ELECTRICAL MACHINES -II
LAB MANUAL

Prepared by

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Name of the student : ________________________

Regd. No : ________________________

Year : ________________________

LABORATORY PRACTICE
SAFETY RULES

1. SAFETY is of paramount importance in the Electrical Engineering Laboratories. Electricity NEVER EXECUSES careless persons. So, exercise enough care and attention in handling **electrical** equipment and follow **safety** practices in the laboratory. (Electricity is a good servant but a bad master).
2. Avoid direct contact with any voltage source and power line voltages. (Otherwise, any such
   contact may subject you to **electrical** shock)
3. Wear rubber-soled shoes. (To insulate you from earth so that even if you accidentally contact a live point, current will not flow through your body to earth and hence you will be
   protected from **electrical** shock)
4. Wear laboratory-coat and avoid loose clothing. (Loose clothing may get caught on an Equipment/instrument and this may lead to an accident particularly if the equipment happens to be a rotating machine)
5. Girl students should have their hair tucked under their coat or have it in a knot.
6. Do not wear any metallic rings, bangles, bracelets, wristwatches and neck chains. (When you move your hand/body, such conducting items may create a short circuit or may touch a live point and thereby subject you **to electrical** shock)
7. Be certain that your hands are dry and that you are not standing on wet floor. (Wet parts of
   the body reduce the contact resistance thereby increasing the severity of the shock)
8. Ensure that the power is OFF before you start connecting up the circuit. (Otherwise you will be touching the live parts in the circuit)
9. Get your circuit diagram approved by the staff member and connect up the circuit strictly
   as per the approved circuit diagram.
10. Check power chords for any sign of damage and be certain that the chords use **safety** plugs and do not defeat the **safety** feature of these plugs by using ungrounded plugs.
11. When using connection leads, check for any insulation damage in the leads and avoid such defective leads.
12. Do not defeat any **safety** devices such as fuse or circuit breaker by shorting across it. **Safety** devices protect YOU and your equipment.
13. Switch on the power to your circuit and equipment only after getting them checked up and approved by the staff member.
14. Take the measurement with one hand in your pocket. (To avoid shock in case you accidentally touch two points at different potentials with your two hands)
15. Do not make any change in the connection without the approval of the staff member.
16. In case you notice any abnormal condition in your circuit (like insulation heating up, resistor heating up etc), switch off the power to your circuit immediately and inform the staff member.
17. Keep hot soldering iron in the holder when not in use.
18. After completing the experiment show your readings to the staff member and switch off the power to your circuit after getting approval from the staff member.
19. While performing load-tests in the **Electrical Machines** Laboratory using the brake drums:Avoid the brake-drum from getting too hot by putting just enough water into the brake-drum at intervals; use the plastic bottle with a nozzle (available in the laboratory) to pour the water. (When the drum gets too hot, it will burn out the braking belts). Do not stand in front of the brake-drum when the supply to the load-test circuit is switched

off. (Otherwise, the hot water in the brake-drum will splash out on you) After completing the load-test, suck out the water in the brake-drum using the plastic bottle with nozzle and then dry off the drum with a sponge which is available in the laboratory. (The water, if allowed to remain in the brake-drum, will corrode it)

20. Determine the correct rating of the fuse/s to be connected in the circuit after understanding correctly the type of the experiment to be performed: no-load test or full load test, the maximum current expected in the circuit and accordingly use that fuse rating. (While an over-rated fuse will damage the equipment and other instruments like ammeters and watt-meters in case of over load, an under-rated fuse may not allow one even to start the experiment)
21. At the time of starting a motor, the ammeter connected in the armature circuit overshoots,

    as the starting current is around 5 times the full load rating of the motor. Moving coil ammeters being very delicate, may get damaged due to high starting current. A switch has been provided on such meters to disconnect the moving coil of the meter during starting. This switch should be closed after the motor attains full speed. Moving iron ammeters and current coils of watt meters are not so delicate and hence these can stand short time overload due to high starting current. No such switch is therefore provided on these meters. Moving iron meters are cheaper and more rugged compared to moving coil meters. Moving iron meters can be used for both a.c. and d.c. measurement. Moving coil instruments are however more sensitive and more accurate as compared to their moving iron counterparts and these can be used for d.c. measurements only. Good features of moving coil instruments are not of much consequence for you as other sources of errors in the experiments are many times more than those caused by these meters.
22. Some students have been found to damage meters by mishandling in the following ways:

    Keeping unnecessary material like books, lab records, unused meters etc. causing meters to fall down the table. Putting pressure on the meter (specially glass) while making connections or while talking or listening somebody.

STUDENTS ARE STRICTLY WARNED THAT FULL COST OF THE METER WILL BE RECOVERED FROM THE INDIVIDUAL WHO HAS DAMAGED IT IN SUCH A MANNER.

Copy these rules in your Lab Record. Observe these yourself and help your friends to observe I have read and understand these rules and procedures. I agree to abide by these rules and procedures at all times while using these facilities. I understand that failure to follow these rules and procedures will result in my immediate dismissal from the laboratory and additional disciplinary action may be taken.

GUIDELINES FOR LABORATORY NOTEBOOK

The laboratory notebook is a record of all work pertaining to the experiment. This record should be sufficiently complete so that you or anyone else of similar technical background can duplicate the experiment and data by simply following your laboratory notebook. Record everything directly into the notebook during the experiment. Do not use scratch paper for recording data. Do not trust your memory to fill in the details at a later time. Organization in your notebook is important. Descriptive headings should be used to separate and identify the various parts of the experiment. Record data in chronological order. A neat, organized and complete record of an experiment is just as important as the experimental work.

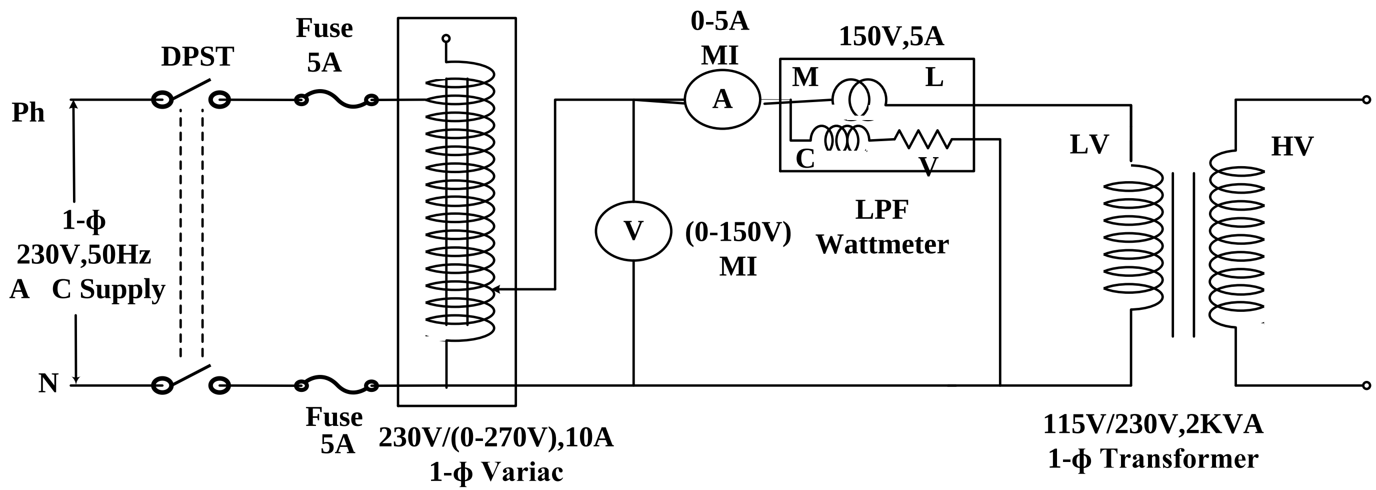
1. **Heading:**
   The experiment identification (number) should be at the top of each page. Your name and date should be at the top of the first page of each day's experimental work.
2. **Object:**
   A brief but complete statement of what you intend to find out or verify in the experiment should be at the beginning of each experiment
3. **Diagram:**
   A circuit diagram should be drawn and labeled so that the actual experiment circuitry could be easily duplicated at any time in the future. Be especially careful to record all circuit changes made during the experiment.
4. **Equipment List:**
   List those items of equipment which have a direct effect on the accuracy of the data. It may be necessary later to locate specific items of equipment for rechecks if discrepancies develop in the results.
5. **Procedure:**
   In general, lengthy explanations of procedures are unnecessary. Be brief. Short commentaries alongside the corresponding data may be used. Keep in mind the fact that the experiment must be reproducible from the information given in your notebook.
6. **Data:**
   Think carefully about what data is required and prepare suitable data tables. Record instrument readings directly. Do not use calculated results in place of direct data; however, calculated results may be recorded in the same table with the direct data. Data tables should be clearly identified and each data column labeled and headed by the proper units of measure.
7. **Calculations:**
   Not always necessary but equations and sample calculations are often given to illustrate the treatment of the experimental data in obtaining the results.
8. **Graphs:**
   Graphs are used to present large amounts of data in a concise visual form. Data to be presented in graphical form should be plotted in the laboratory so that any questionable data points can be checked while the experiment is still set up. The grid lines in the notebook can be used for most graphs. If special graph paper is required, affix the graph permanently into the notebook. Give all graphs a short descriptive title. Label and scale the axes. Use units of measure. Label each curve if more than one on a graph.
9. **Results:**
   The results should be presented in a form which makes the interpretation easy. Large amounts of numerical results are generally presented in graphical form. Tables are generally used for small amounts of results. Theoretical and experimental results should be on the same graph or arrange in the same table in a way for easy correlation of these results.
10. **Conclusion:**
    This is your interpretation of the results of the experiment as an engineer. Be brief and specific. Give reasons for important discrepancies.

List of Experiments

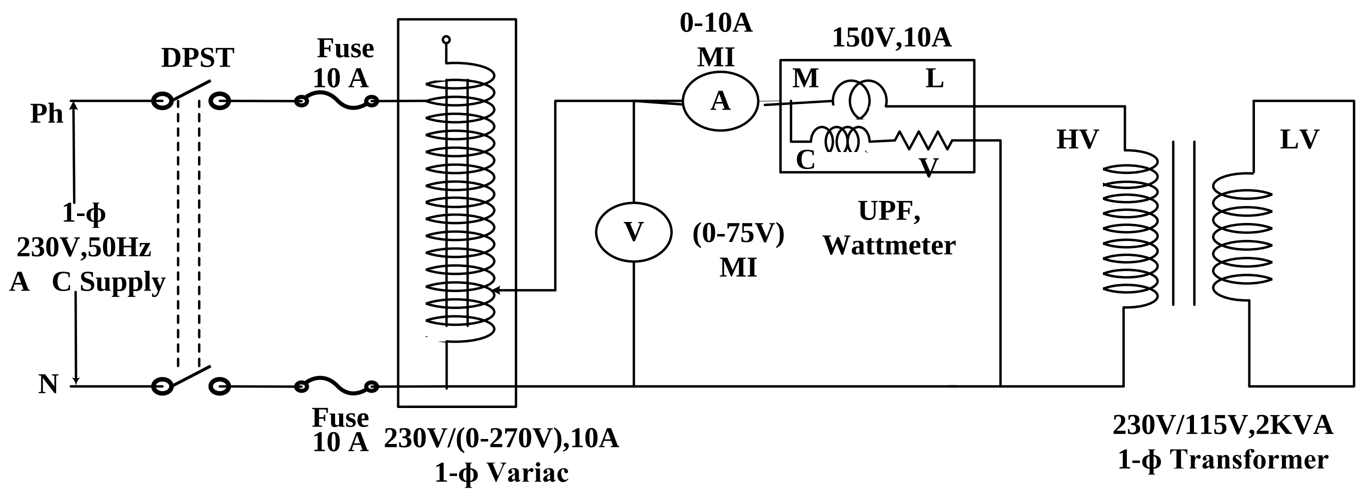
Electrical Machines-II Lab

CIRCUIT DIAGRAM:

Open circuit test



Short circuit test



OPEN CIRCUIT & SHORT CIRCUIT TEST ON A SINGLE PHASE TRANSFORMER

Aim: To conduct OC & SC tests on the given 1-ϕ Transformer and to calculate its

1) Equivalent circuit parameters
    a). Referred to H.V side
    b). Referred to L.V side
2) Efficiency at various loads.
3) Regulation at various power factors
4) Maximum Efficiency.

Name plate details:

1-ϕ Transformer

Transformer	LV side	HV side
Rated power		
Rated voltage		
Rated current		
Frequency		

Apparatus required:

Sl.no	Name of the equipment	Rating	Type	Quantity
1	Voltmeter	(0-300V)	MI	1
		(0-150V)	MI	1
2	Ammeter	(0-10A)	MI	1
		(0-02A)	MI	1
3	Wattmeter	300V/5A, LPF	Dynamometer	1
		150V/10A, UPF	Dynamometer	1
4	1-ϕ Auto Transformer	230V/(0-270V),10A		1
5	Connecting wires			Req

Observations:
O.C test

Sl.no	Voltage V_o(Volts)	Current I_o(Amp)	Power W_o (Watts)

S.C test

Sl.no	Voltage V_{sc} (Volts)	Current I_{sc} (Amp)	Power W_{sc} (Watts)

Calculation
O.C test:

1)No load power factor $\cos\phi_o = \frac{W_o}{V_o I_o}$

$I_w = I_o \cos\phi_o$ $\qquad$ $I\mu = I_o \sin\phi_o$

2) Resistance to account for core losses $R_o = \frac{V_o}{I_W} \Omega$

3) Magnetizing reactance $x_o = \frac{I_o}{I_\mu} \Omega$

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 parameter are denoted by suffix 1 and FIV side parameters by suffix

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 INL 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. Wo = VLV IO Cosφ0

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 VSC 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:

Open circuit test:

1. Connections are made as per the circuit diagram.
2. Ensure that variac is set to zero output voltage position before starting the experiment.
3. Switch ON the supply. Now apply the rated voltage to the Primary winding by using variac.
4. The readings of the Voltmeter, ammeter and wattmeter are noted down in Tabular form.
5. Then Variac is set to zero output position and switch OFF the supply.
6. Calculate $\mathbf{R_0}$ and $\mathbf{X_0}$ from the readings.

S.C test:

Short circuit power factor $\cos\phi_{sc}=\frac{W_{sc}}{V_{sc}\, I_{sc}}$

Equivalent winding resistance refered to HV side$R_{01} = \frac{W_{sc}}{I_{sc}^2}$

Equivalent winding resistance refered to LV side$R_{02}=R_{01}K^2$

Where K (Transformation Ratio) = (V2/ V1)

Equivalent winding Impedance referred to **H V** side $Z_{01} = \frac{V_{sc}}{I_{sc}}$

Equivalent winding Impedance referred to **LV** side$Z_{02}=z_{01}k^2$

Equivalent winding Reactance referred to HV side $X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$

Equivalent winding Reactance referred to LV side $X_{02}=X_{01}k^2$

To find Efficiency:

Core loss or Constant loss (**W_I**)

Rated short circuit current **I2 sc**

KVA rating of transformer

Copper loss (**W_{sc}**) at full load Current

Output for other power factor=V2I2cosϕ

Total power loss $W_T=W_I+W_{SC}$

Output =(X*kVA*cosϕ)watts

where Xis fraction of load

KVA is the power rating of the transformer

Cosϕ is power factor

Copper losses =X^2W_{sc} in watts

Where Wsc Is Copper loss in short circuit condition

Where **'X'** is Fraction of load

Total power loss = (Copper Loss + Iron Loss) In Watts

% efficiency =$\frac{output}{output+total\ losses} \times 100$

% efficiency =$\frac{VI_L cos\phi}{VI_L cos\phi+W_T} \times 100$

% voltage regulation=$\frac{I_2R_{02}\cos\phi+I_2X_{02}sin\phi}{E_2} \times 100$

(+Ve for lagging and unity PF; - Ve for leading PF)

Short Circuit Test:

1. Connections are made as per the circuit diagram.
2. Ensure that variac is set to zero output voltage position before starting the experiment.
3. Switch ON the supply. Now apply the rated Current to the Primary winding by using Variac.
4. The readings of the Voltmeter, ammeter and wattmeter are noted down in Tabular form.
5. Then Variac is set to zero output position and switch OFF the supply.
6. Calculate $\mathbf{R_{01}}$ and $\mathbf{X_{01}}$ from the readings

PRECAUTIONS

1. Loose connections are to be avoided.
2. Circuit connections should not be made while power is ON.
3. Ensure variac position is zero before starting the experiment.
4. Readings of meters must be taken without parallax error.

