Heaven’s Light is Our Guide

Rajshahi University of Engineering and Technology

RUET

Department of Electrical and Electronic Engineering

LAB SHEET
Electrical Machine-I Sessional
EEE2106
(1.5 Credit)

INDEX

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04	Parallel operation of transformers.
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12	Starting an Induction Motor by applying star-delta starter.

LAB INFORMATION

In the laboratory we use :

01. DC Generator.
02. DC Motor.
03. Induction Motor
04. Synchronous machine
05. Starter.
06. Techo Meter.
07. Resistors.
08. Voltmeter.
08. Ammeter.
10. Wattmeter
11. Variac.

Study of the rating of different machines :

DC Generator:

The machine, which can transform mechanical energy to electrical energy, is called generator. If the output is DC voltage, then that machine is called dc generator.

DC motor:

The machine which can transform electrical energy to machine energy is called motor. If the input is DC, then this motor is called DC motor.

Rating Table:

DIRECT CURRENT MACHINE (DC GENERATOR / MOTOR)

KW **2 kW**	Volts- **250/250 V**	AMP – **8.0 A**
RPM **1450**	WOUND COMPOUND	
FLD-AMPS **0.467 A** AS SH GEN	FLD-OHMS 25 C **350 Ω**	
DUTY CONT 60 C RISE	ENCL DP SERVICE FACT **1.5**	
ARMATURE RESISTANCE - **1.68 Ω**		

DIRECT CURRENT MACHINE (DC GENERATOR / MOTOR)

KW 4 1/2 kW	Volts- **250/250 V**	AMP – **18.0 A**
RPM **1450**	WOUND COMPOUND	
FLD-AMPS **1.0 A** AS SH GEN	FLD-OHMS **25 C** **152.8 Ω**	
DUTY CONT **60** C RISE	ENCL DP SERVICE FACT **1.15**	
SUIT AS **5 HP**	**1500/ 3000** RPM **240 V**	
ARMATURE (dc) RESISTANCE - **1.72 Ω**		

SYNCHRONOUS MACHINE (CONSTANT SPEED MACHINE)

TYPE SJ		FRME 254Z
1500 RPM	50 CYCLE	50 C RISE
GENERATOR 4KVA **0.8 P.F**	**220/240 V 3** PHASE	**19.2 /9.6 A** FL AMP
MOTOR **6 HP 1.0 P.F**	**120 /240 V 3 HP**	**22 / 11 A** FL AMP
FILD-AMP MAX **2.1**		FILD VOLTS **125 V**
Line to line stator terminal (dc)Resistance = **0.75 Ω**		

Induction Motor: An AC motor, whose speed is varied with load.

3 – PHASE INDUCTION MOTOR

HP **3**	SERVICE FACTOR **1.15**
FL RPM **1450**	
VOLTS **220 /440**	PHASE **3**
FL AMPS **9.1 /4.55 A**	CYCLE **50**
TYPE M	FRAME **254 U**
C RISE **40** TIME	RATING CONT
SEC VOLTS **145**	SEC AMP **10**
Line to line stator terminal (dc)Resistance = **0.75 Ω**	

SINGLE PHASE INDUCTION MOTOR :

TYPE	DE **1028**
RATED VOLTAGE	**220 V**
RATED CURRENT	**6.6 A**
RATED POWER	**1 kW**
RATED SPEED	**2820 RPM**
FREQUENCY	**50 HZ**
INSULATION	CLASS **E**
P.F.	**COS φ = 0.90**
Main Winding (dc) Resistance = **3.95 Ω**	
Auxiliary Winding (dc) Resistance = **9.32 Ω**	

Experiment No: 01 **Date:**

Name of the Experiment: Polarity test and observation of voltage and current relation between primary and secondary of single phase transformer.

Theory: Transformer is a device for transferring electrical energy from one circuit to another circuit without a change in frequency. The Transformer in which primary voltage is greater than secondary voltage is called Step-up Transformer. Transformer in which secondary voltage is greater than primary voltage is called Step-down Transformer. There are many transformers still in service whose terminal does not have the standard markings. In order to interconnect these transformers with others, either for single-phase parallel operation or for poly-phase operation, it is necessary to determine the relative polarities of the terminals. A simple test is enough to accomplish this. For the circuit connections shown in the circuit diagram, when the voltmeter reading is equal to the sum of the secondary coil voltage, the coils are in additive polarity. Similarly when the voltmeter reading is the difference between the voltages of the secondary coil the coils are connected in subtractive polarity. This is how polarity of the coils with respect to a coil can be determined.

We know that the relation between primary and secondary voltage is,

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

$$\text{or,} \quad \frac{V_1}{V_2} = \frac{N_1}{N_2}$$

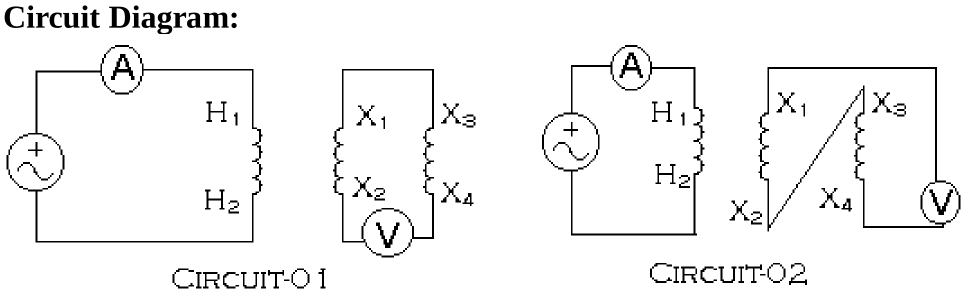
and the relation between primary and secondary current is, $\frac{I_1}{I_2} = \frac{N_2}{N_1} = K$

and secondary side resistance referred to primary is, $R_1 = \frac{R_2}{K^2}$.

Apparatus:

1. Transformer (150 V per coil, 1A).
2. Voltmeter(0-450V)
3. Ammeter(0-2A)
4. AC supply(220V)
5. Variac (0- 250V)

Circuit Diagram:



POLARITY TEST OF TRANSFORMER

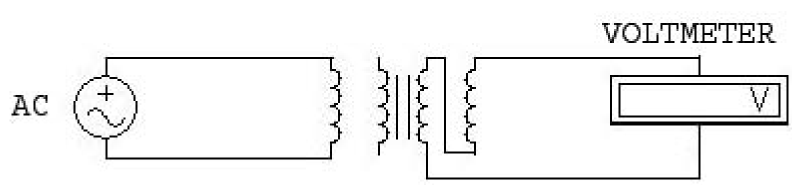


FIG:STEP-UP TRANSFORMER

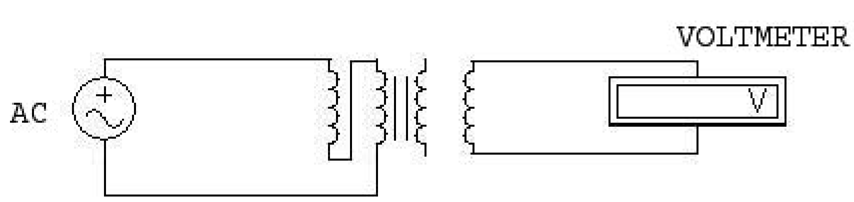
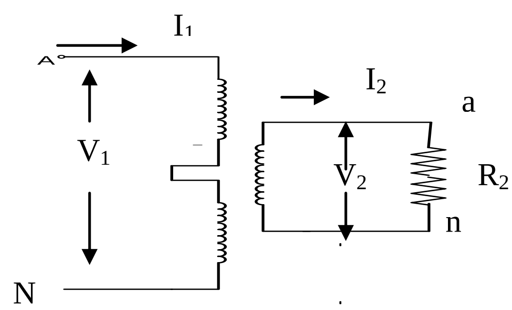


FIG:STEP-DOWN TRANSFORMER



Determination of Polarity: The primary side was given rated supply (150V). So, voltage of each coil was 150 volt. As in circuit-01 voltmeter reading was 0, the coils were in subtractive polarity. So, terminal X_1 and X_2 have opposite polarity and also terminal X_2 and X_4. In circuit-02 Voltmeter reading was 300. So, coils were connected is additive polarity. Thus, X_1 and X_3 have same polarity. Similarly X_2 and X_4 have same polarity.

So, if X_1 and X_3 are positive, X_2 and X_4 are negative and vice versa.

Data Table:

SL NO	Primary side VoltageV_1	Secondary side VoltageV_2	Turns Ratio,N_2/ N_1
01	100	50	0.5
02	150	75	0.5
03	200	150	0.5

SL NO	Primary side VoltageV_1	Secondary side VoltageV_2	Primary side Current I_1	Secondary side CurrentI_2	Turns Ratio, $K=N_2/N_1 = I_1/I_2$	Secondary side Resistance $R_2= V_2/I_2$	Equivalent resistance referred to Primary side $R_1= V_1/I_1 =R_2/K^2$	$R_1 =R_2/K^2$
01	100	50	0.25	0.50	0.50	100	400	400
02	100	50	0.30	0.60	0.50	83.33	333.33	333.32
03	100	48	0.37	0.70	0.53	68.57	270	244.1
04	100	45	0.42	0.80	0.526	56.25	238	203.3

Calculation:

$$\mathbf{R_1=\frac{V_1}{I_1}}$$

$$\mathbf{R_2=\frac{V_2}{I_2}}$$

$$\mathbf{R_1=\frac{R_2}{K^2}}$$

Precautions:

01. Care should be taken so that current in the coils does not exceed the rated value.

02. Winding should be given the rated or less than the rated supply.

Discussion:

Experiment No: 02 **Date:**

Name of the Experiment: Open circuit test and short circuit test of a single phase transformer.

