero if the windings are connected in delta as per the dot convention. Under this condition, voltage is injected on the secondary side using auto transformer till the rated current is reached. The Wattmeter reading on the primary side is unaffected.

The rise in temperature is measured periodically to obtain the thermal equilibrium.

Circuit Diagram:



Heat-run Test

Observation Table (1):

S.No.	Current(A)	Wattmeter Reading(W)	Total corelosses(3xW)
1	8.08	280	840
2	7.0	210	630
3	6.1	160	480

Practical Observations:

S.No.	Current(A)	Wattmeter Reading(W)	Total corelosses(3xW)

Observation Table (2):

S.No.	Time(min)	Temparature(^{0}C)
1	0-15	29.9
2	15-30	38.6
3	30-45	47.6
4	45-60	55.4

Practical Observations:

S.No.	Time(min)	Temparature(^{0}C)

Graph:

Draw the graph between temperatures Vs. Time.

Conclusions: Heat run test is performed on 3-Phase transformers.

Experiment-14
Star - Delta Starter

Objective

Start the induction motor by using star- delta starting method.

Apparatus:

0-20A AC Ammeter	01
0-600V AC Voltmeter	01
Start contactor(Y)	01
On-delay timer (T_1)	01
Main contactor MC	01

Motor Specifications:

Speed	------	1400rpm
Power	------	3.7kw (5hp)
Voltage	------	415V
Current	------	7.9A
Frequency	------	50Hz

Theory:

This method is used in the case of motors which are built to run normally with a delta-connected stator winding. It consists of a two-way switch which connects the motor in star for starting and then in delta for normal running. The usual connections are shown in Figure 30'21. When star-connected, the applied voltage over each motor phase is reduced by a factor of Jf and hence the torque developed becomes 1/3 of that which would have been developed if motor was directly connected in delta. The line current is reduced to 1/3. Hence, during starting period when motor is Y connected,
It takes 1/3rd as much starting current and develops 1/3rd as much torque as would have been developed were it directly connected in delta.

Relation between Starting and F.L. Torques:

I_{st} per phase $= \frac{1}{\sqrt{3}} I_{sc}$ per phase

Where I_{sc} is the current / phase which connected motor would have taken if switched on to the supply directly however, line current at start = l/3 of line current.)

$T_{st}\ KI_{st}^2 \quad (s = 1)$

$T_t\ KI_{f^2/sf}$

$$\frac{\mathrm{Tst}}{\mathrm{Tt}} = \left(\frac{Ist}{If}\right) S_f = \left(\frac{1}{\sqrt{3If}}\right)^3 S_f = \frac{1}{3}\left(\frac{Isc}{If}\right) S_f = \frac{1}{3} K^2 S_f$$

Here I_{st} and I_{sc} represent phase values.

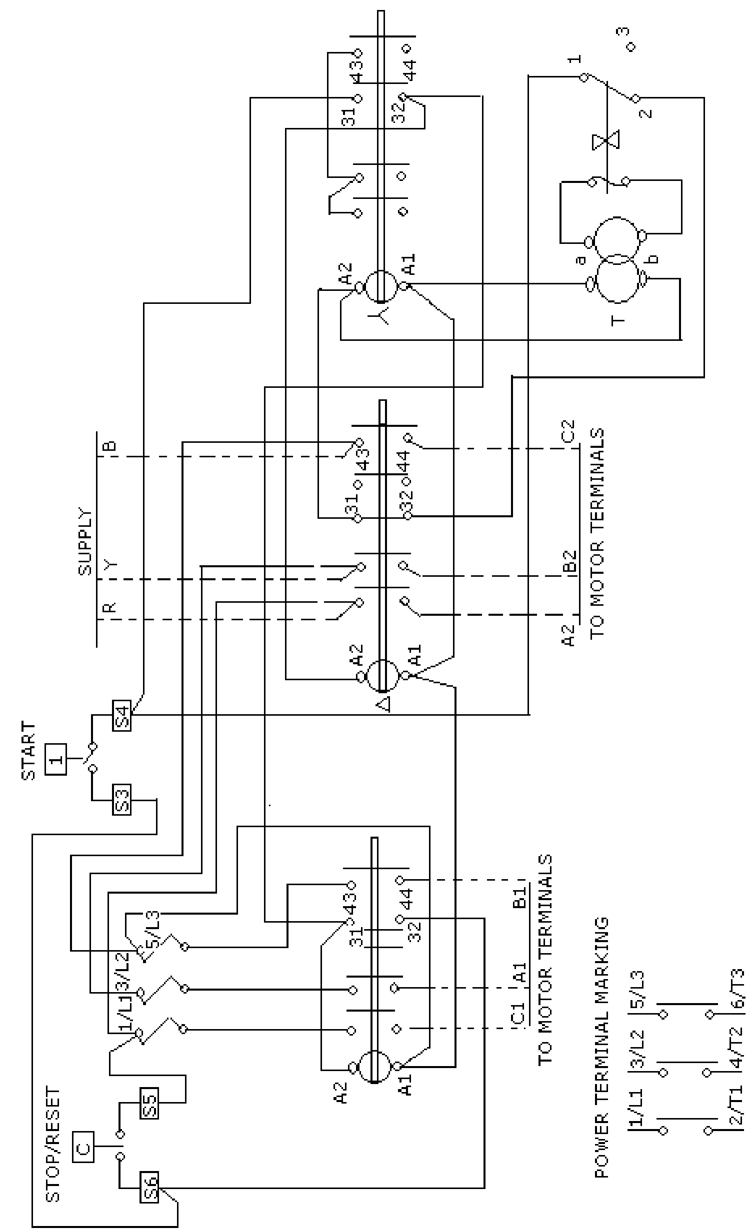
It is clear that the star-delta switch is equivalent on an auto-transformer of ratio l/3 or 58% approximately.