TABULAR COLUMNS:

Efficiency Vs Load

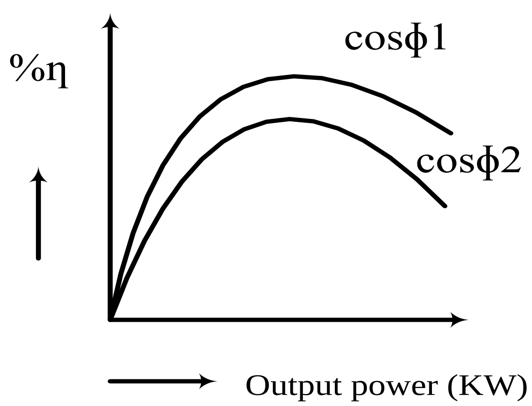
Load	Power Factor Lagging				
	0.2	0.4	0.6	0.8	1.0
25%					
50%					
75%					

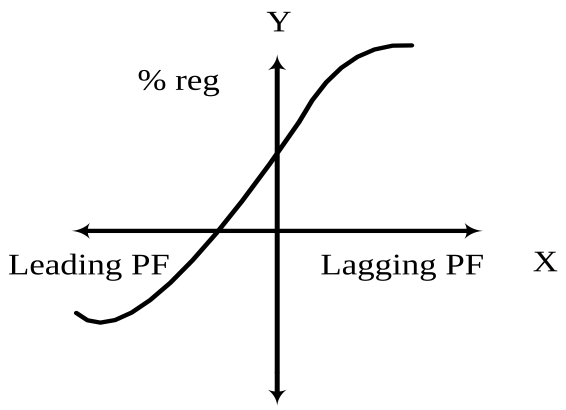
%REGULATION

Sl.no	Power factor Cosϕ	Lagging power factor %regulation	Leading power factor %regulation
1.	0		
2.	0.2		
3.	0.4		
4.	0.6		
5.	0.8		
6.	1.0		

Graphs :

1)% efficiency Vs output
2) % Regulation Vs Power factor



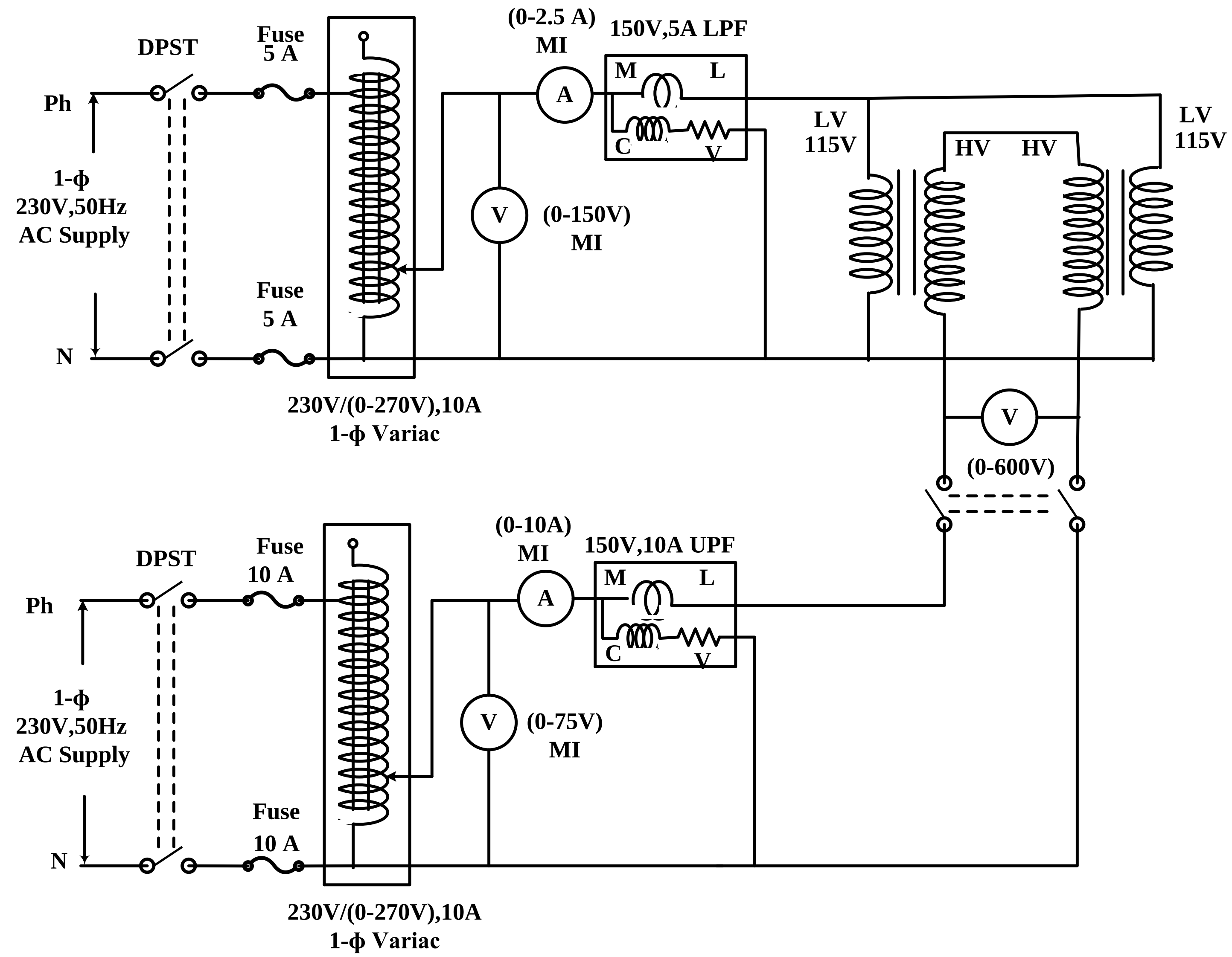


Result:

Viva Questions:

1. What is regulation of a transformer?
2. What are the different losses in a transformer?
3. What are the different types of transformers?
4. What is the efficiency of a transformer when compared with Induction motor?
5. What is the working principle of transformer?
6. What happens when DC is given to primary of a transformer?
7. Why the transformers are rated in KVA?

Circuit diagram:
Sumpners test



SUMPNER'S TEST ON A PAIR OF 1-Φ TRANSFORMER

AIM: To conduct OC & SC tests on the given 1- Transformer and to calculate its

1) Equivalent circuit parameters
   A). Referred to H.V side
   b). Referred to L.V side
2) Efficiency at various loads.
3) Regulation at various power factors
4) Maximum Efficiency

Name plate details: 1-ϕ Transformers

Transformer	Transformer-1		Transformer-2	
	L.V	H.V	L.V	H.V
Rated power				
Rated voltage				
Rated current				
Frequency				

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-150V)	MI	1
		(0-75V)	MI	1
		(0-600V)	MI	1
2	Ammeter	(0-2.5A)	MI	1
		(0-10A)	MI	1
3	Wattmeter	150V,5A LPF	Dynamometer	1
		150V,10A UPF	Dynamometer	1
4	1-ϕ variac	230V/(0-270V),10A	Core	2
5	Connecting wires			Req

Observations:

Sl.no	Primary side			Secondary side		
	V1(Volts)	I1(Amps)	W1(Watts)	V2(Volts)	I2(Amps)	W2(Watts)

Calculations:

Iron losses of each transformer $W_0=W_1/2$

No load current of each transformer $I_0=I_1/2$

Full load copper losses of each transformer $W_{sc}=W_2/2$

Injected voltage of each transformer $V_{sc}=V_2/2$

Efficency at full load and power factor $=\cos\phi$

Output =KVA* $\cos\phi$

Total losses of each transformer under full load $W_0+ W_{sc}= W_1/2 + W_2/2$

Input =Output +Total losses

Efficency=(Output /Input)*100%

$W_0=V_1I_1 \cos\phi_0$ $\qquad\qquad$ $\phi_0 = \cos^{-1}\frac{W_0}{V_1I_1}$

Theory :

The Sumpner's test is another method of determining efficiency, regulation and heating under load conditions. The O.C. and S.C. tests give us the equivalent circuit parameters but ca not give heating information under various load conditions. The Sumpner's test gives heating information also. In O.C. test, there is no load on the transformer while in S.C. circuit test also only fractional load gets applied. In all in O.C. and S.C. tests, the loading conditions are absent. Hence the results are inaccurate. In Sumpner's test, actual loading conditions are simulated hence the results obtained are much more accurate. Thus Sumpner;s test is much improved method of predetermining regulation and efficiency than O.C. and S.C. tests.

The Sumpner's test requires two identical transformers. Both the transformers are connected to the supply such that one transformer is loaded on the other. Thus power taken from the supply is that much necessary for supplying the losses of both the transformers and there is very small loss in the control circuit.

While conducting this test, the primaries of the two identical transformers are connected in parallel across the supply V_1. While the secondaries are connected in series opposition so that induced e.m.f.s in the two secondaries oppose each other. The secondaries are supplied from another low voltage supply are connected in each circuit to get the readings.

T_1 and T_2 are two identical transformers. The secondaries of T_1 and T_2 are connected in series opposition. So $E_{EF} = E_{GH}$ i.e. induced in two secondaries are equal but the secondaries are connected such that E is connected to G and F is connected to H. Due to such series opposition, two e.m.f.s act in opposite direction to each other and cancel each other. So net voltage ion the local circuit of secondaries is zero, when primaries are excited by supply 1 of rated voltage and frequency. So there is no current flowing in the loop formed by two secondaries. The series opposition can be checked by another voltmeter connected in the secondary circuit as per polarity test. If it reads zero, the secondaries are in series opposition and if it reads double the induced e.m.f. in each secondary, it is necessary to reverse the connections of one of the secondaries.

As per superposition theorem, if V_2 is assumed zero then due to phase opposition to current flows through secondary and both the transformers T_1, T_2 are as good as on no load. So O.C. test gets simulated. The current drawn from source V_1 in such case is 2 I_o where I_o is no load current of each transformer. The input power as measured by wattmeter W_1 thus reads the iron losses of both the transformers.

$\therefore$ P_i per transformer $= W_1/2$ as T_1, T_2 are identical

Then a small voltage V_2 is injected into the secondary with the help of low voltage transformer, by closing the switch S. With regulation mechanism, the voltage V_2 is adjusted so that the rated secondary current I_2 flows through the secondaries as shown. I_2 flows from E to F and then from H to G. The flow of I_1 is restricted to the loop B A I J C D L K B and it does not pass through W_1. Hence W_1 continues to read core losses. Both primaries and secondaries carry rated current so S.C.

test condition gets simulated. Thus the wattmeter W_2 reads the total full load copper losses of both the transformers.

∴ (P_{cu}) F.L.per transformer = $W_2/2$

Key Point : Thus in the sumpner's test without supplying the load, full iron loss occurs in the core while full copper loss occurs in the windings simultaneously. Hence heat run test can be conducted on the two transformers. In O.C. and S.C. test, both the losses do not occur simultaneously hence heat run test cannot be conducted. This is the advantage of Sumpner's test.

From the test results the full load efficiency of each transformer can be calculated as,

$$\boxed{\% \, \eta_{FL} \text{ of each transformer} = \frac{\text{Output}}{\text{Output} + \frac{W_1}{2} + \frac{W_2}{2}} \times 100}$$

Where output = VA rating x cos Φ_2

Key Point: As all the voltage, currents and powers are measured during the test, the equivalent circuit parameters also can be determined. Hence the regulation at any load and load power factor condition can be predetermined.

The only limitation is that two identical transformers are required. In practice exact identical transformers cannot be obtained. As two transformers are required, the test is not economical.

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. The secondary winding terminals of the two transformers are connected in series with polarities in phase opposition which can check by means of a voltmeter.
3. Before starting the experiment, check the variacs are in minimum output voltage position.
4. Close the first DPST-1 switch and switch ON the supply.
5. Increase the variac slowly, and apply rated voltage to the primary windings of 1- ϕ transformers and check the voltmeter reading connected across the secondary terminals.
6. If the voltmeter reading is Zero, continue with step 8.
7. If the voltmeter reading is not zero, interchange the secondary terminals.
8. Now close the DPST-2 switch and vary the variac-2 slowly till rated current flows in the two series-connected secondaries.
9. Note down the readings of V_1, V2, I_1, I_2, W_1, and W_2 and enter them in a tabular column.
10. $W_1 = 2P_c$, $W_2 = 2P_{sc}$. Losses of each transformer = $(W_1+W_2)/2$
11. Now the Variacs are brought to zero voltage position and open DPST switches.

Precautions:

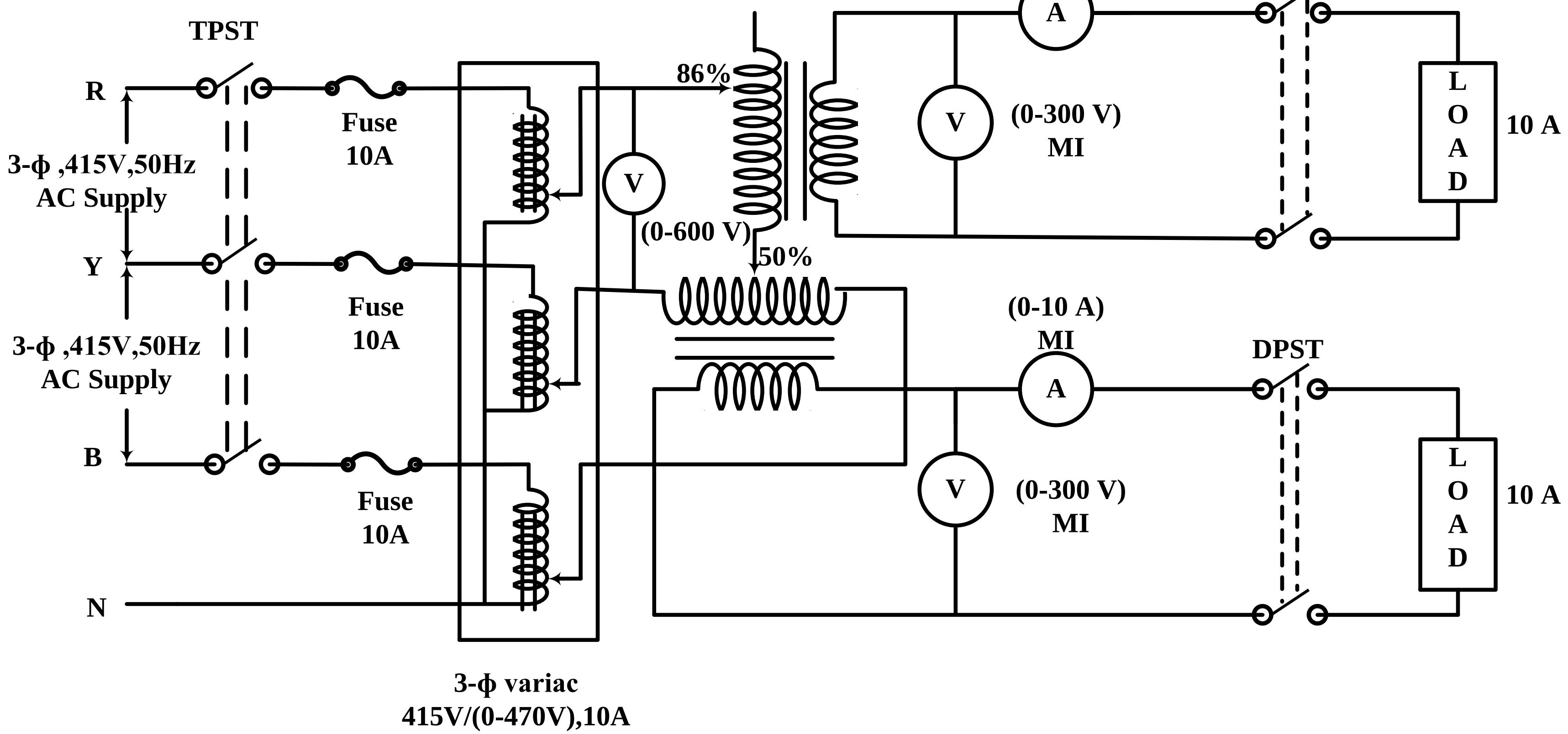
1. There should not be loose connections in the circuit.
2. Don’t apply the secondary current greater than full load current of a transformer.
3. Ensure that the variac should be at zero position while switching ON.
4. LV range voltmeter must be connected in secondary side after checking the phase Opposition

Result:

Viva Questions:

1. What is the other name for sumpner’s test?
2. What are the advantages of Sumpner’s test when compared with the other tests?
3. Define regulation of a transformer
4. What are the disadvantages of Sumpners Test?
5. Sumpner’s test is a direct test or indirect test

Circuit diagram: Scott connection



SCOTT CONNECTION

Aim : To obtain a balanced connection two-phase supply from 3-phase system by using Scott connection

Name plate details:

Transformers	Main Transformer		Teaser Transformer	
	L.V	H.V	L.V	H.V
Rated power				
Rated voltage				

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-600V)	MI	1
2	Voltmeter	(0-300V)	MI	2
3	Ammeter	(0-10A)	MI	2
4	3-ϕVariac	415/(0-470),10A	Core	1
5	Connecting wires			Req

Theory :

In order to supply power to two-phase electric furnaces, to interlink three-phase and two-phase systems, three-phase to two-phase conversion or vice-versa is essential. The common type of connection used to achieve the above conversion is "Scott Connection". Two single-phase transformers of identical rating with suitable tapping's provided on primaries of both are required for this connection

Transformer A _ _ _ 50% tapping and is called the Main Transformer.