Theory: We know that there the two types of losses of in transformer, such as copper loss and core loss. Copper loss is a variable loss and depends on current and core loss is a fixed loss and depends upon the voltage. Now the efficiency of a transformer is define as the ratio of output power to input power. Again the input power is equals to the sum of output power and losses. The losses can be fined out with open circuit test and short circuit test. The copper loss can be obtained by short circuit test and core loss can be obtained by the open circuit test. For Short Circuit Test first 0 voltage is applied to high voltage side and then the voltage is increased until for witch the rated current flows in low voltage side. Now the data or reading of the meters are taken. Again for Open Circuit Test 0 voltage is applied to low voltage side and then the voltage is increased until for which the rated voltage is obtained from high voltage side.
Now the data or reading of the meters are taken.

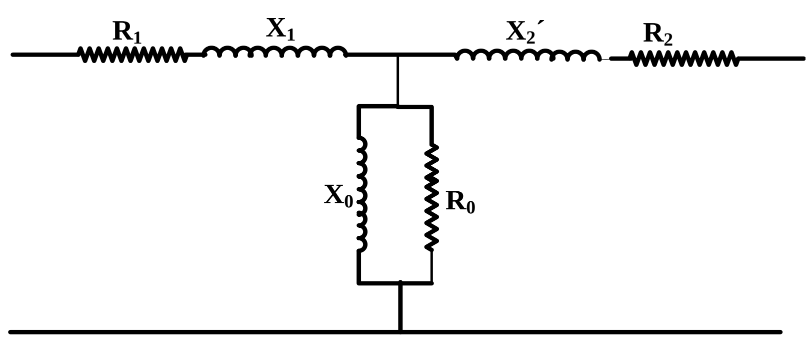
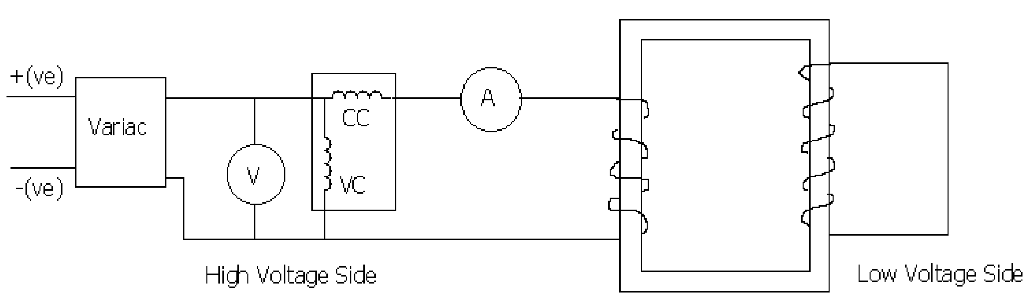


Fig. Equivalent circuit of Transformer

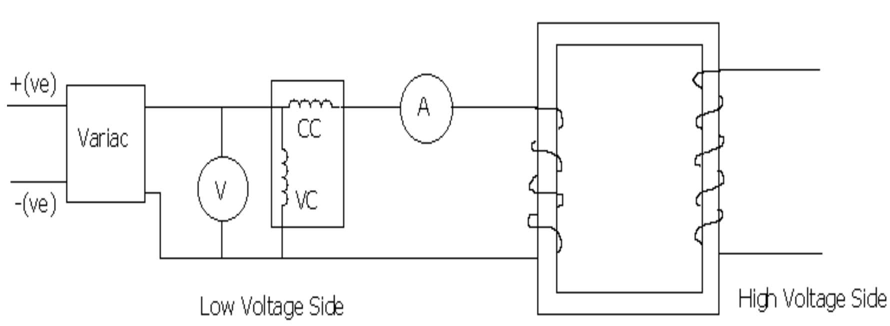
Apparatus:

01. Transformer (150 V per coil, 1A)
01. Voltmeter (0-450V).
02. Ammeter (0-2A).
03. Wattmeter (0-1200W).
04 . Variac (0-240 V)

Circuit Diagram:



Short Circuit Test



Open Circuit Test

Data Table:

Test	Voltage	Current	Power
Short circuit test	7.56	1.00	3.5
Open circuit test	100	0.21	16.5

Calculation:

For short circuit test the applied voltage is very low and core loss is negligible. So it is assumed that current through R_O & X_O is zero

So we can write, $\mathbf{R_{SCT} = R_1 + R_2' = P/I_{SCT}^2 =}$

$\mathbf{Z_{SCT} = V_{SCT}/I_{SCT} =}$

$\mathbf{X_{SCT} = X_1 + X_2' = \sqrt{(Z_{SCT}^2 - R_{SCT}^2)} =}$

For Open circuit test Cu Loss is negligible i.e. loss in R_1 is negligible and voltage drop at R_1 & X_1 is negligible. In this case Loss is assumed only in the core circuit

$$\mathbf{R_{OCT} = R_O = \frac{V_{OCT}^2}{P} =}$$

$$\mathbf{G_{OCT} = \frac{1}{R_{OCT}} =}$$

$$\mathbf{Z_{OCT} = Z_O = \frac{V_{OCT}}{I_{OCT}} =}$$

$$\mathbf{Y_O = \frac{1}{Z_O} =}$$

$$\mathbf{B_O = \sqrt{(Y_O^2 - G_O^2)} =}$$

$$\mathbf{X_O = \frac{1}{B_O} =}$$

% Efficiency =(Output/ input)×100%

%Efficiency = (Input- Losses)×100/ Input %= (200-20)× 100/200 =90 %

Efficiency = Output/ (Output + losses)=

Discussion:

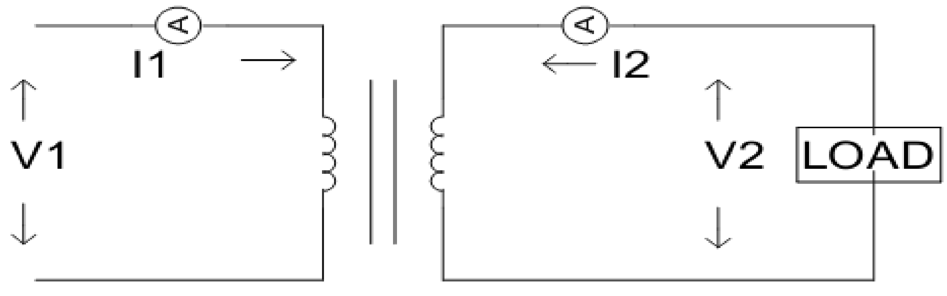
Experiment No: 03 **Date:**

Name of the Experiment: To determine the regulation of a transformer under different power factor.

Theory:

Regulation is an indication of voltage changes due to change in load. Any equipment is said to have good regulation if this change of voltage is less. It is defined as