This method is cheap and effective provided the starting torque required being not more than l.5 times the full-load torque. Hence, it is used for machine tools, pumps and motor-generation etc.

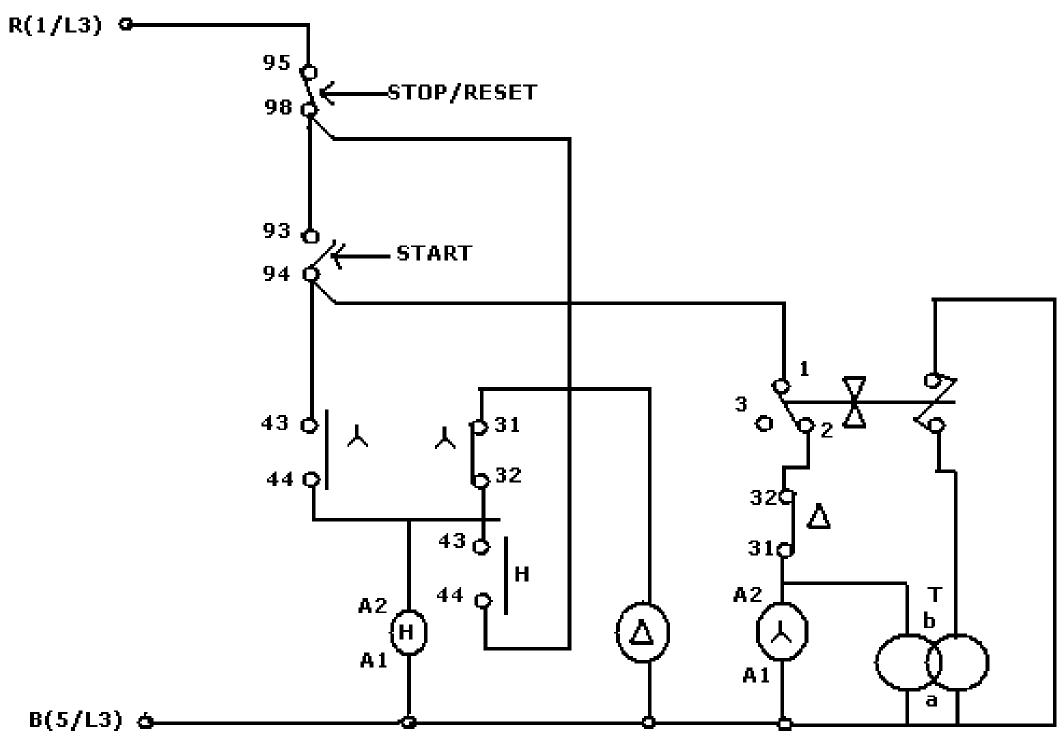
Procedure:

* Make the connections as shown in the circuit diagram.
* Set the timer at the marked position (10 secs).
* Check the three phase supply at the voltmeter.
* check the sequence of the operations of the contactors after switching the start button.
* Connect the power supply terminals R Y B to the M C and delta power terminals RYB on the board.
* Record the no-load current at starting and at rated speed.

Circuit Diagram for Faulty Automatic Star-Delta Starter:



Circuit Diagram for Control Circuit:



Sequence of Operation:

* When start button is pushed:

(a) Y contactor is energized through the path R-Stop-Start-Timer NC-ΔNC -Y Coil-Y Phase

(b) Timer is also energized simultaneously with start contactor is it is connected parallel to it.