Transformer B _ _ _ 86.6% tapping and is called the Teaser Transformer

The voltage across the primary, CO of Teaser transformer will be 86.6% of the voltage across the primary AB of a main transformer (refer to fig). The neutral point of the three-phase system will be on the Teaser transformer, such that the voltage between O & N is 28.8% of the applied

Tabular form:

For balanced two phase supply			
Sl.no	V1(volts)	V2(volts)	V3(volts)

Under loaded condition			
Sl.no	Voltage (volts)	I1(Amps)	I2(Amps)

voltage. Thus the neutral point divides the Teaser primary winding, CO in the ratio 1:2. The phasor diagram of voltages across the primaries and secondaries has shown in the fig.

The voltage across the two secondary's a1a2 and b1b2 should be same in magnitude but in phase quadrature, which may be verified experimentally by recording the voltage across the seconderies **V**a1a2, **V**b1b2 and the voltage a2b2 will a1 and b1 connected together.

The voltage **V**a1a2 and **V**b1b2 will be in phase quadrature, if the following relationship holds well between the three voltages. $V_{a2b2} = \sqrt{(V_{a1a2}^2 + V_{b1b2}^2)}$

The behavior of the above circuit can be studied experimentally, at equal loading on the two seconderies with Upf load → (If the two seconderies of main and teaser transformers carry equal currents, then the current flowing in the primary windings on three-phase side will also be equal)

Procedure:

1. Connect the circuit as shown in the fig.
2. Ensure that the switches S1 and S2 are open
3. Adjust the 3-phase variac for minimum voltage at its output
4. Switch on the A.C. supplies and apply the rated voltage across the primaries of the transformers
5. Record the voltages V1, V2 and V3 and verify that the output is balanced two-phase supply
6. Switch off the A.C. supplies and remove the dotted connection of the two secondary's and the voltmeter V3. Adjust the variac to minimum output
7. Switch on the A.C. supply again. Adjust the output voltage of the variac as per the rated voltage of the primaries of the transformer.
8. Close the switches S1 and S2 to load both the secondaries. Adjust equal loading conditions also.
9. Switch off the load from both secondary's and adjust the variac, so that its output voltage is minimum and then switch off the supply

Precautions:

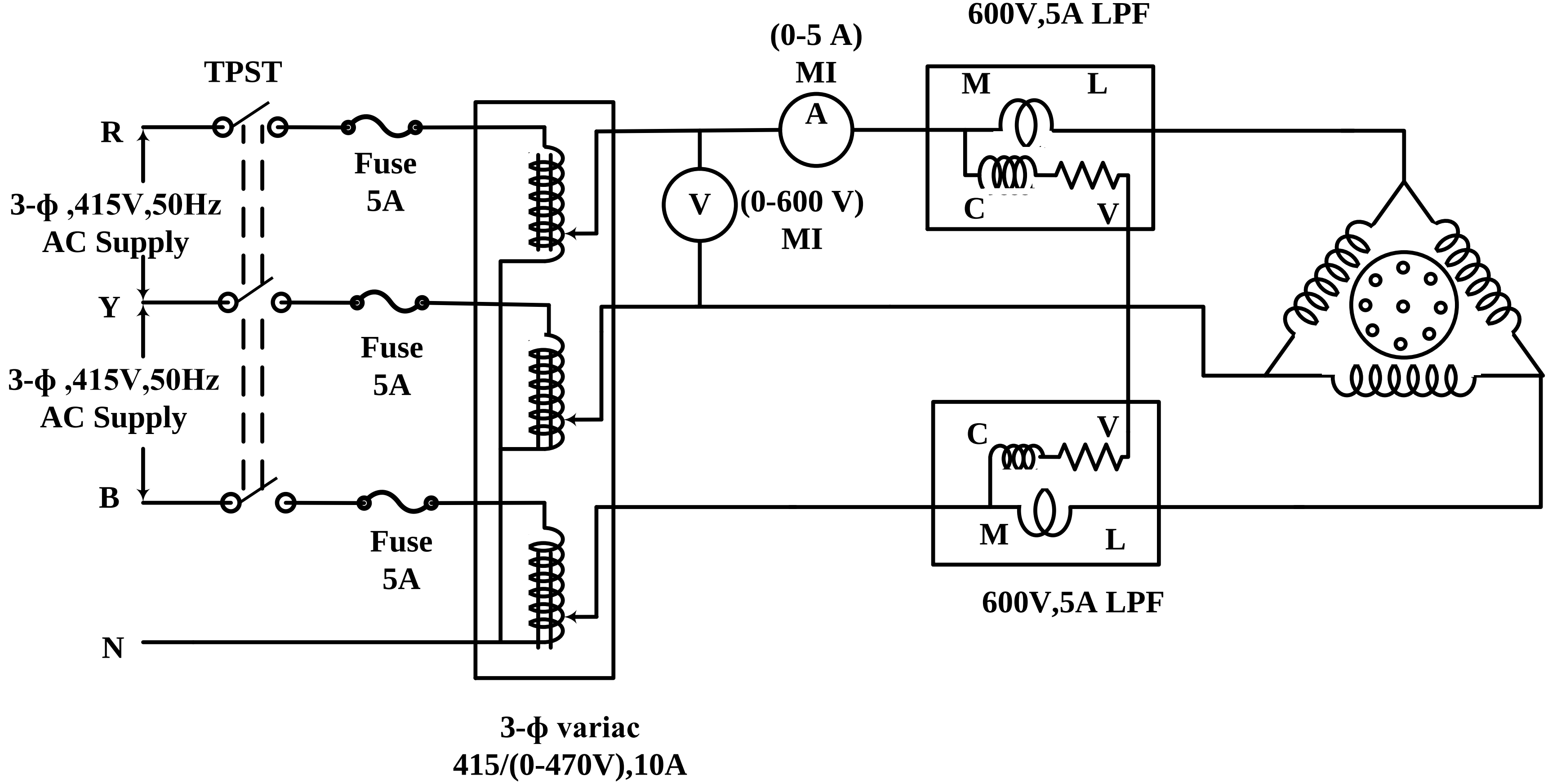
1. Loose connections must be avoided
2. Properly rated and required ranged meters are used
3. The tapping ratios must be properly observed

Result :

VIVA QUESTIONS:

1. What is a teaser transformer?
2. What are the advantages of Scott Connection?
3. What do you mean by Tertiary Winding?
4. What is the percentage of winding at which Scott connection is made?
5. What are the applications of Scott Connection?

Circuit diagram:
No load test



No-load & Blocked rotor tests on three phase Induction motor

Aim: To conduct the no-load and blocked rotor test on 3-phase squirrel cage induction motor and to predetermine the performance using circle diagram.

Name plate details:

Parameters	Induction motor
Rated Power	5HP/3.2KW
Rated Voltage	415V
Rated Current	7.5A
Rated Speed	1500

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmrter	(0-600V)	MI	1
2	Ammeter	(0-5A)	MI	1
3	Wattmeter	600v,5A LPF	Dynamometer	2
4	3-ϕ variac	415V/(0-470V),10A	Core	1
5	Connecting wires			req

Theory:

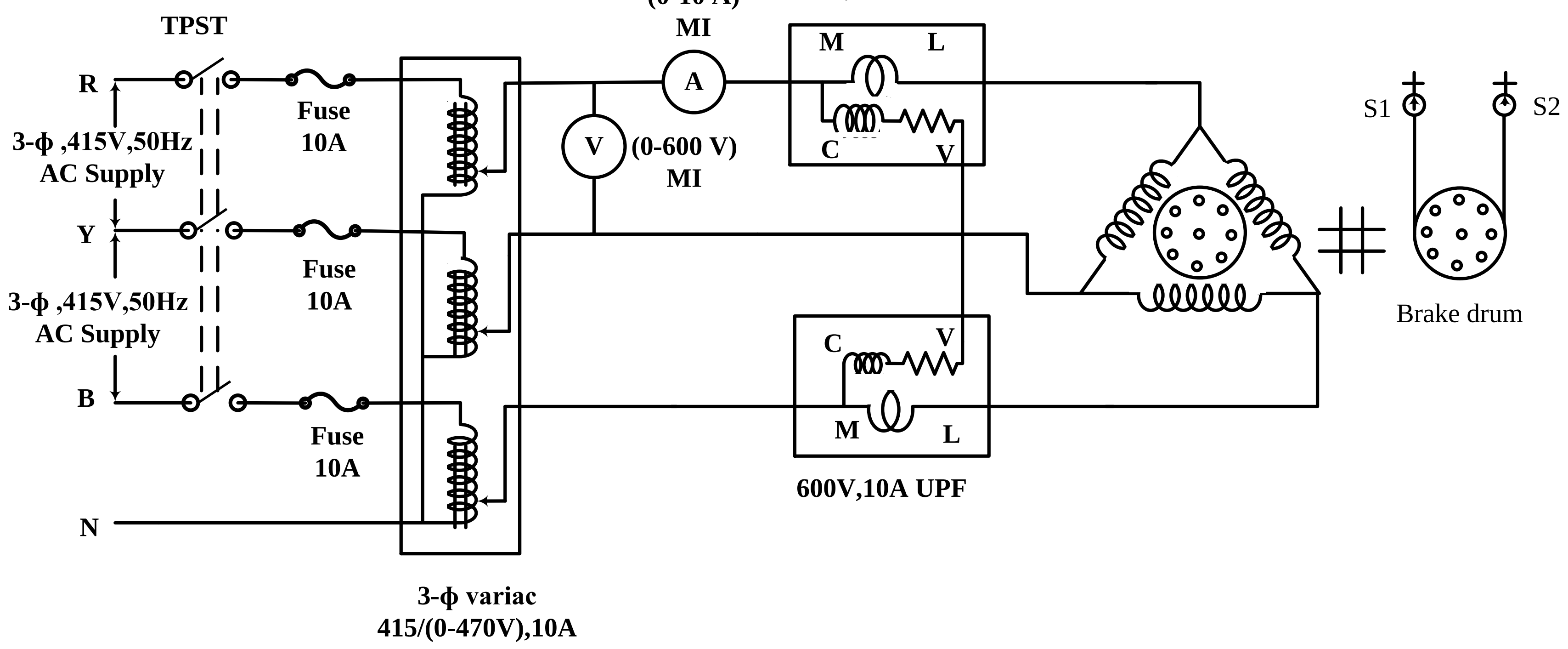
“The locus of the tip of the stator current phasor of an induction motor lies on a semicircle and moves on it as the load on the motor increased from the no-load to full-load value”. This locus is known as circle diagram of the induction motor. The complete set of performance characteristics can be predetermined from the diagram.

Using no-load test and blocked rotor test, the circle diagram for 3-ϕ squirrel cage induction motor can be plotted.

(1) NO-LOAD TEST: this test is performed to determine no-load current Io, no-load power factor cosϕo , Windage losses and friction losses Pwf, no-load core losses Pi, no-load power input Po ,no-load resistance Ro and reactance Xo. Moreover, it also reveals any mechanical fault, noise, etc….

The no-load test is performed with different values of applied voltage below and above the rated voltage, while the motor is running under no-load.

Circuit diagram: Blocked rotor test



The power input for all these three-phase Po, voltage Vo and current Io and measured by wattmeter voltmeter and ammeter. Since motor is running without load, the power factor would be less than 0.5; hence total power input is equal to the difference of the two readings of the wattmeter. At no-load. power input is equal to core losses, stator copper losses and windage, friction losses. Core losses occur only in the stator as the slip is extremely small and so the frequency of the rotor current is low as.05Hz.the magnitude of no-load current in an induction motor is about 30-40 percent of full load current because of the air gap. so the stator copper losses at no-load needs to be accounted for this can be estimated by determining stator resistance

The mechanical power developed corresponding to windage and friction losses only and the rotor circuit can, therefore be considered to be open. This is also evident from the magnitude of rotor circuit resistance. The resistance becomes very high because the slip at no-load is extremely small and soothe rotor circuit is practically open at no-load.

If windage and friction losses so determined, the stator copper losses are subtracted from power input at no-load, core losses can be determined. Knowing the total core losses, no-load current, applied voltage, the value of magnetizing component of no-load current, no-load resistance and reactance can be determined.

(2) BLOKED ROTOR TEST: this test is performed to determine, the short circuit current with normal applied voltage to stator, power factor on short circuit, total equivalent resistance and reactance of the motor as referred to stator. in this circuit the rotor is held firmly and stator is connected across supply of variable voltage. This test is just equivalent to short circuit test on transformer. The connection diagram remains the same as in the case if no-load test.

PROCEDURE:

O.C. Test

1. Make the connections as per the circuit diagram.
2. Give the 3-phase supply to induction motor and by increasing the 3-phase variac, Voltage from zero to rated value.
3. Note down the readings, ammeter (I_0), voltmeter (V_0) & wattmeter (W_0) at rated Voltage

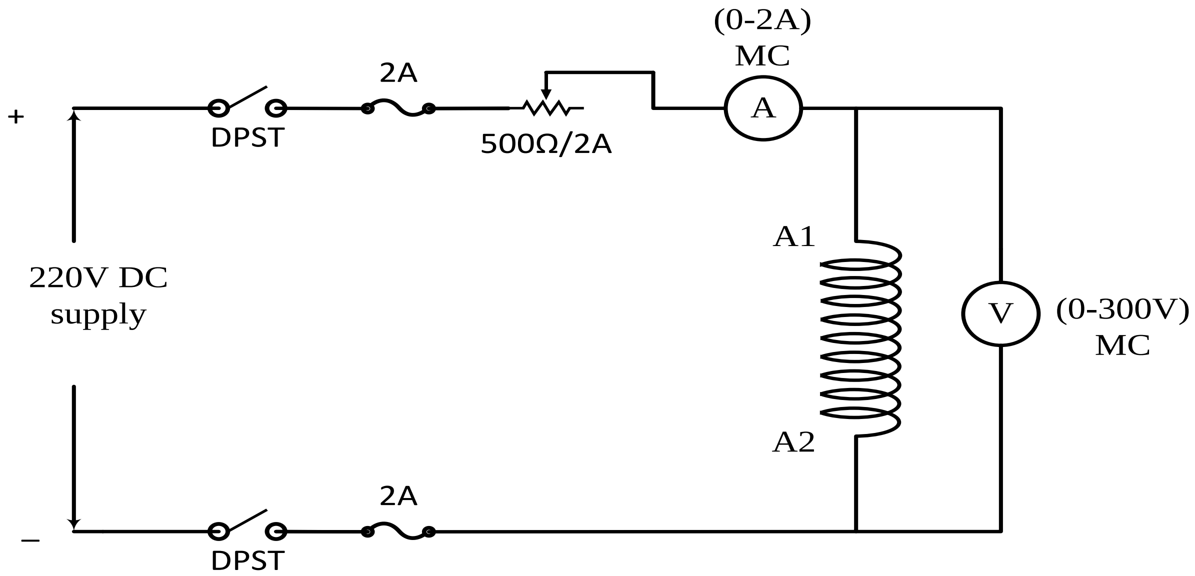
Blocked Rotor Test

1. Make the connections as per the circuit diagram
2. Block the Rotor of 3-phase induction motor by applying the mechanical load on the rotor.
3. Give the 3-phase supply to induction motor and by increasing the 3-phase variac till rated current of the motor.
4. Note down the readings ammeter (I_{SC}), voltmeter (V_{SC}) and wattmeter (W_{SC}) at rated current.
5. Remove the load and keep the 3-phase variac in initial position and switch of the supply.