$$\% R = \frac{V_{N.L.} - V_{F.L.}}{V_{F.L.}} \times 100$$

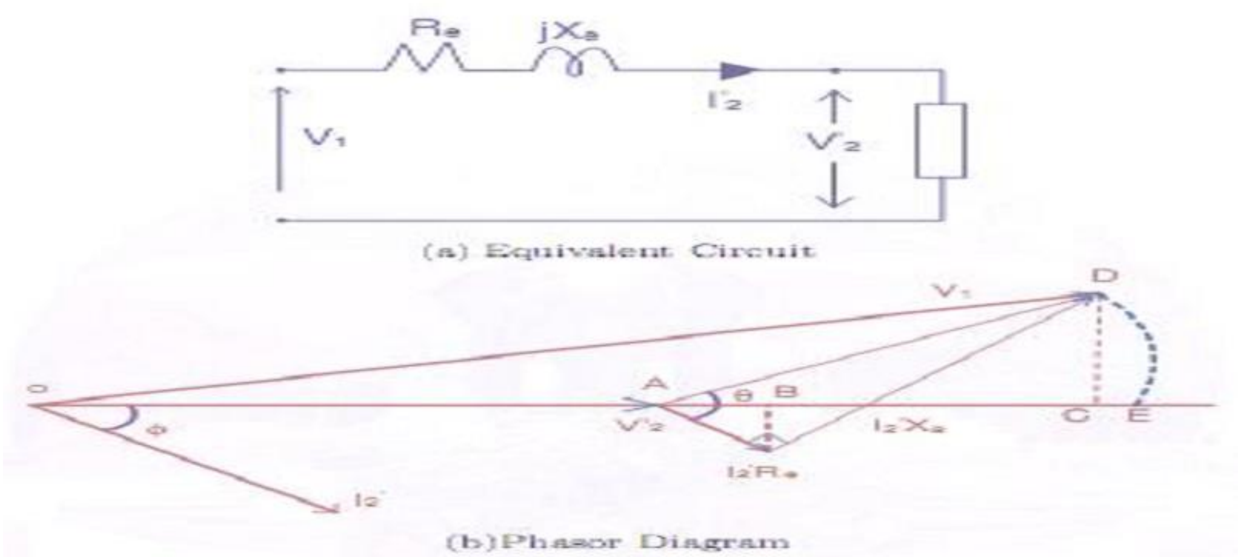


1PH TRANSFORMER

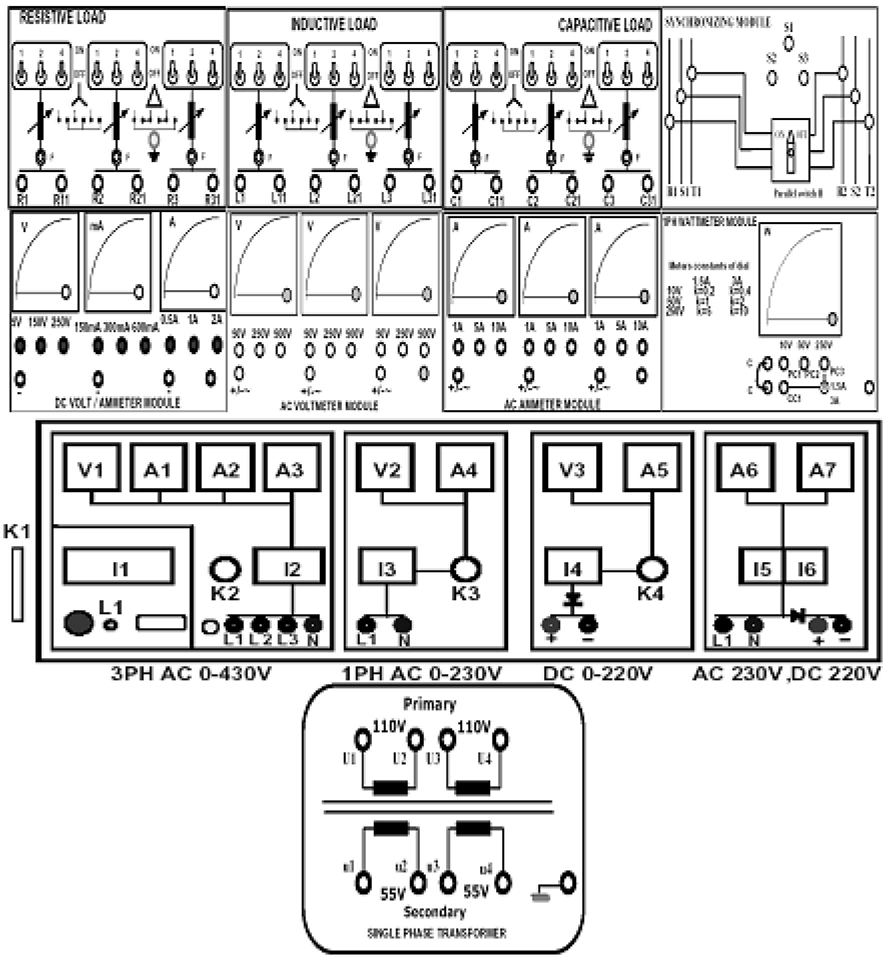
For a transformer, for constant primary voltage as load increases, the voltage at the load decreases, as there is voltage drop due to internal resistance and reactance of the transformer. If we know the resistance and reactance of the transformer, its regulation can be determined under various load conditions.

Apparatus:

1. Universal Power Supply Module
2. 1PH Transformer
3. AC Ammeter Module 0-1A
4. AC Voltmeter Module 0-250 V
5. 1PH Wattmeter Module
6. Resistive Load Module
7. Inductive Load Module
8. Capacitive Load Module
9. Connecting Cables

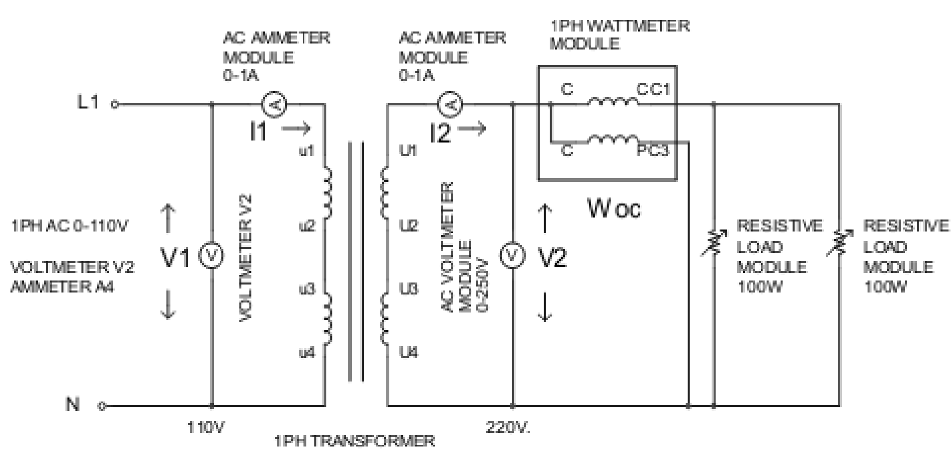


Connection Diagram:



Short Circuit Test:
From the Short Circuit Test done in Experiment 2, note the value of R_{01}, X_{01} referred to the H.T. side.

With Resistive Load:



Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.

3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher

5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.

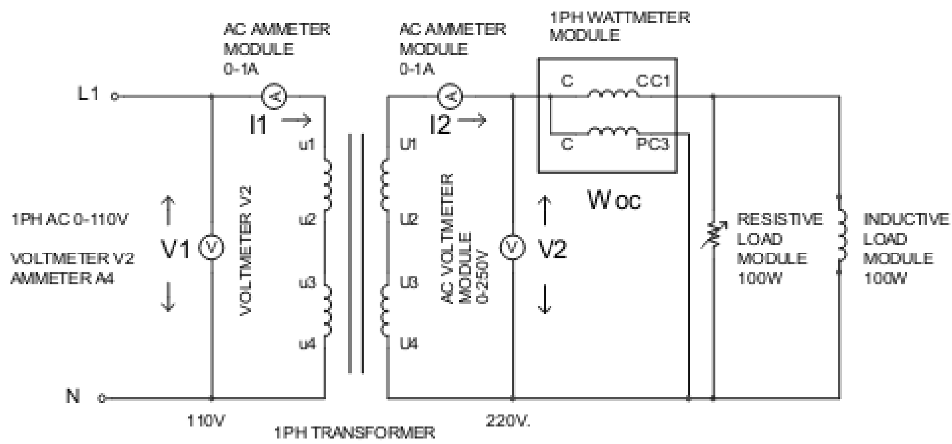
7. Turn Knob K3 at min (CCW)
8. Turn ON switch I3 (upwards).

9. Keep all the Loads at OFF position

10. Apply voltage 110V on the LT side.
11. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

12. Now turn ON all the Loads
13. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

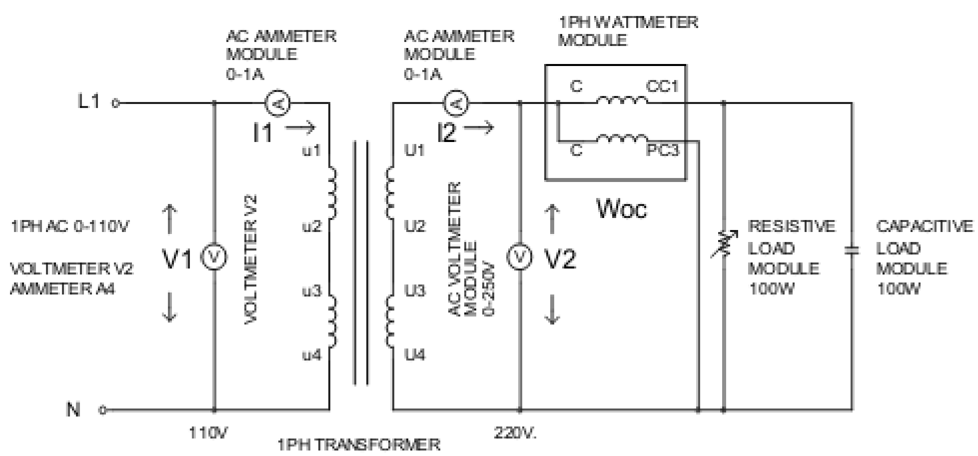
With R-L Load:



Procedure:

1. Follow the procedure mentioned on Resistive Load for the above Diagram

With R-C Load:



Procedure:

1. Follow the procedure mentioned on Resistive Load for the above Diagram

Report:

Draw the vector diagrams under unity, lagging and leading pf and calculate analytically the regulation in each case. Compare the value of regulation found analytically with that of experimental value.

Comment on the regulation under leading pf is it something different? Comment on this value.

Short circuit test

W_{SC} = I_{SC} = V_{SC}

Calculation:

$$\text{Equivalent Resistance (ref. to H.T. side)} = R_{01} = \frac{W_{SC}}{I_{SC}^2} =$$

$$\text{Equivalent Reactance (ref. to H.T. side)} = X_{01} = \sqrt{(V_{SC}/I_{SC})^2 - R_{01}^2}$$

With Resistive Load

Terminal Voltage = Load current =

With R-L Load
Terminal Voltage = Load current = Load power =

With R-C Load
Terminal Voltage = Load current = Load power =

Experiment No: 04 **Date:**

Name of the Experiment: Parallel operation of transformers.