(c) When Y is energized Y NO becomes Y NC and YNC becomes Y NO.

(d) MC is energized through the path R-Stop-Star - Y NO.

(e) Mc coil-Y and also 4 is not energized since YNC has becomes YNO.

(f) At this point, MNO becomes MNC.

* When the push button is released the MC and YC are continuously energized and the motor is running is star mode. The path for MC is R-Stop-MNC-M coil-Y path for Y-Contactor -- R-Stop-MNCYNC-TNC- 1NC-Y Coil-Y Phase.

* As per time set on the on-delay timer the time is energized after the set time. Hence TNC becomes TNO.

* When TNC becomes TNO, the supply Y contactor is cut off and hence Y is de-energized and YNC becomes YNO and YNO become YNC i.e., during on start points how in the figure are re-established.

* Now, a contractor is energized through the path -R-Stop-MNC-YNC- Δ Coil-Y Phase.

* Now the motor switches from Y to 6 modes and continues to run.

* When stop button is pushed the supply for MC & 6 are cut off and the motor goes to off condition.

Experiment-15
Determination of Sub-transient Reactance of Salient Pole Synchronous Machine.

Objective:

The objective of this experiment is to determine the sub-transient reactance of salient pole synchronous machine from Standstill Single-Frequency AC Tests.

Name Plate Details:

1. 3-Phase Alternator Salient Pole Type (Rotating Field)
   5kVA, 1500rpm, 415V, 7A, Y connected
   Exc. Voltage: 180V, Current 1.8A, 0.8 p.f., 50 Hz

Apparatus Required:

1.	M.I. Ammeter	5 A	1
2.	M.I. Ammeter	2 A	1
3.	M.I. Voltmeter	100V	1
4.	1- Phase Autotransformer	10 A	1
5.	Wattmeter	300V, 10A, LPF	1

Theory:

Sub-transient reactance is related to behavior of an alternator under transient conditions. In purely inductive closed circuit the total flux linkages cannot change suddenly at the time of any disturbance. Now if all the three phases of an unloaded alternator with normal excitation are suddenly short circuited, then there will be short circuit current flowing in the armature. As the resistance is assumed to be zero this current lag behind the excitation voltage by 90^0 and the mmf produced by this current will be in d- axis and the first conclusion is that , this current will be affected by d axis parameters X_d, X_d' and X_d'' only.

Further there will be demagnetizing effect of this current but as the flux linkages with field can not change the effect of demagnetizing armature mmf must be counter balanced by a proportional increase in the field current, This additional induced component of field current gives rise to greater excitation, under transient state and results in more short circuit current at this time than the steady state short circuit.

If field poles are provided with damper bars, then at the instant of three phase short circuit the demagnetizing armature mmf induces current in damper bars which in turn produces field in the same direction as main field and hence and at this instant the excitation, further increases in short circuit armature current. This is for a very short duration. Normally 5 to 4 cycles and this period is knows as sub-transient period. Since the field voltages are constant, there is no additional voltage to sustain this increased excitation during sub transient period or transient period. Consequently the effect of increased field current decrease with a time constant determined by the field and armature circuit parameter and accordingly the short circuit armature current also decays with the same time constant.

The reactance's offered by the machine during sub transient periods are known as sub transient reactances. In direct axis it is X_d'' and in quadrature axis it is X_q''

The sub-transient reactance X_d'' and X_q'' are associated with fast transients or large frequency. Consequently, at standstill when supplying the stator line from a single-phase ac (at rated frequency) source, the rotor circuits (field winding is short-circuited) experience that frequency. Adjust the rotor position such that the direct axis coincides with the resultant axis of the phases to which ac is given. When this occurs, the induced ac voltage in the field winding for a given ac to the phase becomes maximum. Keep the rotor stationary in this position. Measure ac input voltage and current to the stator phases. Neglecting the phase winding resistance, ratio of voltage applied to the phases and current through it gives the inductive reactance of two phases. For axis q, it is zero.

The voltage, current, and power in the stator are measured, and thus,

$$z''_{d,q} = \frac{E_{ll}}{2I_a} \; ; \; R''_{d,q} = \frac{P_a}{2I_a^2}$$

$$X''_{d,q} = \sqrt{\left(z''_{d,q}\right)^2 - \left(R''_{d,q}\right)^2}$$

Precautions:

1. The auto transformer should be kept at minimum voltage position before switch ON supply.
2. While adjusting rotor position, rotate the machine slowly.