Measurement of Stator resistance

1. Connect the circuit as per the circuit diagram.
2. Keeping rheostat in maximum resistance position switch on the 220 V Dc supply.
3. Using volt-ammeter method measure the resistance of the stator winding.
4. After finding the stator resistance, Rdc must be multiplied with 1.6 so as to account for skin effect i.e. Rac = 1.6 Rdc.

Circuit diagram:



Observations:
No-load test:

Sl.No	No load voltage	No load current	Wattmeter 1	Wattmeter 2	Total power

Blocked rotor test:

Sl.No	Blocked voltage	Blocked current	Wattmeter 1	Wattmeter 2	Total power

Tabular form

Sl.no	V(volts)	I(Amps)	R

Procedure to draw circle diagram:

Circle diagram can be drawn using the following steps:

Step 1: Take reference phasor V as vertical (Y-axis).

Step 2: Select suitable current scale such that diameter of circle is about 20 to 30 cm.

Step3: From no load test, I_o and are Φ_o obtained. Draw vector I_o, lagging V by angle Φ_o. This is the line OO' as shown in the Fig. 1.

Step 4: Draw horizontal line through extremity of I_o i.e. O', parallel to horizontal axis.

Step 5: Draw the current I_{SN} calculated from I_{sc} with the same scale, lagging V by angle Φ_{sc}, from the origin O. This is phasor OA as shown in the Fig. 1.

Step 6: Join O'A is called output line.

Step 7: Draw a perpendicular bisector of O'A. Extend it to meet line O'B at point C. This is the Centre of the circle.

Step 8: Draw the circle, with C as a center and radius equal to O'C. This meets the horizontal line drawn from O' at B as shown in the Fig. 1.

Step 9: Draw the perpendicular from point A on the horizontal axis, to meet O'B line at F and meet horizontal axis at D.

Step 10: Torque line. The torque line separates stator and rotor copper losses.

Note that as voltage axis is vertical, all the vertical distances are proportional to active components of currents or power inputs, if measured at appropriate scale.

Thus the vertical distance AD represents power input at short circuit i.e. W_{SN}, now which consists of core loss and stator, rotor copper losses.

Now FD = O**'G =** Fixed loss

Where O'G is drawn perpendicular from O' on horizontal axis. This represents power input on no load i.e. fixed loss.

Hence AF α Sum of stator and rotor copper losses

Then point E can be located as,

AE/EF = Rotor copper loss / Stator copper loss

The line O'E under this condition is called torque line.

Power scale: As AD represents W_{SN} i.e. power input on short circuit at normal voltage, the power scale can be obtained as,

Power scale = W_{SN}/l(AD) W/cm

Where l (AD) = Distance AD in cm

Location of Point E: **In a slip ring induction motor,** the stator resistance per phase R_1 and rotor resistance per phase R_2 can be easily measured. Similarly, by introducing ammeters in stator and rotor circuit, the currents I_1 and I_2 also can be measured.

. $K = I_1/I_2$ = Transformation ratio

Now AF/EF = Rotor copper loss / Stator copper loss = $(I_2^2R_2)/(I_1^2R_1) = (R_2/R_2)(I_2^2/I_1^2) = (R_2/R_2).(1/K^2)$

But $R_2' = R_2/K^2$ = Rotor resistance referred to stator

$\therefore$ $AE/EF = R_2'/R_1$

Thus point E can be obtained by dividing line AF in the ratio R_2' to R_1

Calculation:

No load test $W_o = V_{ph} I_o \cos \phi_o$

No load power factor $\cos \phi_o = \frac{W_o}{\sqrt{3} V_o I_o}$

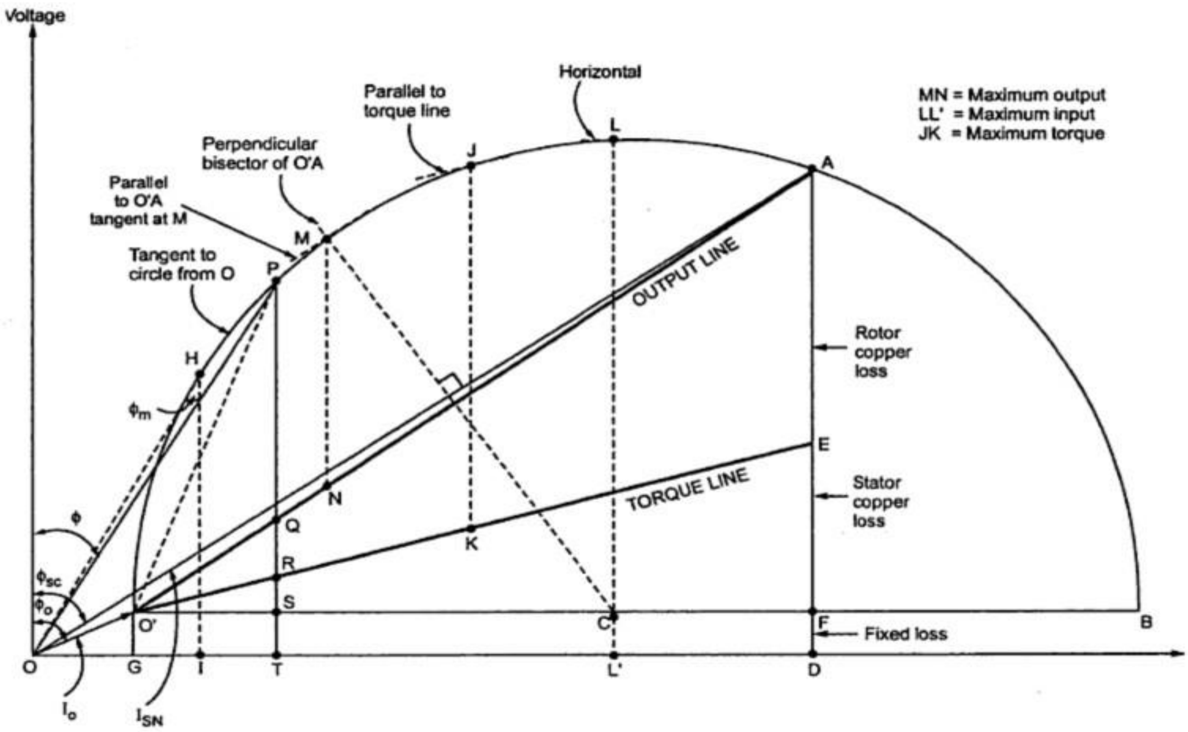
No load power factor angle $\phi_o = \cos^{-1} \frac{W_o}{\sqrt{3} V_o I_o}$

Short circuit power factor $\cos \phi_{sc} = \frac{W_{sc}}{\sqrt{3} V_{sc} I_{sc}}$

Short circuit power factor angle $\phi_{sc} = \cos^{-1} \frac{W_{sc}}{\sqrt{3} V_{sc} I_{sc}}$

Short circuit current with normal voltage $I_{sc} = I_{sc} \left(\frac{V_o}{V_{sc}}\right)$

Short circuit input with normal voltage $P_{sc} = W_{sc} (\frac{V_o}{V_{sc}})^2$



In **a squirrel cage motor**, the stator resistance can be measured by conducting resistance tset.

$\therefore$ Stator copper loss = $3I_{SN}^2 R_1$ where I_{SN} is phase value.

Neglecting core loss, W_{SN} = Stator Cu loss + Rotor Cu loss

$\therefore$ Rotor copper loss = $W_{SN} - 3I_{SN}^2 R_1$

$\therefore$ $AE/EF = (W_{SN} - 3I_{SN}^2 R_1)/(3I_{SN}^2 R_1)$

Dividing line AF in this ratio, the point E can be obtained and hence O'E represents torque line.

1.1 Predicting Performance Form Circle Diagram

Let motor is running by taking a current OP as shown in the Fig. 1. The various performance parameters can be obtained from the circle diagram at that load condition.

Draw perpendicular from point P to meet output line at Q, torque line at R, the base line at S and horizontal axis at T.

We know the power scale as obtained earlier.

Using the power scale and various distances, the values of the performance parameters can be obtained,

Total motor input = PT x Power scale

Fixed loss = ST x power scale

Stator copper loss = SR x power scale

Rotor copper loss = QR x power scale

Total loss = QT x power scale

Rotor output = PQ x power scale

Rotor input = PQ + QR = PR x power scale

Slip S = Rotor Cu loss = QR/PR

Power factor cosϕ = PT/OP

Motor efficiency = Output / Input = PQ/PT

Rotor efficiency = Rotor output / Rotor input = PQ/PR

Rotor output / Rotor input = 1 - S = N/N_s = PQ/PR

The torque is the rotor input in synchronous watts.

1.2 Maximum Quantities

The maximum values of various parameters can also be obtained by using circle diagram.

1. Maximum Output: Draw a line parallel to O'A and is also tangent to the circle at point M. The point M can also be obtained by extending the perpendicular drawn from C on O'A to meet the circle at M. Then the maximum output is given by l(MN) at the power scale. This is shown in the Fig. 1.

2. Maximum Input: It occurs at the highest point on the circle i.e. at point L. At this point, tangent to the circle is horizontal. The maximum input given l(LL') at the power scale.

3. Maximum Torque: Draw a line parallel to the torque line and is also tangent to the circle at point J. The point J can also be obtained by drawing perpendicular from C on torque line and extending it to meet circle at point J. The l(JK) represents maximum torque in synchronous watts at the power scale. This torque is also called stalling torque or pull out torque.

4. Maximum Power Factor: Draw a line tangent to the circle from the origin O, meeting circle at point H. Draw a perpendicular from H on horizontal axis till it meets it at point I. Then angle OHI gives angle corresponding to maximum power factor angle.

$\therefore$ Maximum p.f. = cos ∟{OHI}

= HI/OH

5. Starting Torque: The torque is proportional to the rotor input. At s = 1, rotor input is equal to rotor copper loss i.e. l(AE).

$\therefore$ T_{start} = l(AE) x Power scale ....in synchronous watts

PRECAUTIONS:

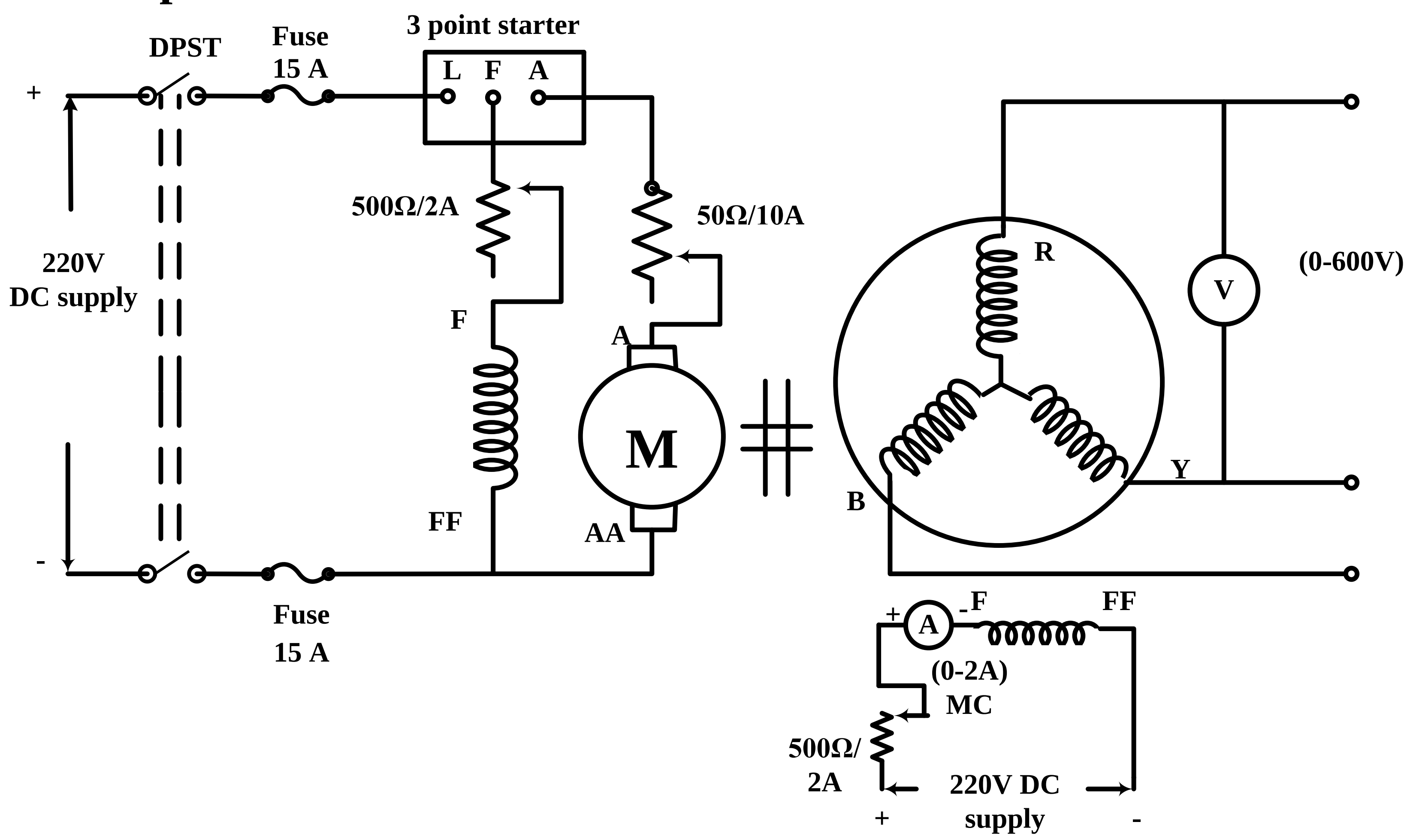
1. The autotransformer should be kept at its minimum position when not required.
2. In blocked rotor test only rated current is applied and not rated voltage.
3. When blocked rotor test is performed values should be taken quickly.
4. In no-load test the rotor should be made to move freely.
5. In no-load LPF wattmeter and at blocked rotor UPF wattmeter should be used.
6. Accurate values should be noted without any errors.

Result:

Viva Questions

1. What is the torque line in the Circle Diagram?
2. In comparison with transformer Induction motor is having high efficiency or low efficiency
3. What are the advantages of circle diagram?
4. What is the assumption made for drawing a circle diagram?
5. Is SC and OC test being Possible for both type of Induction motors
6. What are the different starting methods of a 3 phase induction motor?
7. What is the value of slip for an induction generator?