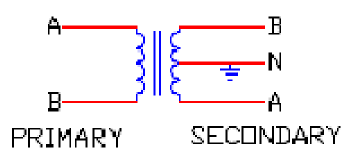
Theory:

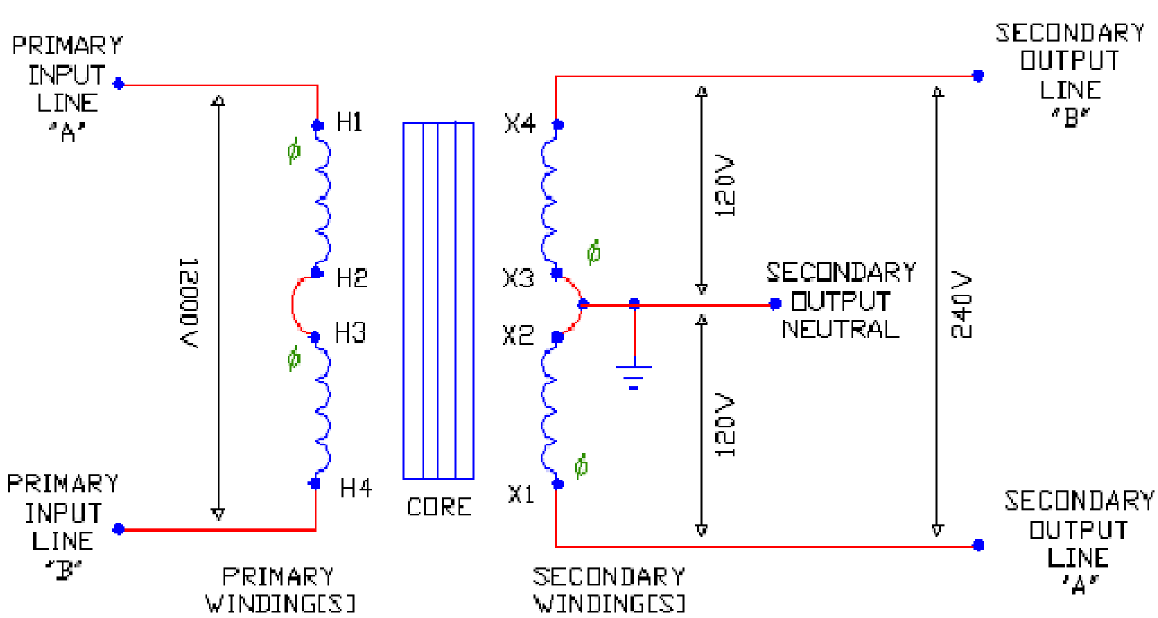
When in a power system the demand for load increases, a single transformer may not be able to supply the extra load. In that case, another transformer is connected in parallel with the existing transformer to share the load. In order to make two transformers parallel, some conditions have to be fulfilled. These are:

1) Terminal voltages on the primary and secondary side should be identical.
2) The relative polarities on the primary and secondary sides should be identical.
3) Preferably R/X ratio of both the transformers should be same.
4) Primary windings of the transformer should be suitable for the supply system voltage and frequency.

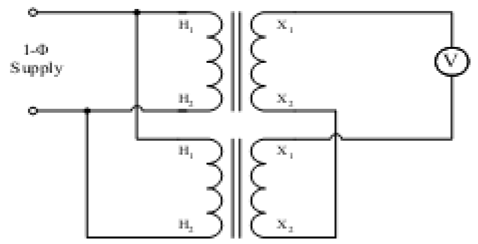
Apparatus:

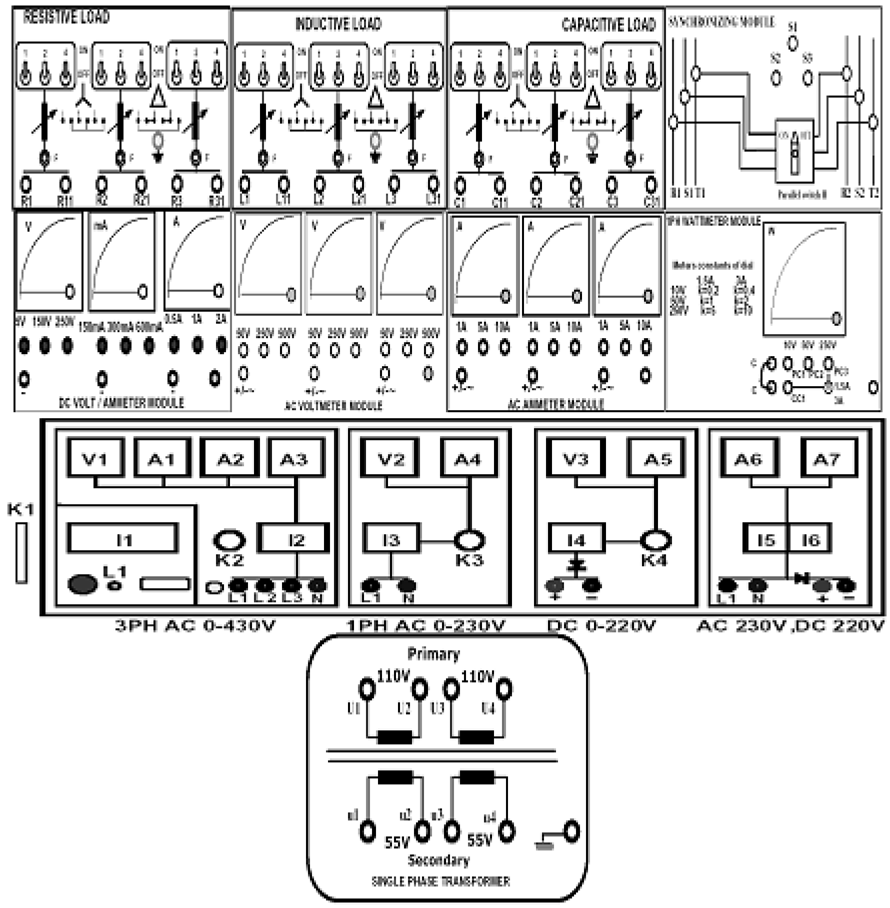
1. 1PH Transformer 2 pieces
2. AC Ammeter Module 0-1A
3. AC Voltmeter Module 0-250 V
4. DC ammeter (0 to 600 mA)
5. Load 100 watts - 2 pieces.
6. Clamp-on-meter -1 piece
7. DC Supply – 9 V
8. Connecting Cables





Connection Diagram:



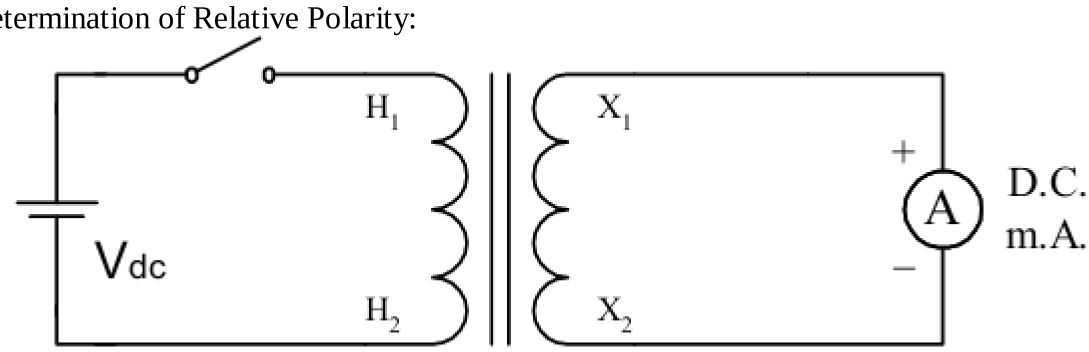


Procedure:

1. Select two 1-φ transformers of identical manufacturer.

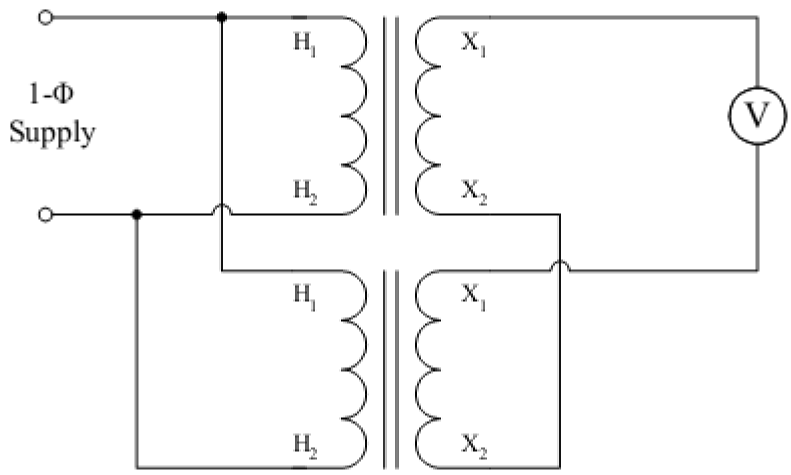
2. On the secondary side of the transformer, determine R and X with an R-L-C meter.