Procedure:

1. Connections are given as per the circuit diagram shown in the figure.
2. Apply a single phase voltage to two phases (of the stator) in series of a stationary star-connected alternator using an auto-transformer.
3. Adjust the rotor position so that the current due to the induced voltage in the short-circuited field winding is maximum.

4. While adjusting the rotor position for maximum field current, see that stator current will not exceed the rated value. If it exceeds reduce the applied voltage to the stator.
5. If field current reaches maximum value note down the readings of input power, stator current and applied voltage and calculate X''_d using the equations given in theory.
6. Now adjust the rotor position so that the current due to the induced voltage in the short-circuited field winding is minimum.
7. If field current reaches minimum value note down the readings of input power, stator current and applied voltage and calculate X''_q using the equations given in theory.
8. Bring the auto transformer to zero voltage position and switch OFF the supply.

Formula Used:

1. Stator impedance $z''_{d,q} = \frac{E_{ll}}{2 I_a}$
2. Stator resistance $R''_{d,q} = \frac{P_a}{2I_a^2}$
3. Sator Sub-transient reactance $X''_{d,q} = \sqrt{(z''_{d,q})^2 - (R''_{d,q})^2}$

Observations:

At maximum field current (I_{fmax}):

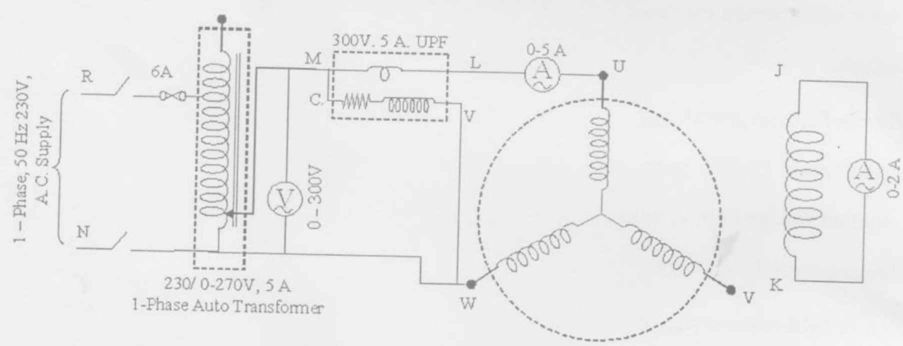
1. Input Power $P_a = W_1$ watts
2. Applied voltage $E_{ll} = V_1$ volts
3. Stator current $I_a = I_1$ amps.

At minimum field current (I_{fmin}):

1. Input Power $P_a = W_2$ watts
2. Applied voltage $E_{ll} = V_2$ volts
3. Stator current $I_a = I_2$ amps.

Calculations:

Circuit Diagram:



Experiment-16
Determination of Sequence Impedances of Salient Pole Synchronous Machine

Objective:

The objective of this experiment is to determine positive, negative and zero sequence impedances of salient pole synchronous machine.

Name Plate Details:

1. D C Shunt Motor
   3.7 kW, 1500 rpm, 220V, 19A
   Winding: Shunt, Exc. Voltage: 220V, Current: 1A
2. 3-Phase Alternator salient pole Rotor Type
   3.5kVA, 1500rpm, 415V, 5A, Y connected
   Exc. Voltage: 180V, Current 1.8A, 0.8 p.f., 50Hz

Apparatus Required:

1.	DC Ammeter	0-20A	1
2.	DC Ammeter	0-2A	1
3.	DC Voltmeter	0-300V	2
4.	AC Ammeter	0-2A	1
5.	AC Ammeter	0-10A	1
6.	AC Voltmeter	300V	1
7.	Wattmeter	110V, 220W, 10A,LPF	1
8.	1-F , Auto Transformer	230/0-270V, 10A	1
9.	1-F , Auto Transformer	230/0-270V, 2A	1
10.	3-F , Auto Transformer	415/0-470V, 10A	1
11.	Tachometer	0-2000rpm	1

Theory:

The positive sequence impedance of equipment is the impedance offered by the equipment to the flow of positive sequence currents. Similarly, the negative or zero sequence impedance of the equipment is the impedance offered by the equipment to the flow of corresponding sequence current. In a symmetrical rotating machine the impedances met by armature currents of a given sequence are equal in the three phases. Since by the definition of inductance, which forms a part of impedance, is the flux linkages per ampere, it will depend on the phase order of the sequence current relative to the direction of rotation of the rotor; positive, negative and zero sequence impedances are unequal in general case.