Circuit diagram:
Open circuit



Regulation of a three -phase alternator by Synchronous Impedance & M.M.F. methods

Aim: To obtain the percentage regulation of an alternator at full load by using

I. Synchronous impedance method
II. MMF method

Name plate details:

3-phase alternator	DC shunt motor
Rated voltage:415V	Rated voltage:220V
Rated current:4.2A	Rated current:19A
Rated speed:1500	Rated speed:1500 RPM
Excitation current1.2A:	Excitation current:1.6A
Frequency: 50	Rated power:5 HP
Rated power:3KVA	

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-600V)	MI	1
2	Ammeter	(0-5A)	MI	1
		(0-2A)	MC	1
3	Rheostat	500Ω/2A	Wire wound	2
4	Rheostat	50Ω/10A	Wire wound	1
5	Tachometer	0-9999	Digital	1
6	Connecting wires			Req

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'= X 100.

Where E0 and V are respectively the no Load voltage and full load voltage.

Regulation of an alternator by synchronous impedance method:

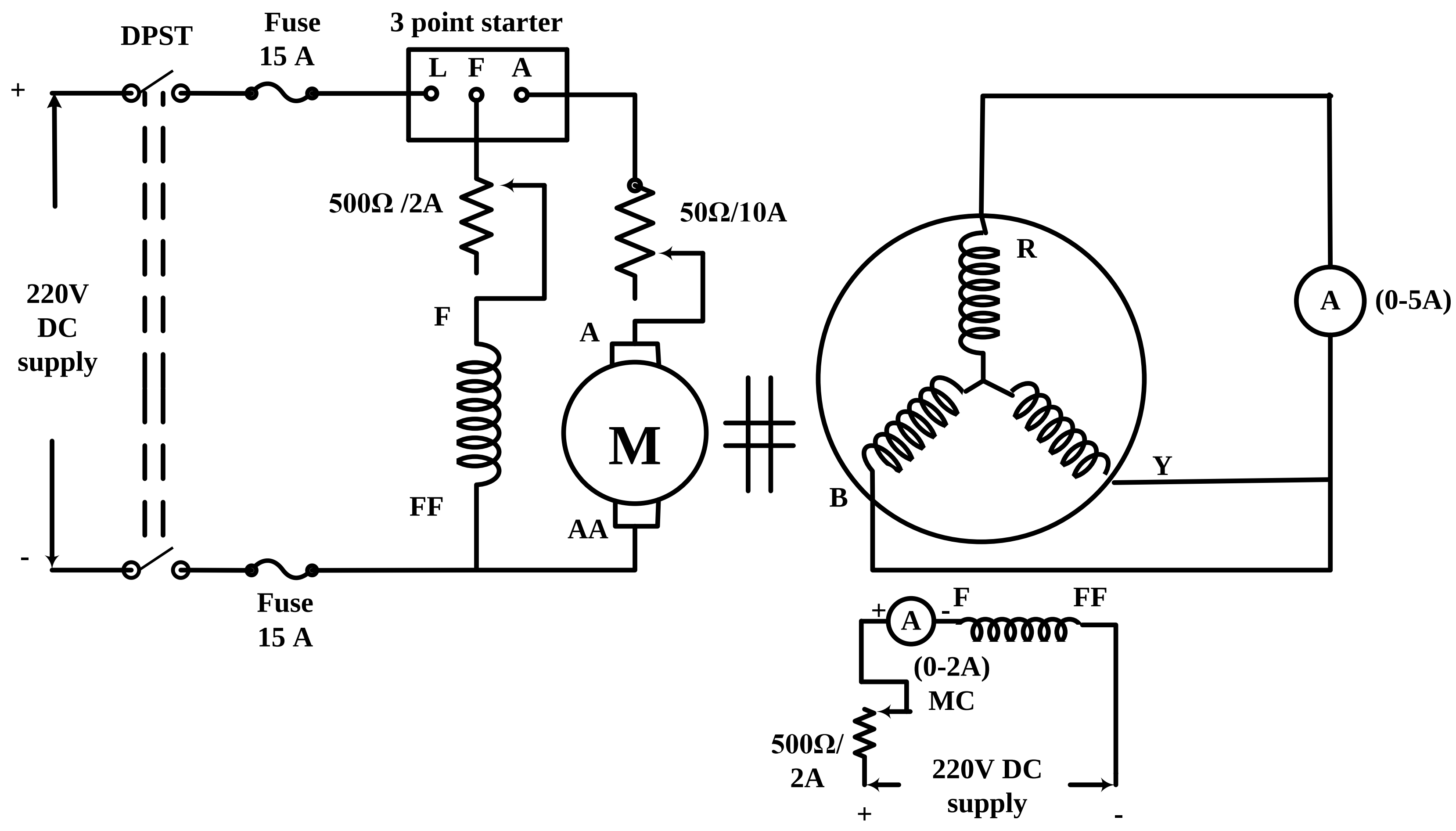
Ra per Phase: It is obtained from direct voltmeter and ammeter method by applying DC supply or by using multimeter to the stator winding. The effective value of Ra is increased due to skin effect,

Ra=1.3 x Ra(DC)

Open circuit: O.C.C 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.

Circuit diagram:
Short circuit



Short circuit:

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 aredrawn 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 E1. It may be assumed that the whole of this voltage E1 is being used to circulate the armature short circuit current I1 against the synchronous impedance Zs.

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 Ra is to be taken into account, then V+IRa cosф)on no load.
- Field AT required to overcome 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 If for normal voltage V.
OC represents If required for producing full load current on S.C vector AB=OC is drawn at an angle of
(90+ф) to OA. (if the p.f is lagging and 90-ф if pf is leading). The total field current is OB for which the
corresponding O.C voltage is E0.
:. percentage regulation= X 100.

Procedure:

Open circuit test:

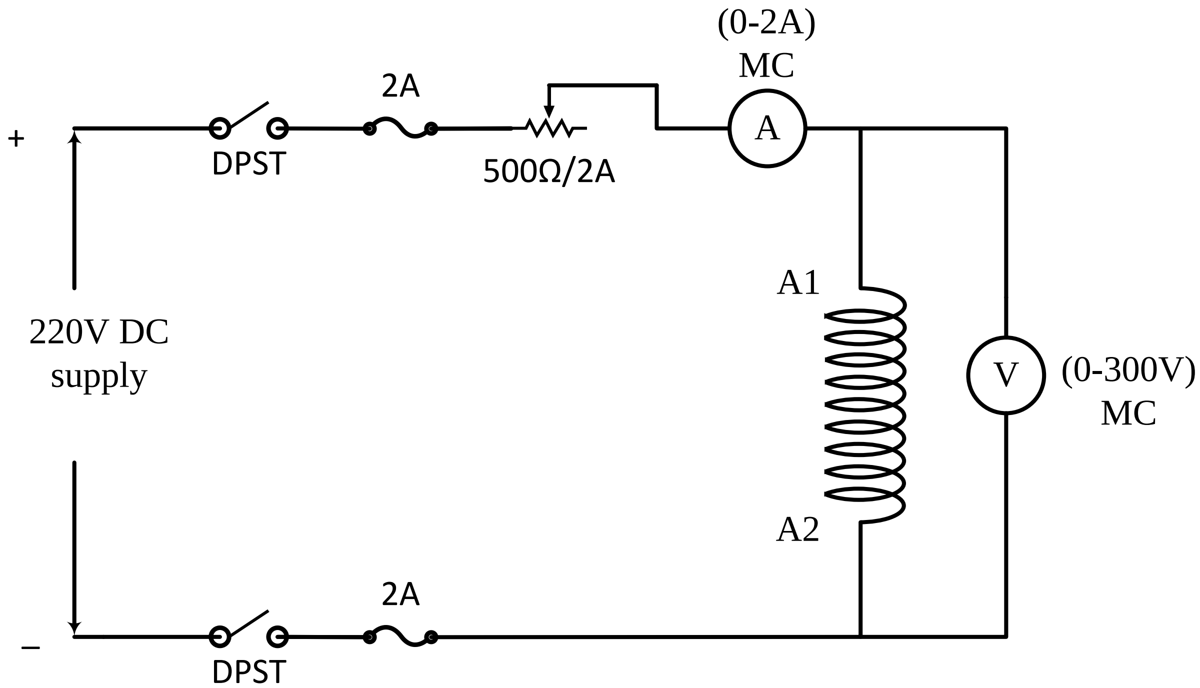
1. Connections are made as per the circuit diagram
2. Keep the potential divider in minimum output position
3. DC supply is given to the Motor & Excitation circuit
4. Start the motor by gently & steadily pushing the handle from start to run position
5. By Adjusting the field regulator of the motor set the speed of Alternator to rated Speed
6. Now vary the field excitation of alternator in steps and note down the voltmeter Reading (E_g) and ammeter reading as (I_f)
7. From the above data draw the curve between the Field Current **Vs** Generated EMF, which is **OCC**.

.

Tabular form:

Sl.no	OC test		Sl.no	SC test	
	Field current I_f (Amps)	OC voltage per phase(V_o)		Field current I_f (Amps)	SC current I_{sc} (Amps)

Determination of armature circuit Resistance R_a per phase



Tabular form

Sl.no	V(volts)	I(Amps)	R

Average R_a

Short circuit test:

1. After the completion of O.C.C keep the potential divider in minimum Output position
2. Close TPST knife Switch, and vary the field current in steps such that the ammeter Reads short circuit current
3. Note down the readings of field current (I_f) and short circuit Current as (I_{sc})
4. Continue the procedure till the Ammeter reads I_{fL}
5. Graph is plotted as SCC and Regulation is calculated from the graph.

PROCEDURE TO DRAW GRAPH FOR EMF METHOD:

1. Draw the Open Circuit Characteristic curve (Generated Voltage per phase VS Field current).
2. Draw the Short Circuit Characteristics curve (Short circuit current VS Field current)
3. From the graph find the open circuit voltage per phase (E1 (ph) for the rated short circuit current (Isc).
4. By using respective formulae find the Zs, Xs, Eo and percentage regulation.

PROCEDURE TO DRAW GRAPH FOR MMF METHOD:

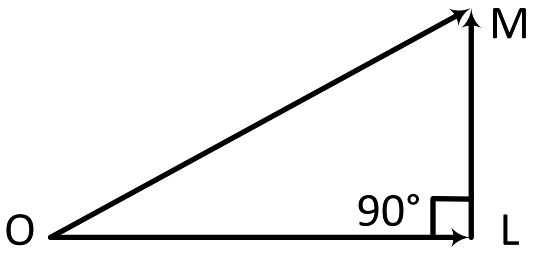
1. Draw the Open Circuit Characteristic curve (Generated Voltage per phase VSField current).
2. Draw the Short Circuit Characteristics curve (Short circuit current VS Field current)
3. Draw the line **OM** to represent

Determination of armature circuit Resistance R_a per phase
Procedure:

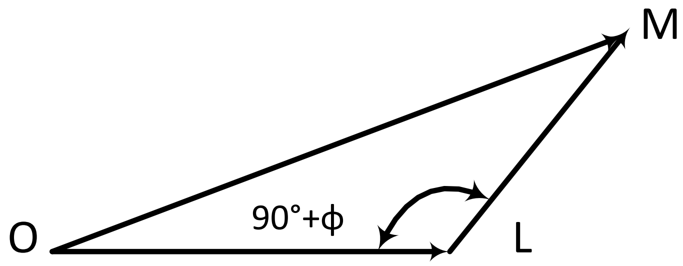
Measurement of Stator resistance

5. Connect the circuit as per the circuit diagram.
6. Keeping rheostat in maximum resistance position switch on the 220 V Dc supply.
7. Using volt-ammeter method measure the resistance of the stator winding.
8. After finding the stator resistance, Rdc must be multiplied with 1.6 so as to account for skin effect i.e. Rac = 1.6 Rdc.

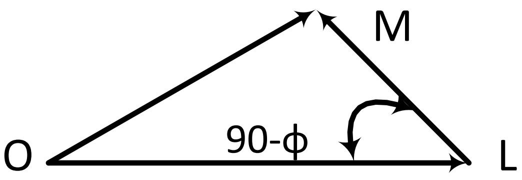
Phasor diagram for MMF method:



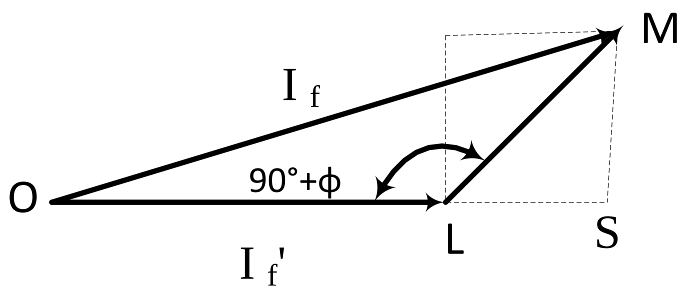
Unity power factor ϕ=0



lagging power factor



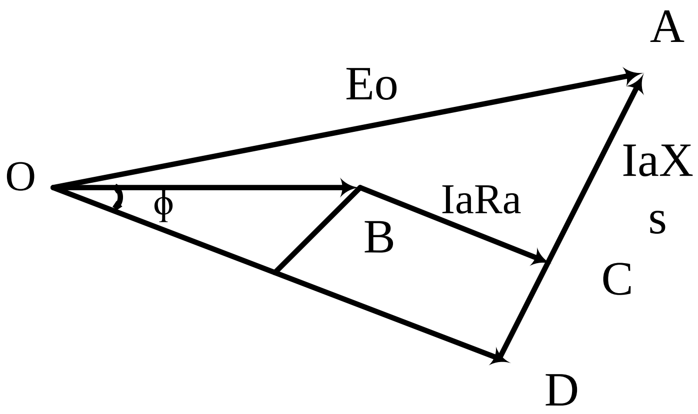
leading power factor



$$OM = \sqrt{(OL + LS)^2 + MS^2}$$

$$OM = \sqrt{(OL + LM \sin \phi)^2 + (LM \cos \phi)^2}$$

Phasor diagram of Synchronous impedance method



Calculations:

$$E_O = OA = \sqrt{OD^2 + DA^2}$$

$$Z_S = \frac{V_{OC}}{I_{SC}} \Omega \; at\ constant\ I_F$$

$$Z_S = \frac{AC}{BC} \Omega$$

Where AB= Rated open circuit voltage at a field current/Ph

AC= Rated short circuit current at that field current /Ph

$$X_S = \sqrt{Z_S^2 - R_a^2}$$

$$E = \sqrt{(V\cos\phi + I_a R_a)^2 + (V sin\phi \pm I_a X_s)^2}$$

+ve for lagging power factor - ve for leading power factor

Eo = No load voltage developed in armature

E = No load voltage after allowing for armature reaction

V = Rated terminal voltage

Armature resistance Ra (DC) = ……………Ω

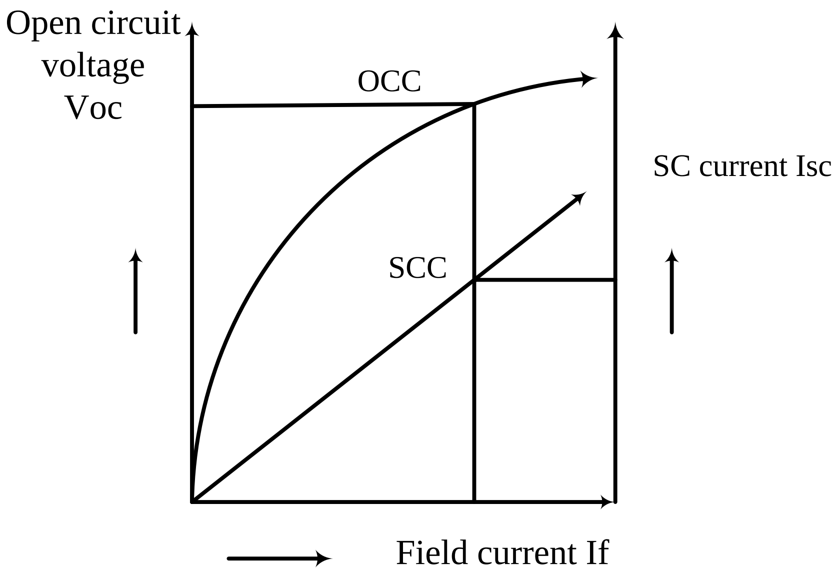
Armature resistance Ra (AC) = 1.6 Ra in DC = ……………. Ω