3. Determination of Relative Polarity:



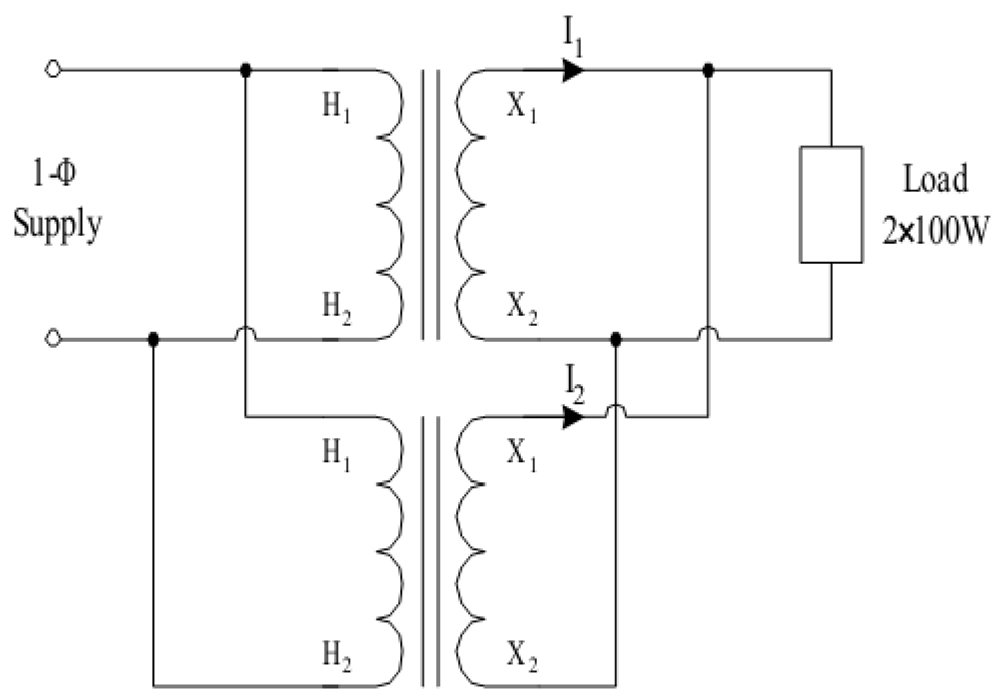
Connect a D.C. mA with polarity as shown on the secondary side, and a battery through a switch on the primary side. Push the switch (give a kick). If the mA deflects in the positive direction, then H_1 and X_1 have the same mode of winding. Repeat the step for TR2 and confirm that the modes of windings are identical.

4. Connection for Parallel Operation:



a) Connect a voltmeter and connect the transformers as shown. If the polarities are correct, the voltmeter should read zero.
b) Disconnect the supply, remove the voltmeter and connect the two secondary terminals (X_1, X_1) of TR1 and TR2. With a clamp-on-meter, check if there is any circulating current. If there is any, note this circulating current.

5. Now, re-connect TR1 and TR2 as in step 4(a). On the secondary side, connect 2 load of 100W each.



With clamp-on-meter, determine the currents supplied by TR1 and TR2

For TR1: R1 = X1 =

For TR2: R2 = X2 =

Voltmeter reading on step 4:

clamp-on-meter reading on step 5:

Currents supplied by TR1 =

Currents supplied by TR2 =

1. Discuss on the value of circulating current found in step 4(c).
2. Why is parallel operation necessary? Why is relative polarity test necessary for parallel operation?
3. Why the voltmeter gives zero reading if the polarities are same at step 4(a)?

Experiment No: 05 **Date:**

Name of Experiment:

Construction of three-phase transformer using three single-phase transformer and observation of line voltage & phase voltage and line current & phase current relation in primary and secondary winding with balance and unbalance loading.

Theory:

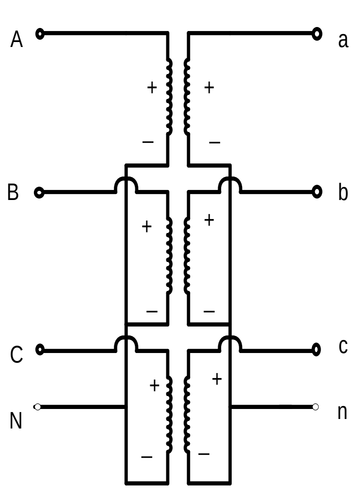
A three phase transformer of both Δ and Y configuration can easily be constructed by using single phase transformer. For connecting the transformers of single phase we need to know the polarity of each coil. After knowing the polarity of each coil 3- phase connection can be made properly. There are many transformers still in service whose terminal does not have the standard markings. In order to interconnect these transformers with others, either for single-phase parallel operation or for polyphase operation, it is necessary to determine the relative polarities of the terminals.

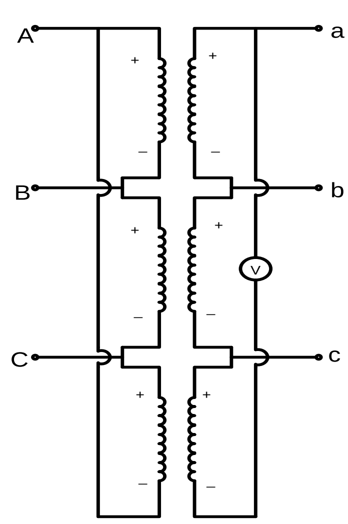
Y- Y connection without primary neutral grounded works satisfactorily only if the load is balanced. With the unbalanced load to the neutral, the neutral point shifts thereby making the three line-to-neutral *(i.e.* phase) voltages unequal. The effect of unbalanced loads can be illustrated by placing a single load between phase (or coil) *a* and the neutral on the secondary side. The power to the load has to be supplied by primary phase (or coil) A. This primary coil A cannot supply the required power because it is in series with primaries *B* and C whose secondaries are open. Under these conditions, the primary coils *B* and *C* act as very high impedances so that primary coil can obtain but very little current through them from the line. Hence, secondary coil a cannot supply any appreciable power. In fact, a very low resistance approaching a short-circuit may be connected between point a and the neutral and only a very small amount of current will flow. This, as said above, is due to the reduction of voltage E_{an} because of neutral shift. In other words, under short-circuit conditions, the neutral is pulled too much towards coil *a*. This reduces E_{an} but increases E_{bn} and E_{cn} (however line voltage E_{AB} E_{BC} and $E_{CA}$are unaffected). On the primary side, E_{AN} will be practically reduced to zero whereas E_{BN} and E_{CN} will rise to nearly full primary line voltage. This difficulty of shifting (or floating) neutral can be obviated by connecting the primary neutral (shown dotted in the figure) back to the generator so that primary coil A can take its required power from between its line and the neutral.

Apparatus:

01. Transformer -3 (1-φ, 150V, 1A each coil)
02. 3- phase Variac. (0-50V)
03. Voltmeter. (0-450V)
04. Ammeter. (0-2A)
05. Variable Resistor(107 Ω, 2A)

Circuit Diagram:





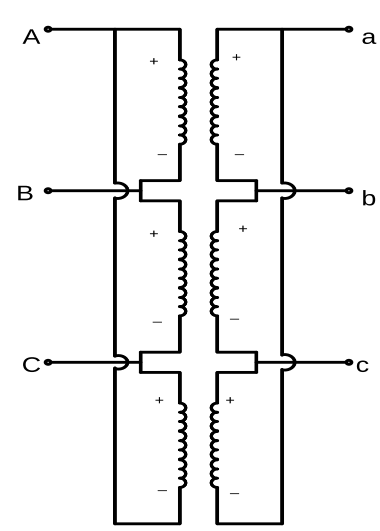


Fig1: Y-Y Connection, Fig2 polarity test for Δ-Δ connection Fig2 : Δ-Δ connection

Fig. Construction of three phase transformer using single phase transformer:

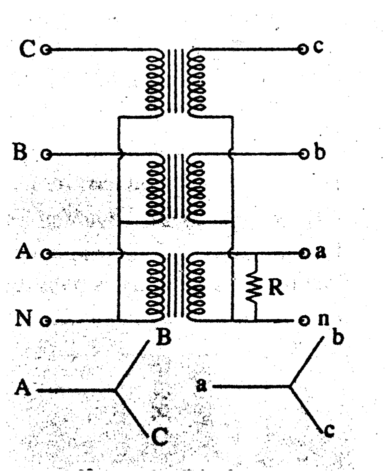


Fig1: Unbalanced load in Y-Y connection without primary neutral grounded.

Precautions:

01. Care should be taken so that current in the coils does not exceed the rated value.
02. Winding should be given the rated or less than the rated supply.
03. Polarity of each coil should always be tested before construction of 3-φ transformer.

Data Table:

For Y-Y connection

Sl. NO.	V_{AN}	V_{BN}	V_{CN}	V_{AB}	V_{BC}	V_{CA}	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
01	158	170	164	290	290	290	84	88	86	144	144	144
02	134	132	134	229	230	232	67	66	67	114	114	115

For Δ-Δ connection

Sl. NO.	V_{AB}	V_{BC}	V_{CA}	V_{ab}	V_{bc}	V_{ca}	I_a	I_b	I_c	I_{an}	I_{bn}	I_{cn}
01	210	215	214	106	108	108	0.97	1.0	0.94	0.55	0.58	0.57

For balance /unbalance loading, in Y-Y connection with / without primary neutral grounded

Conditions	V_{AN}	V_{BN}	V_{CN}	V_{AB}	V_{BC}	V_{CA}	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}	I_{cn}
Balanced/primary neutral grounded	158	170	164	290	290	290	84	88	86	144	144	144	
Unbalanced & primary neutral ungrounded	250	198	86	290	290	290	128	100	38	144	144	144	
Balanced/primary neutral grounded	134	132	134	229	230	232	67	66	67	114	114	115	
Unbalanced & primary neutral ungrounded	207	178	52	230	231	233	103	88	25	114	114	115	

Discussion:

Experiment No: 06 **Date:**

Name of Experiment: Study of the efficiency of Three-Phase Transformers.