Positive Sequence Impedance:

Since a synchronous machine is designed with symmetrical windings, it ,induces emf's of positive sequence only, when the machine carries positive sequence currents only, this mode of operation is the balanced mode. The armature reaction field caused by positive sequence currents rotates at synchronous speed in the same direction as the rotor, i.e., it is stationary with respect to field excitation. The impedance offered under steady state condition is known as the synchronous impedance or positive sequence impedance and it can be measured by slip test for a salient pole synchronous machine.

Negative Sequence Impedance

Synchronous machine has zero negative sequence induced voltages. With the flow of negative sequence currents in the stator a rotating field is created which rotates in the opposite direction to that of the positive sequence field and, therefore, at double synchronous speed with respect to rotor. Currents at double the stator frequency are therefore induced in rotor field and damper winding. In sweeping over the rotor surface, the negative sequence mmf is alternately presented with reluctance. The machine is driven by the prime mover at its rated synchronous speed and a reduced voltage is applied with the field winding short circuited. The ratio of V/ph and Ia/ph gives negative sequence impedance Z_2 /ph. The negative sequence impedance presented by the machine is given by

Zero Sequence Impedance

We state once again that no zero sequence voltages are induced in a synchronous machine. The flow of zero sequence currents creates three mmfs which are in time phase but are distributed in space phase by 120^0. The resultant air gap field caused by zero sequence currents is therefore zero. Hence, the rotor windings present leakage reactance only to the flow of zero sequence currents. The zero sequence impedance may be determined by connecting the armature windings of the three phases in parallel and then connecting them to the single phase source of power. If the machine is driven at synchronous speed with field winding shorted, then zero sequence impedance Z_0 =3V/I. If windings are connected in series, then Z_0 = V/3I.

Procedure:

(A) For Positive Sequence Impedance:

1. Connections are given as per the circuit diagram shown in figure 1.
2. Switch on the supply by pushing START button.

3. Vary the 1-F auto transformer connected to the armature of the DC motor through diode bridge rectifier till it reaches synchronous speed of the synchronous machine.
4. Now adjust the 3-phase autotransformer, and apply 20% to 30% of the rated voltage to the armature of the synchronous machine.
5. Make sure that the direction of rotation of the prime mover and the direction of rotation of the magnetic field produced in the armature are the same.
6. If the voltmeter reading across the alternator field winding is very small, both the directions are correct.
7. If the voltmeter reading is high, interchange the two lines of 3 phase supply after switching off the supply.
8. The speed is slightly reduced/ increased from synchronous speed, so that slip is increased and the voltmeter and ammeter readings are oscillating.
9. The maximum and minimum readings of voltmeter and ammeter are noted.
10. The above said procedure can be repeated with two more different autotransformer settings.

Note: During this test, it would be observed that swing of the ammeter pointer is very wide, whereas the voltmeter has only small swing because of the low impedance voltage drop in the leads and 3-phase autotransformer.

(B) For Negative Sequence Impedance:

1. Connections are given as per the circuit diagram shown in figure 2.
2. Switch on the supply by pushing START button.
3. Vary the 1-F auto transformer connected to the armature of the DC motor through diode bridge rectifier till it reaches synchronous speed of the synchronous machine.
4. Now adjust the 3-phase autotransformer and take 4-5 readings for different voltages.
5. Note down the armature current and voltage.
6. If the ammeter pointer is oscillating take the mean reading.
7. The applied voltage should not be increased beyond the rated capacity of synchronous machine i.e. 5A.

8. Bring the 3- phase autotransformer to minimum voltage position and switch off the supply

(C) For Zero Sequence Impedance:

1. Connections are given as per the circuit diagram shown in figure 3.
2. Switch on the supply by pushing START button.
3. Vary the 1-F auto transformer connected to the armature of the DC motor through diode bridge rectifier till it reaches synchronous speed of the synchronous machine.
4. Gradually increase 3-phase autotransformer output and note the ammeter reading for suitable voltage applied.
5. Repeat reading for suitable voltage applied.
6. It should be kept in mind that the ammeter reading should not exceed the rated current capacity of the machine i.e. 5A.
7. Bring the 3-phase autotransformer to minimum voltage position and switch off the supply

Observations:

(A) For Positive Sequence Impedance:

S. No.	V_{Max} (V)	V_{Min} (V)	I_{Min} (A)	I_{Max} (A)	$X_d = \frac{V_{Max}}{I_{Min}}\Omega$	$X_q = \frac{V_{Min}}{I_{Max}}\Omega$

(B) For Negative Sequence Impedance:

S. No.	V (V)	I (A)	$Z_2 = \frac{V}{I}\Omega$

(C) For Zero Sequence Impedance:

S. No.	V (V)	I (A)	$Z_0 = \frac{3V}{I}\Omega$

Result:

Positive sequence Impedance Z_1 = ……….O

Negative sequence Impedance Z_2 = ……….O

Zero sequence Impedance Z_0 = ……….O

Circuit diagram to determine Positive Sequance Reactance:

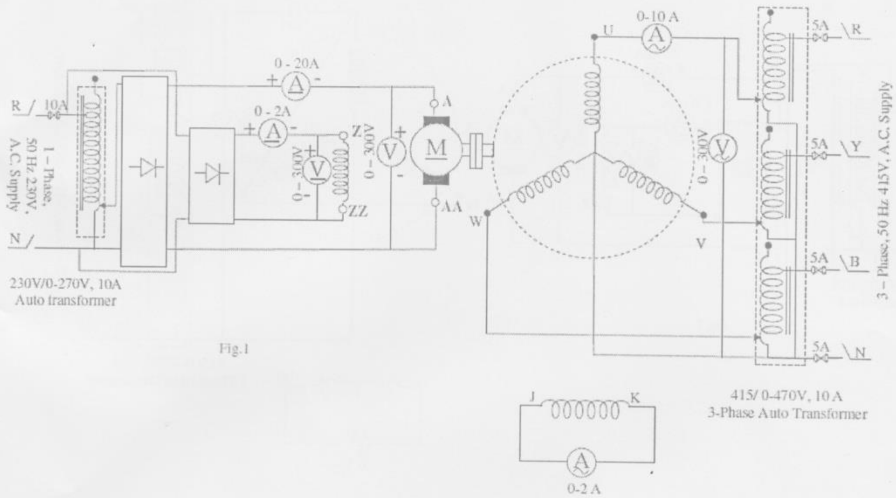


Fig.1

Circuit diagram to determine Negative Sequance Reactance:

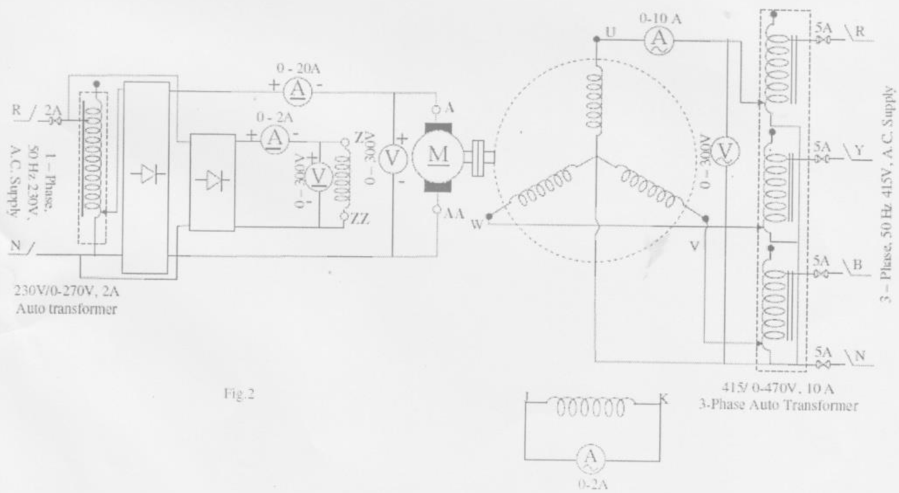


Fig.2

Circuit diagram to determine zero sequance impedance:

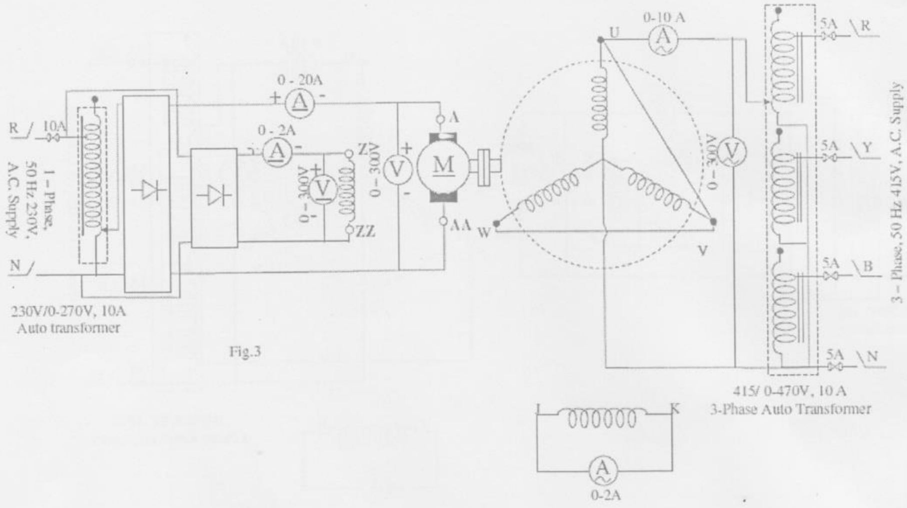


Fig.3

VIVA QUESTIONS

Transformers:

1. Which losses are called magnetic losses?
2. Write equations for hysteresis and eddy-current losses?
3. What are the conditions for maximum efficiency in a transformer?
4. Explain why low power factor meter is used in O.O. test?
5. Why iron losses are neglected when S.C test on a Transformer?
6. What are the advantages of Sumpner’s test?
7. Draw the phasor diagram for a S.C. test on a transformer?
8. How do you reduce the hysteresis and eddy-current losses?
9. ls the transformer core laminations are insulated? Why?
10. Represent the step up and step down transformer?
11. Draw the equivalent circuit of a transformer?
12. Why transformer efficiency is more than an induction motor?
13. Write equations for emf of a transformer?
14. What is the magnitude of no-load current?
15. What is the function of an auto-transformer?
16. What happens to Transformer when DC supply is given?
17. How do you mark dot on a transformer?
18. Does flux in a transformer changes with load?
19. Why transformer no-load current is a small value in spite of its primary impedance is very small?
20. A transformer is designed for 50Hz. lf the supply frequency is 60 Hz. What is the change in its performance?
21. A transformer has primary more than secondary turns. ls it step-down or step-up transformer?
22. How do you identify core-type of transformer?
23. One transformer has cruciform type and second transformer has square type of core which is the better one?
24. Define voltage regulation with equation for lagging and leading loads.
25. Draw the phasor diagrams for leading and lagging loads.
26. For a step-down transformer which winding has low resistance?
27. Draw the phasor diagram for lagging load.
28. What are the conditions required to parallel two transformers?
29. What is the full name of C.R.G.O.S. core material?
30. Generally what is the efficiency percentage of a transformer?
31. What is the role of Buchholz relay?
32. What is the material kept inside a breather?
33. Write the relations between line-currents, phase-currents and line, phase voltages in a star and delta connections.
34. What is the use of Scott connection?
35. Compare open delta, Scott connections
36. Draw the phasor diagram for Scott connection.
37. Draw star/star, star/delta, delta/star, delta/delta winding connections when three single phase transformers are used.
38. What is the use of tertiary winding in a transformer?
39. How can you use a 3-phase auto-transformer as a step-up autotransformer?
40. Explain, the working principle of Back to Back Transformer Test.

41. What is Magnetostriction?
42. If a transformer primary is energized from a square wave voltage source, what type of output voltage is obtained?
43. Why noises exist in Power Transformer?
44. Why transformer rating is given in KVA?
45. What is meant by leakage flux?
46. Differentiate Sumpner's test and OC, SC tests on transformer?
47. What is the basic principle of a transformer?
48. Draw the phasor diagrams when the load on the transformer is;
    (a) Lagging (b) Leading and (c) UPF

Three phase induction Motor:

1. How do you connect the six terminals of the motor as Delta or Star?
2. What are the different starting methods used?
3. What is the role of a rotating flux?
4. How do you change the direction of rotation?
5. Why star point of the motor is not connected to neutral point of the Supply?
6. Does the motor start when supply lines are connected?
7. For a two-phase supply waveform & leading current, lagging current with respect to the voltage.
8. Draw the Three-phase supply waveform& leading current, lagging current with respect to the voltage.
9. What is the advantage of star delta starter when compared to, D.O.L. starter?
10. For a 6-pole machine what is the value of synchronous speed?
11. Why slip cannot be zero in induction motor?
12. What are the two different types of rotors?
13. Why one spring balance always indicate zero in a load test?
14. When one phase is removed in a three-phase supply it is called single phase supply instead of two-phase supply. Why?
15. Draw the Torque-slip, Torque-speed characteristics of a wound rotor motor and mark stable and unstable area.
16. What is the relation between Torque and voltage?
17. Is it possible to get speed control from zero to rated speed in an induction motor?
18. Why do we say that induction motor is similar to DC shunt motor characteristic?
19. If one phase flux is from a three phase running motor, does it continues to rotate or stops?
20. Which type of motor is used to start with load?
21. Draw the equivalent circuit of a 3-phase induction motor.
22. Why do we say that Induction motor is similar to a rotating transformer?
23. What are the parameters required to draw a circle diagram?
24. Draw the performance curves of an induction motor.
25. What is the advantage of a circle diagram?
26. Why iron losses are considered-as zero?
27. What is relation between Torque, power and angular velocity?
28. Define speed regulation.
29. Does speed falls from no load to full load. if so, how much?
30. Why rotor bars in a squirrel cage rotor are skewed?
31. If the external resistance is kept permanently in the rotor circuit, what is the disadvantage?
32. What are the different power stages in an induction motor?