Synchronous impedance Zs = (Eo / Isc) Ω = ……………… Ω

$$\%Regulation = \frac{(E_o - V)}{V} * 100$$

Graph:

1. Field current I_f V_s Generated EMF/Ph
2. Field current I_f V_s Short circuit current I_{sc}

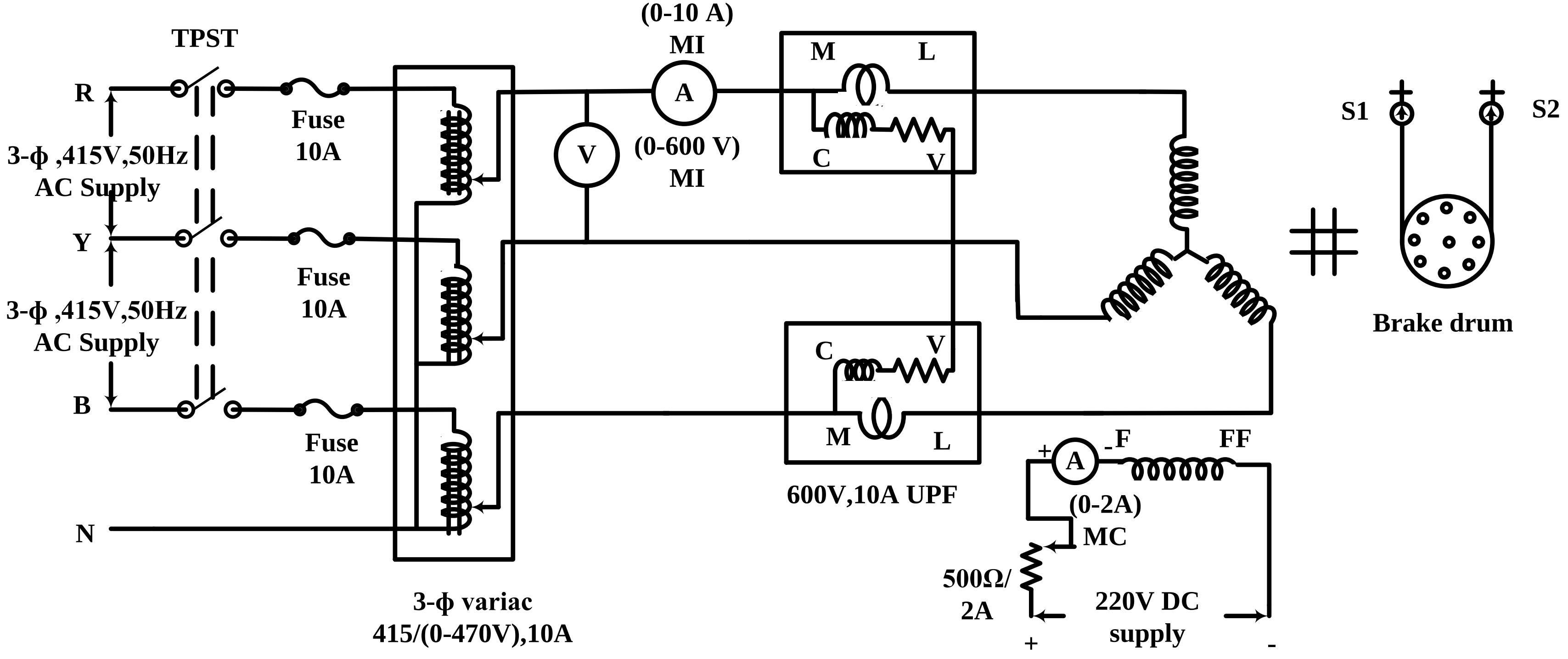


Result:

Viva Questions:

1. What is the working principle of alternator?
2. Give the difference between A.C. Generator and D.C Generator.
3. Why alternators are rated in KVA?
4. What are advantages of stationary armature?
5. Is the efficiency of the alternator is determined by direct loading?
6. Give the e.m.f equation of an Alternator?

Circuit diagram:
V and inverted V curves of synchronous motor



V and Inverted V curves of a three— phase synchronous motor.

Aim: To determine the variation of armature current and power factor of a synchronous motor with excitation

Name plate details:

Parameter	Synchronous motor
Rated power	5 HP
Rated voltage	415 V
Rated current	6.2 A
Rated speed	1500 RPM
Excitation current	2 A

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-600V)	MI	1
2	Ammeter	(0-10A)	MI	1
3	Ammeter	(0-2A)	MC	1
4	Wattmeter	600V,10A UPF	Dynamometer	2
5	3-ϕ variac	415V/(0-470V),10A	Core	1
6	Connecting wires			req

Theory:

The variations of the stator current against the field current of a synchronous motor for a constant mechanical output are called a V-curve. This curves is drawn taking field current on x axis and armature current on y-axis. Inverted 'V' curves are drawn taking field current on X axis and power factor on Y-axis.

Normal Excitation: The armature current is minimum at a particular value of field current, which is called. The normal field excitation. The operating p.f of the motor is unity at this excitation and thus the motor is equivalent to a resistive type of load.

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

A synchronous motor is a double-excited machine; its armature winding is energized from an a.c source and its field winding from d.c source. Synchronous motor operates at unity power factor when field current is enough to set up the air-gap flux, as demanded by constant applied voltage. This field current, which causes unity power factor operation of the synchronous motor, is called normal excitation or normal field current.

If the motor is under excited i.e, current is less than normal excitation, there will be some deficiency in flux to compensate that winding draws a magnetizing current from the a.c source and

Tabular form:

Sl.no	Supply voltage	Wattmeter W_1(Watts)	Wattmeter W_2(Watts)	Armature current I_a	Field current I_f	$\cos\phi = \frac{W}{\sqrt{3}V_L I_L}$

Calculations:

$$\cos\phi = \frac{W}{\sqrt{3}V_L I_L}$$

Where $I_L = I_a + I_f$

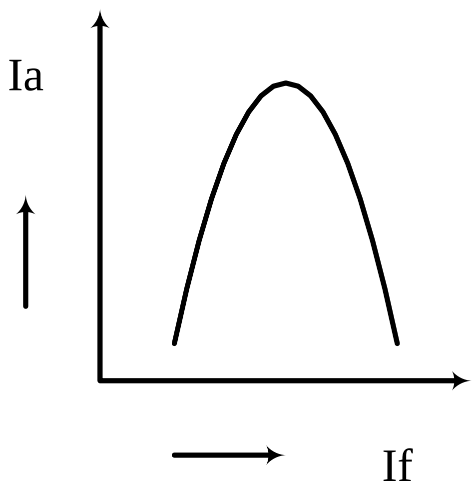
Or

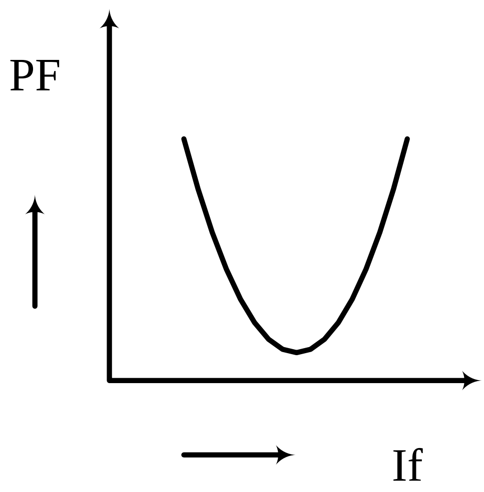
Power factor $\cos\phi = \cos(\tan^{-1}\frac{(\sqrt{3}W_1 - W_2)}{W_1 + W_2})$

$$\phi = (\tan^{-1}\frac{(\sqrt{3}W_1 - W_2)}{W_1 + W_2})$$

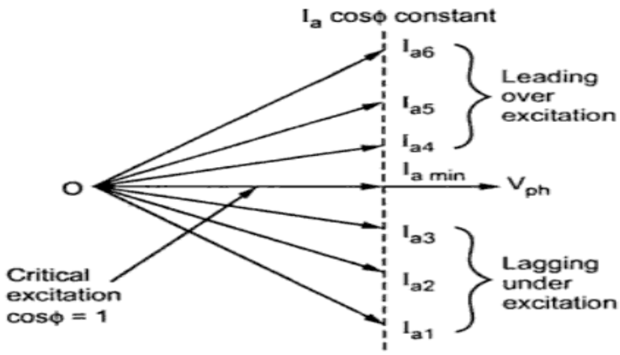
Model Graphs:

1. Armature current V_s Excitation
2. Power factor V_s Excitation





as a result of it, the motor operates at a lagging power factor. In other case, in over excited i.e, field current more than normal excitation machine operates at leading power factor. In the below figure you can observe leading and lagging variations.



Procedure:

1. Make the connections as per the circuit diagram.
2. Keep the variac in minimum position and field rheostat in max position before giving supply to synch motor
3. Close the TPST switch. By adjusting the autotransformer from minimum position to Maximum position till rated supply is given to the motor
4. In order to give the excitation to the field for making it to run as synchronous motor Close the DPST switch.
5. By varying the field rheostat note down the excitation current, armature current and the power factor for various values of excitation.
6. The same process will be repeated for the loaded condition.
7. Later the motor will be switched off and graph will be plotted

Precautions:

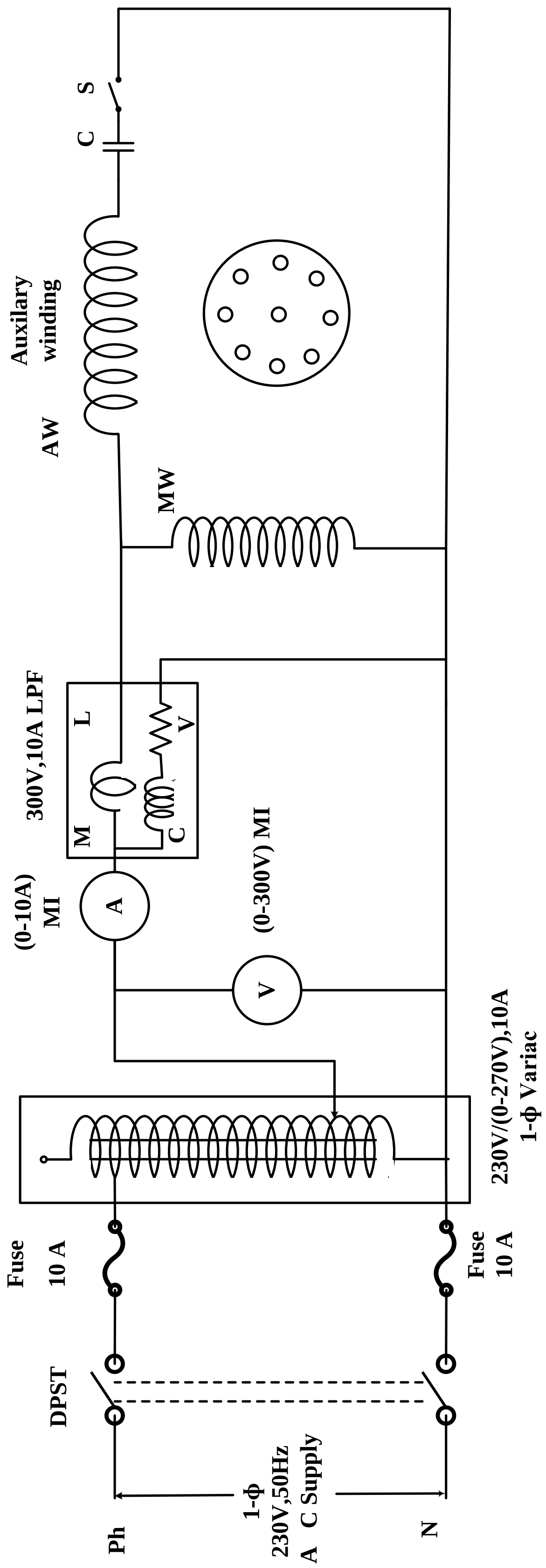
1. The Potential barrier should be in maximum position.
2. The motor should be started without load.
3. Initially TPST switch is in open position.

Result:

Viva Questions:

1. What is the principle operation of a Synchronous Motor?
2. What is the application of Synchronous Motor?
3. What is advantage of plotting the V & Λ Curves
4. What is Load Angle?
5. The active component of armature current is having const magnitude or varies
6. What happens to the power factor if the field current is gradually increased?

Circuit diagram :
No load



Equivalent Circuit of a single phase induction motor

Aim: To draw the performance characteristics of a single phase induction motor by Conducting the no-load and blocked rotor test.

Name plate details:

Parameters	1-ϕinduction motor
Rated power	1.5KW/2HP
Rated voltage	230V
Rated current	18A
Rated speed	1420 RPM

Apparatus required:

Sl.no	Name of the Apparaturs	Range	Type	Quantity
1	Voltmeter	(0-300V)	MI	1
		(0-150V)	MI	1
2	Ammeter	(0-10A)	MI	1
		(0-15A)	MI	1
3	Wattmeter	300V,1A LPF	Dynamometer	1
4	Wattmeter	150V,15A upf	Dynamometer	1
5	1-ϕ variac	230V/(0-270V),10A	Core	1
6	Connecting wires			Req

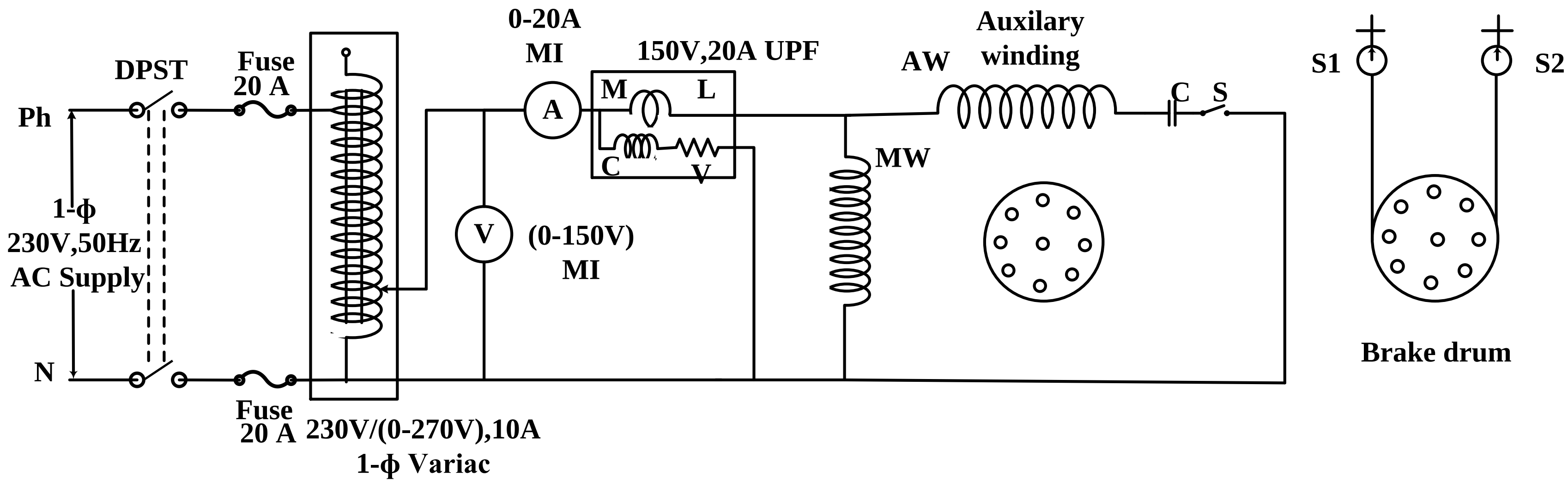
Theory:

No-load and blocked rotor tests are performed on 1-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 a stator winding, represented by its resistance R1 and leakage reactance X1 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 the equivalent circuit can be calculated from the following steps.