Theory: In an ideal transformer, the power in the secondary windings is exactly equal to the power in the primary windings. This is true for transformers with a coefficient of coupling of 1.0 (complete coupling) and no internal losses. In real transformers, however, losses lead to secondary power being less than the primary power. The degree to which a real transformer approaches the ideal conditions is called the efficiency of the transformer:

$$Efficiency\ (\%) = \frac{P_{out}}{P_{in}} \cdot 100\%$$

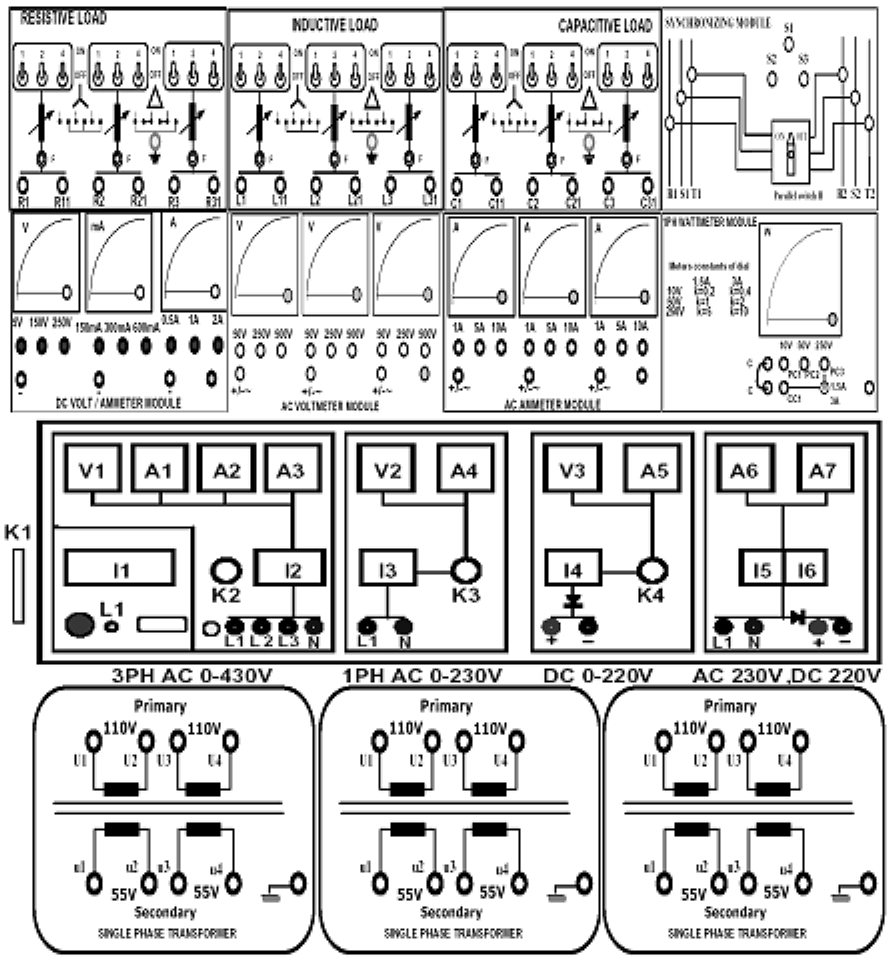
where Pout and Pin are the real output and the input powers. Apparent and reactive powers are not used in efficiency calculations. Transformers may be connected in parallel to supply currents greater than rated for each transformer. Two requirements must be satisfied:

1) The windings to be connected in parallel must have identical output ratings;
2) The windings to be connected in parallel must have identical polarities.

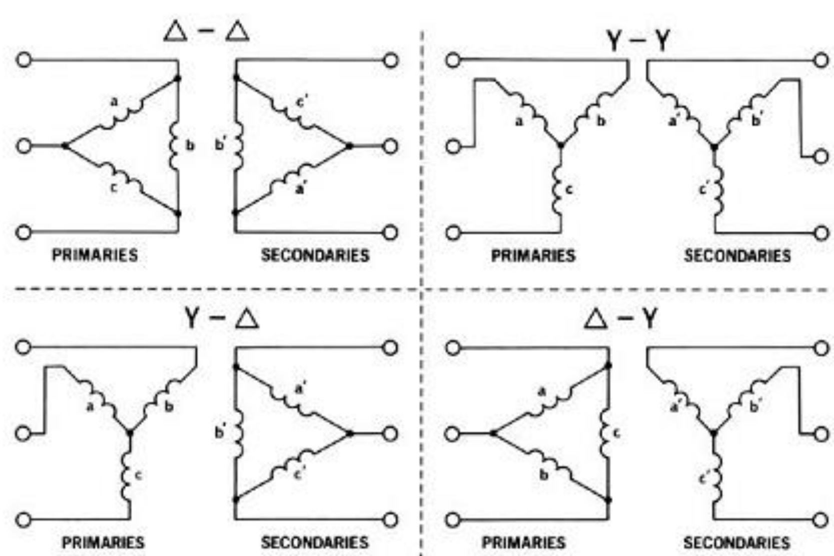
Severe damage may be made to circuitry if these requirements are not satisfied.
Single-phase transformers can be connected to form 3-phase transformer banks for 3-phase power systems. Four common methods of connecting three transformers for 3-phase circuits are Δ-Δ, Y Y, Y-Δ, and Δ-Y connections.

Equipments:

1. 1PH Transformer 2 pieces
2. AC Ammeter Module 0-1A
3. AC Voltmeter Module 0-250 V
4. DC ammeter (0 to 600 mA)
5. Load 100 watts - 2 pieces.
6. Clamp-on-meter -1 piece
7. DC Supply – 9 V
8. Connecting Cables



Connection to form three-phase transformer:



Procedure:

1. Select three 1-φ transformers of identical manufacturer.
2. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
3. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher
6. Now verify the advantages for each type of combination.
7. Keep all the Loads at OFF position
8. Apply voltage 110V on the LT side.
9. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module.
10. Now turn ON all the Loads.
11. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module.
12. With constant resistive load determine the efficiency for each combination.

With Δ-Δ connection

Terminal Voltage = Load current = Load power =

With Y- Y connection

Terminal Voltage = Load current = Load power =

With Y-Δ connection

Terminal Voltage = Load current = Load power =

With Δ-Y connection

Terminal Voltage = Load current = Load power =

Experiment No: 07 **Date:**

Name of Experiment: Observation of speed torque characteristic curve of 3-phase induction motor.

Theory:

From the general torque equation, the running torque may be written in an equation:

$$T = \frac{k\varphi s E_2 R_2}{R_2^2 + (sX_2)^2}$$

It is clear that When s = 0,T = 0.

At normal speed, close to synchronous speed the term sX_2 is small and hence negligible with respect to R_2

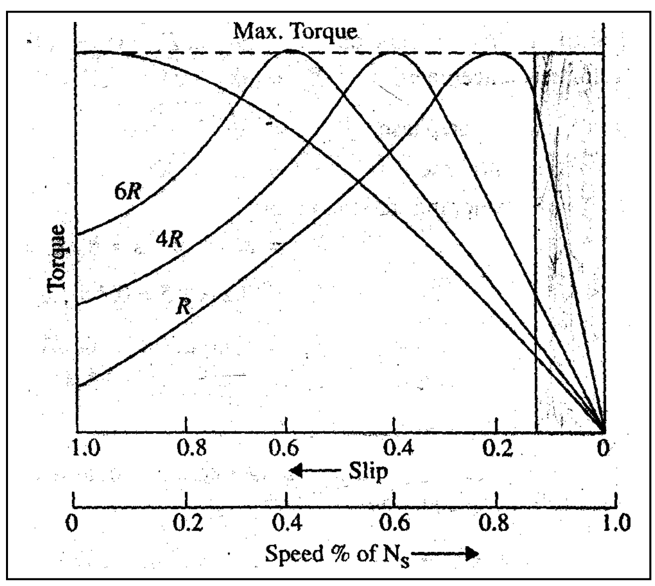
So, $T \propto \frac{s}{R_2}$

Or $T \propto s$ if R_2 is constant.