33. What is the electrical equivalent of mechanical load in an induction motor?
34. Which types of instruments are used in A.C. circuits and D.C. circuits and both?
35. Which instruments are called Transfer instruments?
36. What are the different types of analogue instruments?
37. Write Torque equation for induction motor.
38. Explain circle diagram
39. What is Cogging and Crawling in an induction motor? How are they prevented?
40. What is the speed of an induction motor for (i) 4% Slip (i) 100% slip?

Synchronous Machines:

1. Why Synchronous motor is not self starting motor?
2. What happens if excitation is changed?
3. When load is increased on a synchronous motor, does the speed fall like an induction motor? If not, explain how the load torque is produced?
4. Which motor requires both AC and DC supplies?
5. Define pull in and pull out Torques?
6. What is potier Triangle?
7. What are the different types of field constructions in a synchronous
8. Draw V and inverted V curves of a Synchronous motor.
9. Significance of Xd and Xq in an alternator.
10. Why ASA method is superior to ZPF method?
11. Why do you conduct Slip-test?
12. Describe voltage regulation of an alternator.
13. Describe Speed regulation of a Synchronous motor.
14. What is another name of potier Triangle method?
15. What are the different methods used to rind out the regulation? Compare them.
16. What is the reaction theory and what is its significance?
17. What is emf equation of an alternator?
18. How do you calculate Synchronous Impendence using OCC and SC test on Synchronous machine?
19. What is the use of Damper Windings?
20. What are the different methods of starting a synchronous motor?
21. Define Pitch factor, Distribution factor and their advantages.
22. The armature winding of an alternator is in star or delta or both.
23. What are the conditions required to synchronize an alternator with. APSEB supply?
24. How can you increase the share of an alternator when it is connected to an infinite bus?
25. At what condition the power output of a synchronous generator connected to an infinite bus?
26. How can we run a synchronous motor as synchronous condenser?
27. Expression for Power developed in an alternator.
28. What is meant by Hunting?
29. Explain why synchronous machines are designed to have a high ratio of armature reactance to resistance?
30. Why alternators run in parallel?
31. Draw the phasor diagram for alternator and synchronous motor for leading and lagging power factors.
32. What is the role of damper windings?
33. ln which type of alternator, damping windings does not exist?

34. When do we say an alternator is under floating condition during parallel operation?
35. Which machine requires both AC and DC?
36. Equation for emf generated in a synchronous motor.
37. What is pitch factor and distribution factor?
38. What is meant by full pitch winding?
39. Draw the curves between V and l. at distribution power factor loads.
40. What is short circuit ratio?
41. Potier triangle is drawn between which two characteristics?
42. Which method is used to find out the regulation in a salient pole Synchronous machine?
43. Define X_q and X_d .
44. Draw the graph between torque angle and Po for a Synchronous machine.
45. What are the different methods used for parallel operation of the alternator?
46. How do you increase the voltage of an alternator?
47. Draw the graph of V and inverted V curves for different loads.
48. When do you say the synchronous motor is running as a reluctance motor?

Single Phase induction motor:

1. Which theory explains the performance of the single phase induction motors?
2. What are the different types of single-phase motors?
3. Draw the phasor diagram for sprit-phase and capacitor-run motors.
4. Explain Cross field theory.
5. Explain' Double revolving field theory.
6. What is the importance of the compensation in single phase motors?
7. What are the applications of Universal motors?
8. What are the applications of Shaded pole motor?
9. Explain the importance of capacitors in capacitor start motors.
10. Why the single phase motors are not self starting?
11. When a single phase series motor is operated on no-load.
12. What are the motors used for household refrigerators, ceiling fans, hair dryers and mixes.
13. When a capacitor start single phase induction motor is switched on the supply with its capacitor replaced by an inductor of equivalent reactance value. What will happen?
14. Lf the ceiling fan when switched on, runs at slow speed in the reverse direction what is your conclusion?
15. How can you reverse the speed of the split phase motors?
16. How will the reluctance motor run?
17. How will the repulsion motor run?
18. How will the hysteresis motor run?
19. What are the differences between AC series motors & DC series motors?