1. Measurement of A.C. resistance of stator main winding:

The D.C. resistance of main winding of stator i.e., Rdc is measured by V-I method at full load current the effective value of resistance is taken 1.3 times Rdc.

Circuit diagram:
Blocked rotor test



2. **Magnetizing reactance Xm from no-load test:** At no-load $\cos \Phi 0 = W0 / (V0 * I0)$

Now voltage across a and b is
$Vab = (V0 – I0) / (\Phi 0 * (r1 + r2^1/4) + J * (x1 + x2^1/2))$
Thus $Xm = 2 * (Vab/ I0)$
3. PARAMETERS FROM BLOCKED ROTOR TEST
$Ze = Vsc/Isc$ $Re = Wsc/I^2sc$
$Xe = \sqrt{(Ze^2 - Re^2)} = X1^1 + X2^1$
Moreover, X1 can be taken equal to $X2^1$
i.e., $X1 = X2^1 = ½ Xe$
Thus $X2f = X 2b = ½ X2^1$
Similarly, $R2f = R2b = ½ R2^1$
FROM NO-LOAD TEST:
Under no-load, motor runs at rated voltage and frequency. S is extremely small under no-load and then the equivalent circuit can be simplified as
1. Term $R2^1/ 2S$ concerning to forward rotating field becomes quite large and can be treated as infinite.
2. Term $R2^1/ (2(2-S))$ reduces equal to $R2^1/4$ which is much smaller than Xm/2 and as such the exciting branch of backward rotating field may be considered to be open as shown in the figure.

Procedure:
No load Test:
1. The circuit connections are made as per the circuit diagram.
2. Be sure that variac (auto transformer) is set to zero output voltage position before starting the experiment.
3. Now switch ON the supply and close the DPST switch.
4. The variac is varied slowly, until rated voltage is applied to motor and rated speed is obtained.
5. Take the readings of Ammeter, Voltmeter and wattmeter in a tabular column.
6. The variac is brought to zero output voltage position after the experiment is done, and switch OFF the supply.

Blocked Rotor Test:
1. To conduct blocked rotor test, necessary meters are connected to suit the full load conditions of the motor.
2. Connections are made as per the circuit diagram.
3. Before starting the experiment variac (auto transformer) is set to zero output voltage position. The rotor (shaft) of the motor is held tight with the rope around the brake drum.
4. Switch ON the supply, and variac is gradually varied till the rated current flows in the induction motor.
5. Readings of Voltmeter, Ammeter, and wattmeter are noted in a tabular column.
6. The variac is brought to zero output voltage position after the experiment is done, and switch OFF the supply.
7. Loosen the rope after the experiment is done

Tabular form:
No-load test

Sl.no	Voltage Vo	Current I_o	Power W_o

Blocked rotor test

Sl.no	Voltage Vsc	Current I_{sc}	Power W_{sc}

Calculations

Impedance due to forward field $Z_f = R_f + jX_f = \frac{R'_2}{2s} + j\frac{X'_2}{2}$ $in\ parallel\ with$ $\frac{jX_m}{2}$

Impedance due to backward field $Z_b = R_b + jX_b = \frac{R'_2}{2(2-s)} + j\frac{X'_2}{2}$ $in\ parallel\ with$ $\frac{jX_m}{2}$

Stator impedance $Z_1 = R_1 + jX_1$

Total equivalent impedance $Z_{eq} = Z_1 + Z_f + Z_b$

Motor current $I_1 = \frac{V}{Z_{eq}} = \frac{V}{Z_1+Z_f+Z_b}$

Power factor $= \frac{R_{eq}}{Z_{eq}} = \frac{R_1+R_f+R_b}{Z_1+Z_f+Z_b}$

$$E_{mf} = I_1 Z_f$$

$$E_{mb} = I_1 Z_b$$

$$I'_{2f} = \frac{E_{mf}}{\frac{R'_2}{2s} + j\frac{X'_2}{2}} = \frac{I_f Z_f}{\sqrt{(\frac{R'_2}{2s})^2 + (\frac{X'_2}{2})^2}}$$

$$I'_{2b} = \frac{E_{mb}}{\frac{R'_2}{2(2-s)} + j\frac{X'_2}{2}} = \frac{I_b Z_b}{\sqrt{(\frac{R'_2}{2(2-s)})^2 + (\frac{X'_2}{2})^2}}$$

Air gap power for forward field $P_{gf} = (I'_{2f})^2 \frac{R'_2}{2s}$ $watts$

Air gap power for backward field $P_{gb} = (I'_{2b})^2 \frac{R'_2}{2(2-s)}$ $watts$

Precautions:

1. While conducting O.C. test, at starting time, increase the auto transformer voltage up to 30Volts and wait for some time, because the motor speed increase slowly and current is very high during starting and it decreases slowly.
2. Avoid loose connections.
3. Make sure that auto transformer is in zero position before starting

Mechanical power output for forward field $P_{mech\,f} = (1-s)P_{gf} = (I'_{2f})^2 \frac{R'_2}{2}\frac{(1-s)}{s}$

Mechanical power output for backward field $P_{mech\,b} = 1-(2-s)P_{gb} = -(I'_{2f})^2 \frac{R'_2}{2}\frac{(1-s)}{(2-s)}$

Mechanical power output $P_{mech\,net} = P_{mech\,f} + P_{mech\,b}$

$$= (1-s)P_{gf} + [1-(2-s)P_{gb}]$$

$$= (1-s)\left[P_{gf} - P_{gb}\right] = P_{mech\,f} - P_{mech\,b}$$

Torque developed for forward field= $\frac{P_{gf}}{\frac{2\pi N_S}{60}} = \frac{9.55P_{gf}}{N_S}$

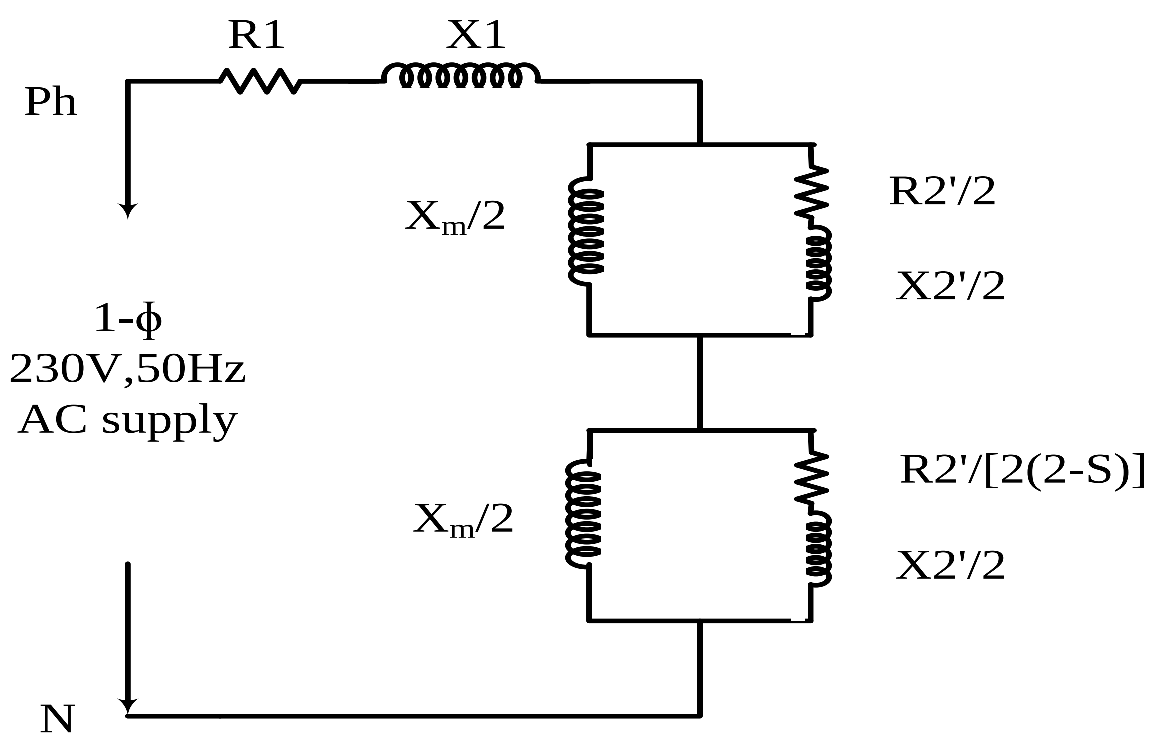
Torque developed for backward field= $\frac{9.55P_{gb}}{N_S}$

Net torque developed $\frac{9.55}{N_S}(P_{gf} - P_{gb})$

Net power output =$P_{mech\,net} - friction\ and\ windage\ losses - core\ losses$

Motor efficiency η = $\frac{OUTPUT}{INPUT}$×100

Equivalent circuit of 1-ϕ Induction motor

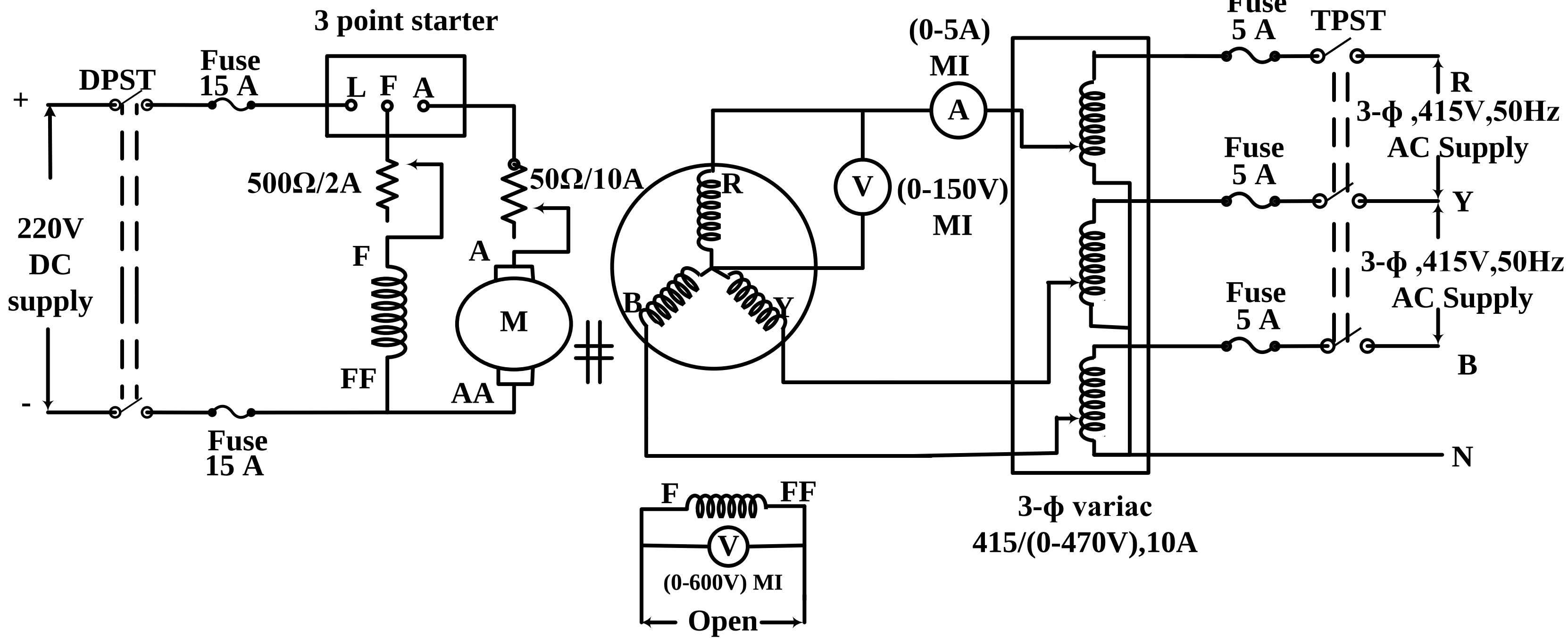


Result:

VIVA QUESTIONS:

1. State the conditions, under which no-load test is performed?
2. Which theory is commonly used for the analysis of induction motor?
3. What is the slip of forward and backward rotors?
4. What is the phase displacement in space between the two windings?
5. How the phase splitting can be increased between the two windings?
6. How is the starting winding disconnected from the supply?

Circuit diagram:
Slip test



Determination of Xd and Xq of a salient pole synchronous machine

Aim: To determine Xd i.e direct-axis synchrounous reactance and quadrature axis synchronous reactance xq of a salient pole synchronous machine by slip test

Name plate details:

Parameter	DC shunt motor	Alternator
Rated power	5Hp	3KVA
Rated voltage	220V	415V
Rated current	19A	4.2A
Rated speed	1500	1500
Rated field current	1.04A	

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-150V)	MI	1
2	Ammeter	(0-5A)	MI	1
3	Rheostat	500Ω/2A	Wire wound	1
4	Rheostat	50Ω/10A	Wire wound	1
5	3-ϕ variac	415/(0-470V),10A	Core	1
6	Tachometer	0-9999	Digital	1
7	Connecting wires			Req

Theory:

Using slip test, slip test, xd and xq can be determined. The synchronous machine is driven by a separate motor at a speed slightly different from synchronous speed. the field winding is left open and positive sequence balanced voltages of reduced magnitude and of rated frequency are impressed the armature terminals. Under these conditions, the relative velocity between the field poles and the rotating armature mmf wave is equal to the difference between synchronous speed and the rotor speed i.e slip speed. A small A>C voltage across the open field winding indicates that the field poles and rotating MMF wave, are revolving in the same direction and that is what is required in the slip test. if the field poles revolve in a direction opposite to the rotating MMF wave, negative sequence reactance would be measured.

At one instance, when the peack of armature MMF wave is in line with the field pole or direct axis, the reluctance offered by the small air gap is minimum. At this instant the impressed terminal voltage per phase divided by the corresponding armature current per phase divided by the corresponding armature current per phase give d axis synchronous reactance.

After on e-quarter of slip cycle, the peack of armature MMF wave acts on the interplar or q-axis of the magnetic circuit and the reluctance offered by long airgap is maximum. at this instant,

Tabular form:

Sl.no	I_{max}	I_{min}	V_{max}	V_{min}	X_d	x_q

Calculations:

$$X_d = \frac{\text{Maximum}\, armature\ terminal\ voltage\ per\ phase}{Minimum\ armature\ current\ per\ phase}$$

$$X_q = \frac{Minimum\ armature\ terminal\ voltage\ per\ phase}{Maximum\ armature\ current\ per\ phase}$$

the ratio of armature terminal voltage per phase to the corresponding armature current per phase, gives q-axis synchronous reactance xq

Oscillograms of armature current, terminal voltage and the induced EMF in the O.C field winding much larger slip than would be used in practice, has been shown in fig. when the armature MMF wave is along the direct axis, the armature flux passing through Of winding is maximum. Therefore, the induced field EMF i.e dqa/dt is zero. When armature MMF wave is along q-axis the armature flux linking the field winding is zero. therefore, the induced field emf dqa/dt is maximum. thus the q-axis can be located on the oscillogram . Waveforms of voltage across open field and the armature current varies cyclically at twice the slip frequency.

Procedure:

1. Give connections as per the circuit diagram.
2. Initially the external resistance in armature circuit is kept at maximum position and Resistance in field circuit is kept at minimum position.
3. Switch ON the power supply, start the motor with help of 3-point starter.
4. Gradually cutoff the external resistance in the motor armature circuit and adjust the field resistance till the motor attain the rated speed.
5. Apply 20% to 30% of the rated voltage to the armature of the alternator by adjusting the 3-phase autotransformer.
6. To obtain the slip and the maximum oscillation of pointers, the speed is reduced Slightly lesser than the synchronous speed.
7. Maximum current, minimum current, maximum voltage and minimum voltage are noted.
8. Find out the direct and quadrature axis impedances.