Hence, for low values of slip, the torque/slip curve is approximately a straight line. As slip increases (for increasing load on the motor), the torque also increases and becomes maximum when $s = \frac{R_2}{X_2}$. This torque is known as *'pull-out* or *'breakdown'* torque T_b or stalling torque. As the slip further increases (i.e. motor speed falls) with further increase in motor load, then R_2 becomes negligible as compared to sX_2 Therefore, for large values of slip

$$T \propto \frac{s}{(sX_2)^2} \propto \frac{1}{s}$$

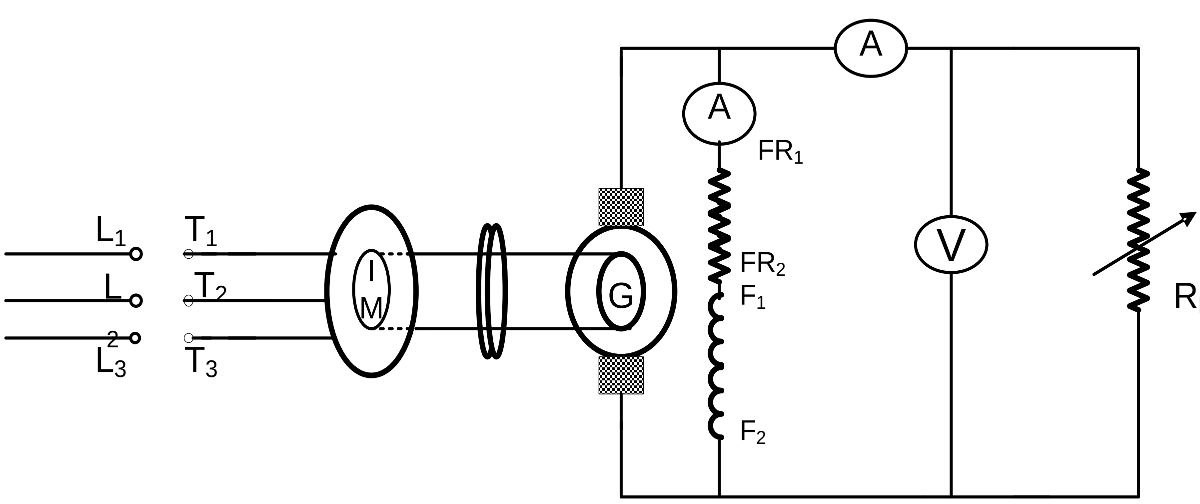
Hence, the torque/slip curve is a rectangular hyperbola. So we see beyond the point of maximum torque, any further increase in motor load results in decrease of torque developed by the motor. The result is that the motor slows down and eventually stops. In fact, the stable operation of the motor lies between the values s= 0 and that corresponding to maximum torque.



Apparatus:

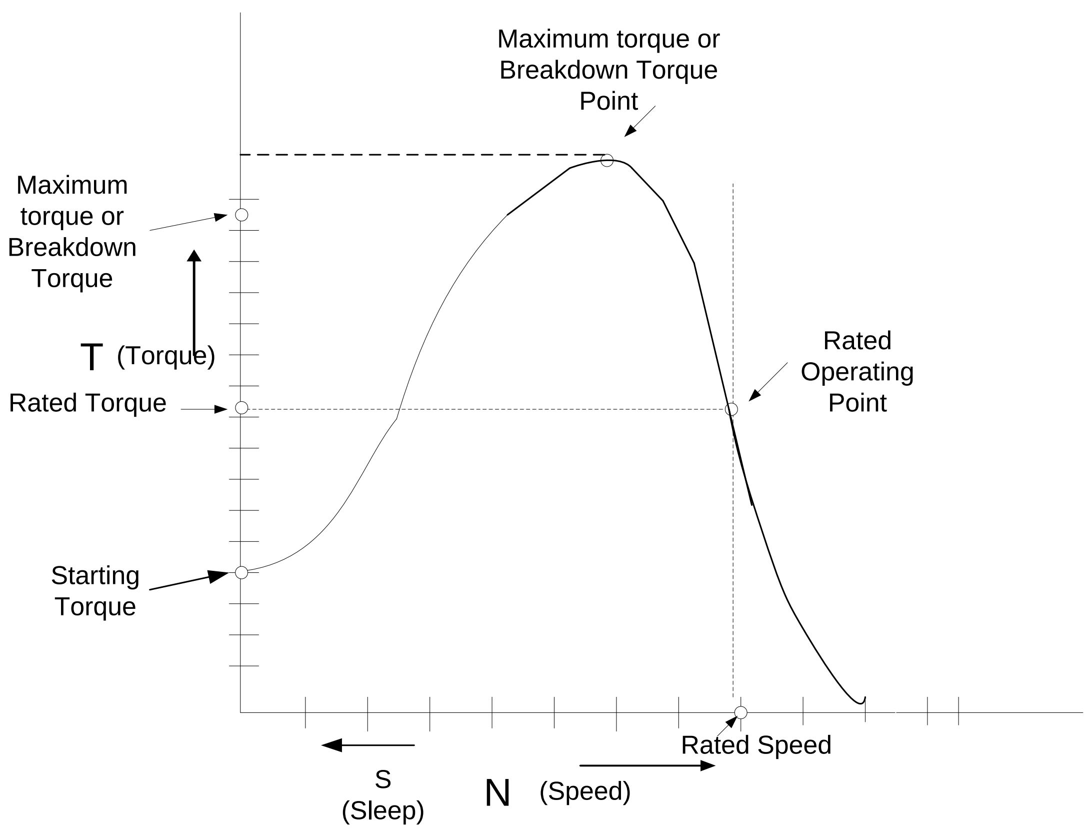
1) Three phase induction motor (440V, 4.55 A, 1420 rpm).
2) Ammeter (0-5 A).
3) voltmeter (0-450v).
4) D.C generator.(250v, 8A, I_f=0.467A, 1450 rpm)
5) Tachometer.
6) Variable Resistor -4 (107 Ω, 2A).

Circuit Diagram:



Data Table:

S. NO .	V_{DC}	I_L	I_F	I_a	$P_{DC}= V_{DC}\times I_L$	$P_{LF}= V_{DC}\times I_F$	$P_L= I_a^2 \times R_a$	N	$P_{W+F} = K\times N$	$P_{LOSS}= V_{DC}\times I_f + I_L^2 R_a + P_{W+F}$	P_M	$T= \frac{60P}{2\pi N}$ N-m
01	207	0.93	0.37	1.30	192.51	76.59	1.45	1460	146	225.43	417.94	2.73
02	206	0.99	0.37	1.36	203.94	76.22	1.65	1458	145.8	225.13	429.07	2.81
03	205	1.08	0.37	1.45	221.4	75.85	1.96	1456	145.6	224.98	446.38	2.93
04	203	1.15	0.37	1.52	233.45	75.11	2.22	1455	145.5	224.49	457.94	3.01
05	202	2.25	0.36	1.61	252.5	72.72	2.63	1452	145.2	222.27	474.74	3.12
06	200	1.38	0.36	1.74	276	72	3.20	1451	145.1	222.19	498.19	3.28
07	198	1.56	0.36	1.91	308.88	69.3	4.09	1447	144.7	220.13	529.01	3.40



Calculation:

$\mathbf{P_{DC}=V_{DC}\times I_L}$

$\mathbf{I_L=I_a+I_F}$

$\mathbf{P_{LOSS}}$ includes friction & windage loss in DC Generator and induction motor ($\mathbf{P_{W+F}}$) which is proportional to speed, Field losses ($\mathbf{V_{DC}\times I_f}$) & armature Cu Losses ($I_L^2\mathbf{R_a}$) in DC generator.

$\mathbf{P_{LOSS}= V_{DC}\times I_F + I_L^2 R_a + P_{W+F}} =$

$\mathbf{P_{W+F}= K\times N=}$ (Assume, K=0.10)

For the case when DC generator Load current is zero

$\mathbf{P_M = P_{DC} + P_{LOSS}=}$

Again, $\mathbf{P_M} = \mathbf{T}\times\boldsymbol{\omega} = \mathbf{T}\times\frac{2\Pi N}{60}$

$\mathbf{T}=\frac{60P_m}{2\pi N} =$

Discussion:

Experiment No: 08 **Date:**

Name of Experiment: Blocked rotor test & no-load test of 3-phase induction motor and determination of circuit parameters.

Theory:

Blocked Rotor Test:

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

1. short-circuit with *normal* voltage applied to stator
2. power factor on short-circuit
3. total leakage reactance X_{01}, of the motor as referred to primary (*i.e.* stator)
4. total resistance of the motor R_{01} as referred to primary.

In this test, the rotor is locked (or allowed very slow rotation) and the rotor windings are short-circuited at slip-rings, if the motor has a wound rotor. Just as in the case of a short-circuit test on a transformer, a reduced voltage (up to 15 or 20 per cent of normal value) is applied to the stator terminals and is so adjusted that full-load current flows in the stator. As in this case s=1, the equivalent circuit of the motor is actly like a transformer, having a short-circuited secondary. The values of current, voltage and power input on short circuit are measured by the ammeter, voltmeter and wattmeter connected in the circuits.

W = total power input on short-circuit

V_s= line voltage on short-circuit

I_S = Line current on short-circuit.

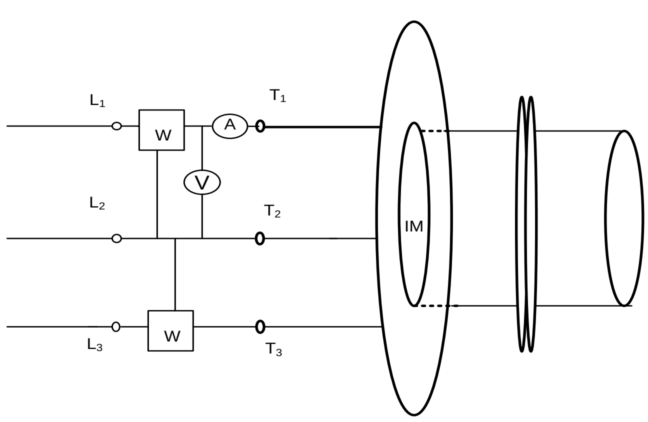
Now, the motor input on short-circuit consists of mainly stator and rotor Cu losses. Core-loss, which is small due to the fact that applied voltage is only a small percentage of the normal voltage.