Precautions:

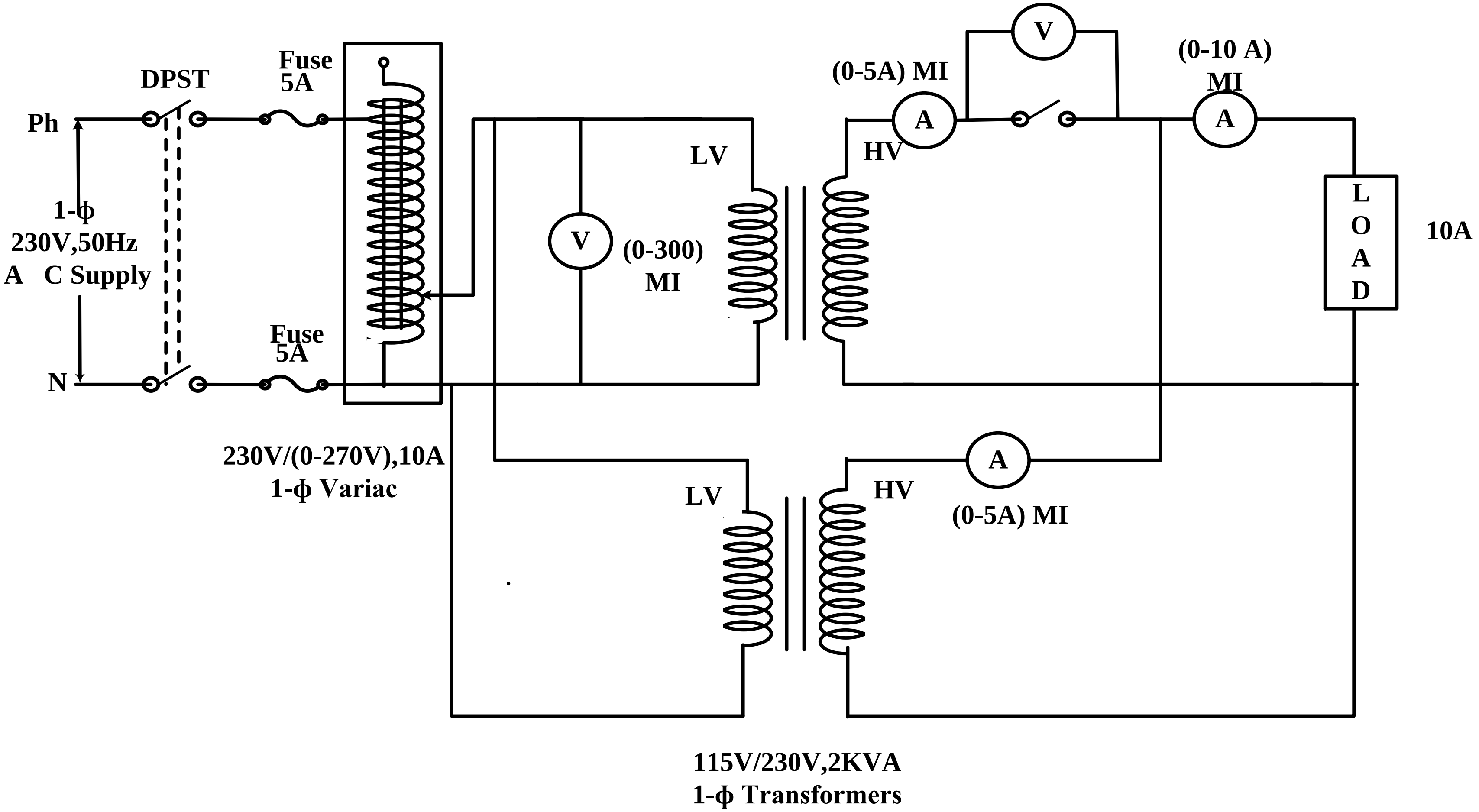
1. The motor field rheostat should be kept in the minimum resistance position.
2. The Alternator field should be kept open throughout the experiment.
3. The direction of rotation due to prime mover and due to the alternator run as the motor should same.
4. Initially all the switches are kept open

Result:

Viva Questions:

1. What is meant by Quadrature and Direct axis reactance?
2. What is meant by two axis reactance theory
3. What is the relation between Xd &Xq for non-salient pole machine?
4. Why this test is called as Slip test
5. What are the advantages of Slip Test?
6. Which type of power plants Salient Pole Alternators are used.

Circuit diagram: Parallel operation



Parallel operation of Two Single Phase Transformers

Aim: To operate two transformers in parallel and to determine the relation of sharing of loads to their impedances

Name plate details:

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-300V)	MI	1
		(0-600V)	MI	1
2	Ammeter	(0-10A)	MI	1
		(0-5A)	MI	2
3	1-ϕ variac	230V/(0-270V)	Core	1
4	Connecting wires			Req

Theory:

If the load on a transformer is increased beyond its capacity, then there are two alternatives.

a) to change transformer of increased capacity.

b) to connect another transformer in parallel to the existing transformer to meet the increased load.

There are certain definite conditions which must be satisfied in order to avoid any load circulating currents and to ensure that the transformers share the common load in proportion to their KVA ratings. Those are:

1. Primary winding of the transformers should be suitable for the supply system voltage and frequency.
2. The transformers should be properly connected with regar to polarity.
3. The voltage ratings of both primaries and secondaries should be identical. In other words,the transformers should have the same turn ratio i.e. transformation ratio.
4. The percentage impedances should be equal in magnitude and have the same X/R ratio inorder to avoid circulating currents and operation at different power factors.
5. With transformers having different KVA ratings, the equivalent impedances should be inversely proportional to the individual KVA rating if circulating currents are to be avoided.

Observation:

Sl.no	Transformer 1 current I_1	Transformer 2 current I_2	Load current I_L

Procedure:

Polarity Test

1. Connections are made as per the circuit diagram.
2. Apply voltage of say 100 V.
3. Measure voltage across terminals A-a
4. If VA-a is equal to V_1+V_2 then it is Additive polarity.
5. If VA-a is equal to V_1-V_2 then it is Subtractive polarity.
6. Mark the terminals (Dot convention) after the polarity test.

Parallel operation

1. Connections are made as per the circuit diagram.
2. Switch on the power supply.
3. Slowly increase the voltage up to its rated value of transformer primaries.
4. Verify the voltage across the switch is one of the secondary of transformer, if it is zero, then close the switch, otherwise switch off the supply and change for correct polarity and repeat the steps 3 and 4.
5. After closing the switch, gradually increase the load in steps and note the values of all meters at each step till full load is reached. Decrease the load and switch off the mains supply
6. Tabulate the readings as shown.

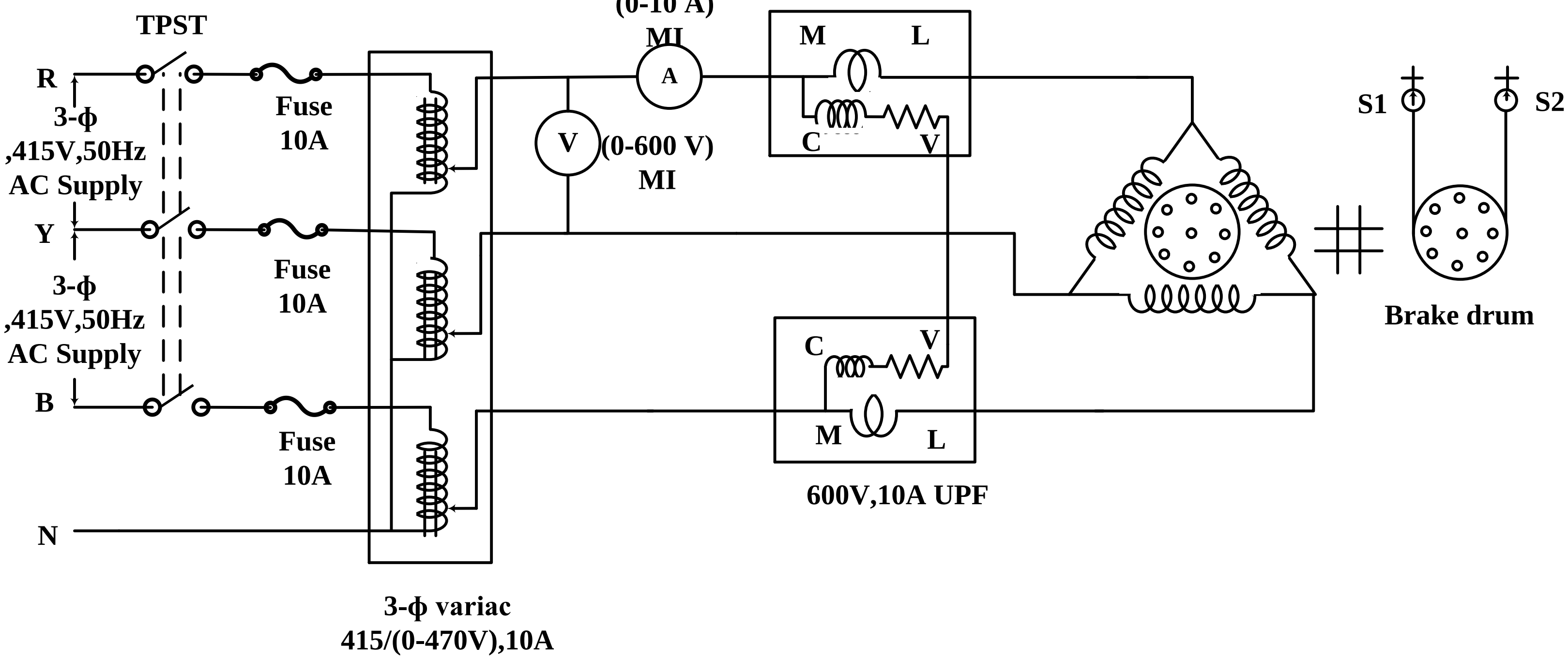
Result:

Viva Questions:

1. What should be the rating of two transformers for parallel operation
2. What is the advantage of parallel operation of transformers?
3. With the help of parallel operation can we calculate the efficiency
4. What are the different losses in a transformer?
5. If the regulation is less than the transformer is a good transformer or not
6. Define regulation of a transformer
7. What is the effect on losses of a transformer with variation supply frequency?

CIRCUIT DIAGRAM:

Brake test on 3-ϕ Induction motor



Brake test on three phase Induction Motor

Aim: To perform the Brake test on the given 3-ϕ Induction motor and to obtain the performance characteristics of the motor.

Name plate details:

Rated voltage	415V
Rated current	7.5A
Rated speed	1430
Power	5HP/3.2KW
Frequency	50 Hz

Apparatus required:

Sl.no	Name of the apparaturs	Range	Type	Quantity
1	Voltmeter	(0-600V)	MI	1
2	Ammeter	(0-10A)	MI	1
3	Wattmeters	600V,10A.UPF	Dynamometer	2
4	3-ϕ Variac	415/(0-470V),10A	Core	1
5	Tachometer	0-9999	Digital	1
6	Connecting wires			Req

Theory:

Slip ring induction motor is a type of induction motor in which the rotor is provided with 3 phase double layer distributed winding consisting of coils as used in alternators. The rotor is wound for as many poles as the number of stator poles and is always wound 3 phase even when the stator is wound two phase. The three phase are starred internally. The other three winding terminals are brought out and connected to three insulated slip rings mounted on then shaft with brushes resting on them. These brushes are further externally connected to a three phase star connected rheostat. This makes possible the introduction of additional resistance in the rotor circuit during the starting period for increasing the starting torque of the motor and for changing its speed torque /current characteristics. When running under normal conditions the slip rings are automatically short circuited by means of a metal collar which is pushed along the shaft and connections all the rings together. Next the brushes are automatically lifted from the slip rings to reduce the frictional losses and the wear and tear.

In the wound rotor type the rotor slots accommodate an insulated winding similar to that used on the stator. The rotor winding is uniformly distributed and is usually connected in star. The three leads from the star connection ate then connected to three slip rings of collector rings mounted on but insulated from the shaft. Carbon brushes pressing on the slip rings allow external resistors to be inserted in series with the rotor

Winding for speed and starting torque control. Actually the wound type rotor of induction motor costs more and requires increased maintenance it is therefore only used where

i) The driven load requires speed control

ii) High starting torque is required.

Sl.no	V	I	Watts W		Spring balance S		Speed N	Torque =9.81*r*(S_1-S_2)	Input W=W_1/+ W_2	Output = 2πNT/ 60	%η= OP/IP
			W1	W2	S1	S2					

Since the rotor is wound with polyphase windings and carrier slip rings it is called slip ring induction motor or wound rotor

Procedure:

1. Connections are made as per the circuit diagram.
2. Switch on the 3–phase AC supply, apply the rated voltage by using 3-φ variac
3. Take down the readings of all the meters, spring balance readings and the speed under No load condition.
4. Increase the load on the motor gradually by tightening the belt.
5. Record the readings of all the meters, spring balance readings and the speed at every Setting of the load.
6. Observations may be continued up to the full load current rating of the motor.
7. Reduce the load gradually and finally unload it completely and decrease the voltage to zero. Switch off the supply.
8. Note down the effective diameter of the brake drum.

Precautions:

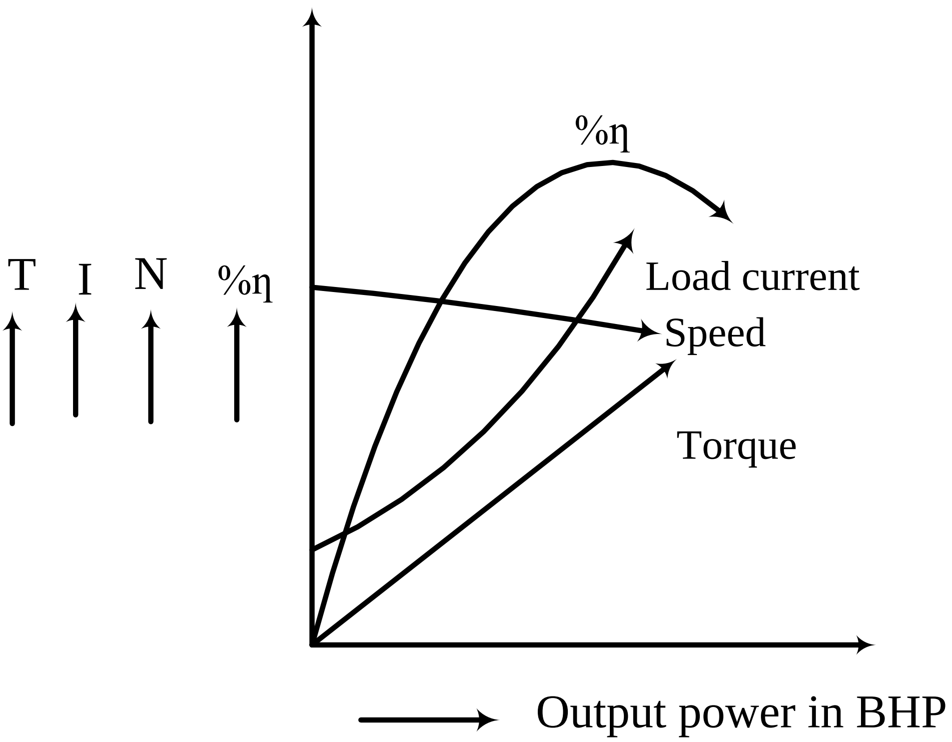
1. There should not be loose connections in the circuit.
2. Don’t run the machine beyond the full-load current.
3. Make sure that Auto Transformer is in zero position before starting.

Formulae used:

1. Input power $W=W_1+W_2$ Watts
2. Output power $=2\pi NT/60$ Watts
3. Torque $T= 9.81*R*(S_1-S_2)$ N-M where R is the radius of the drum
4. % Efficiency = (Output power/Input power) *100
5. % slip =(Ns-N)/Ns*100

Model graphs:

1. Output Vs Speed
2. Output Vs Torque
3. Output Vs Efficiency
4. Output Vs Current
5. Slip Vs Torque



Result:

Viva Questions:

1. What is the working principle of 3 – phase induction motor?
2. What are the different types of 3 – phase induction motor?
3. As the load increases, what happens to the speed of the motor?
4. Why 3 – phase induction motor is widely used for industrial applications?
5. What are the various losses in induction motors?
6. Why induction motor is called as rotating transformer?