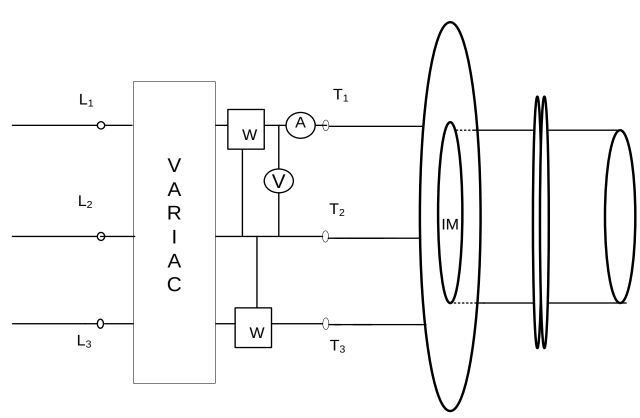
No load test: In this test rated voltage is applied to the induction motor without any mechanical load and the speed is assumed synchronous speed. In practice, it is not feasible to run the induction motor synchronously for getting R_0 and X_0. Instead the motor is run without any external mechanical load on it the speed of the rotor would not be synchronous, but very much near to it; so that for all practical purposes, the speed may be assumed synchronous. The no load test is carried out with different values of applied voltage below and above the value of normal voltage. The power input is measured by two watt meters, As motor is running on light load, the p.f. would be low *i.e.* less than 0.5, hence total power input will be the difference of the two wattmeter readings W_1 and W_2.The readings of the total power input W_O and total current I_0 and voltage V_0. The no-load input W_0 to the motor consists of small stator Cu loss $3Io^2 R_1$, stator core loss and friction and windage. The stator core loss and friction and windage losses *are* collectively known as fixed losses, because they are independent of load.

Apparatus:

1) Three phase induction motor (440V, 4.55 A, 1420 rpm).
2) Ammeter (0-10 A).
3) voltmeter (0-450v).
4) Wattmeter.(450 V, 10A)
5) Ohm meter.

Circuit Diagram:





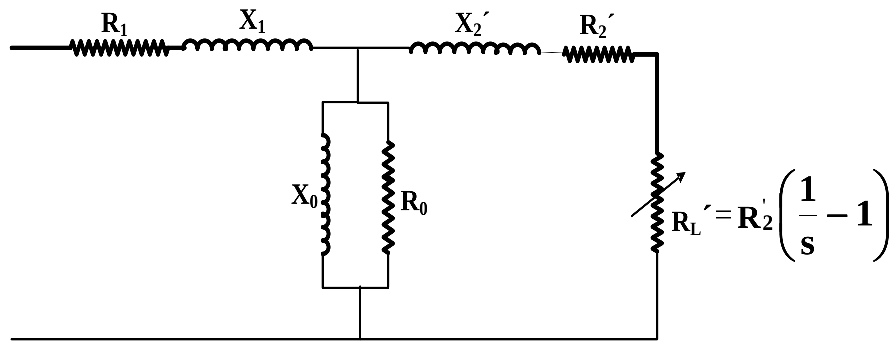


Fig. Electrical equivalent circuit of 3- φ induction motor.

Data Table:

For Blocked rotor Test

S.NO.	V_S	I_S	W_1	W_2	W_T	$R_{01}=P/3I_S^2$	$Z_{01}=V_0/\sqrt{3}\,I_0$	$X_{01}=\sqrt{(Z_{01}^2-R_{01}^2)}$
01	**99**	**4.55**	**255**	**140**	**395**	**6.36**	**12.56**	**10.83**

No load test

S.NO.	V_O	I_o	W_1	W_2	W_T	P_{CORE}	$R_0=V_O^2/P_O$	$Z_0=V_0/\sqrt{3}\,I_0$	$B_0=\sqrt{(Y_0^2-G_0^2)}$	$X_O=\frac{1}{B_O}$
01	440	2.15	200	820	620	458.47	422.27	118.16	8.125×10^{-3}	123.07
02	400	1.95	110	690	580					
03	354	1.80	35	580	545					
04	270	1.6	70	420	490					

DC resistance test of Stator winding : $R_{T\text{-}T}$= 4.18 **Ω**

Calculation:

For Block rotor test the applied voltage is lower Than the rated voltage and core loss is negligible. So it is assumed that current through R_O & X_O is zero

So we can write, $R_S = R_1 + R_2' = P/3I_S^2 =$

For **Y** connected induction motor $R_{1dc} = \frac{R_T}{2} = 2.09$

$R_1 = 1.4\times R_{1dc} = 2.926$

So, $R_2' = R_S - R_1 =$

$Z_S = V_S/\sqrt{3}\,I_S =$

$X_S = X_1 + X_2' = \sqrt{(Z_S^2 - R_S^2)} =$

It is assumed that $X_1 = X_2' = \frac{X_S}{2}$

For No Load test there are mainly core loss, very little Cu Loss and friction & windage loss .It is assumed that the voltage drop at R_1 & X_1 is negligible. In this case Core Loss is

$P_{F+W} = K\times N =$ 148 **(N=** 1480, Assuming, K=0.10)

Stator Cu loss = $I_O^2\times R_1$

$P_{CORE} = W_T - I_O^2\times R_1 - P_{F+W} = 620 - 2.15^2\times 2.926 - 148 = 458.47$

$$R_O = \frac{3V_{OCT}^2}{3P_{CORE}} = \frac{V_{OCT}^2}{P_{CORE}} =$$

$$G_O = \frac{1}{R_O} =$$

$$Z_O = \frac{V_O}{\sqrt{3}I_O} =$$

$$Y_O = \frac{1}{Z_O} =$$

$$B_O = \sqrt{(Y_O^2 - G_O^2)} =$$

$$X_O = \frac{1}{B_O} = 123.07$$

The rated voltage and current of the tested induction motor are 440V and 4.55 A respectively. So If it is assumed that at rated condition p.f is 0.80

Then the input power is = $\sqrt{3}\, V_L\, I_L \cos\theta$ = 2774.05 W

And Losses = $P_{CU} + P_{CORE} + P_{F+W}$ =1001.5 W

% Efficiency =(Output/ input)×100%

%Efficiency = (Input- Losses)×100/ Input %= 63.9 %

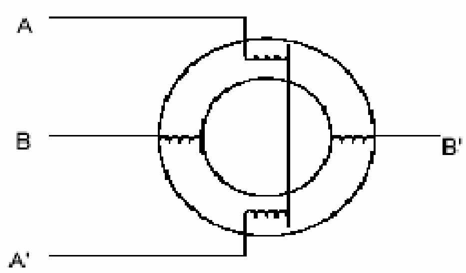
Efficiency = Output/ (Output + losses)= 63.9%

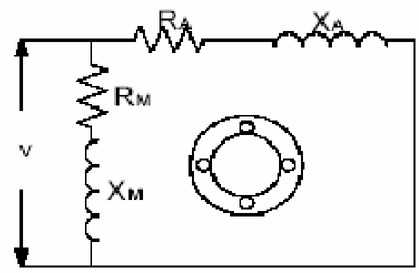
Discussion:

<u>Experiment No: 09</u> **Date:**

<u>Name of Experiment</u>: Study of a 1-φ induction motor.

<u>Theory:</u> The single-phase induction motor when fed from 1-φ supply, its stator winding produces a flux which is alternating i.e. which alternates along one space axis only. An alternating or pulsating flux acting on a stationary squirrel-cage rotor cannot produce rotation. That is why single-phase induction motor is not self-starting. But if the rotor of such machine is given initial start by hand or somewhat other means in either direction, then immediately torque arises and accelerates to its final speed. To make the motor self starting another winding called a starting/auxiliary winding is placed 90 electrical degrees apart from the main or running winding and connected in parallel across the 1-φ supply.



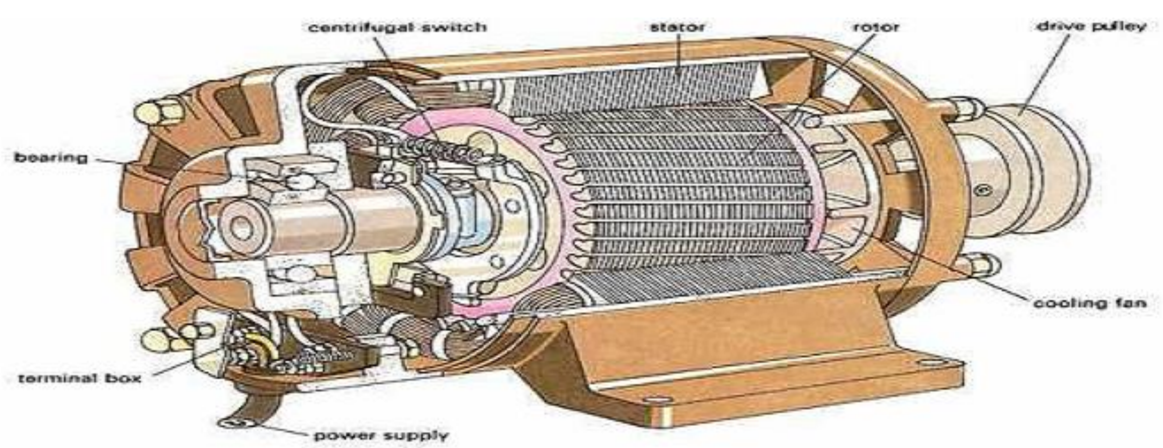


AA/ = Main winding.
BB/ = Auxiliary winding.

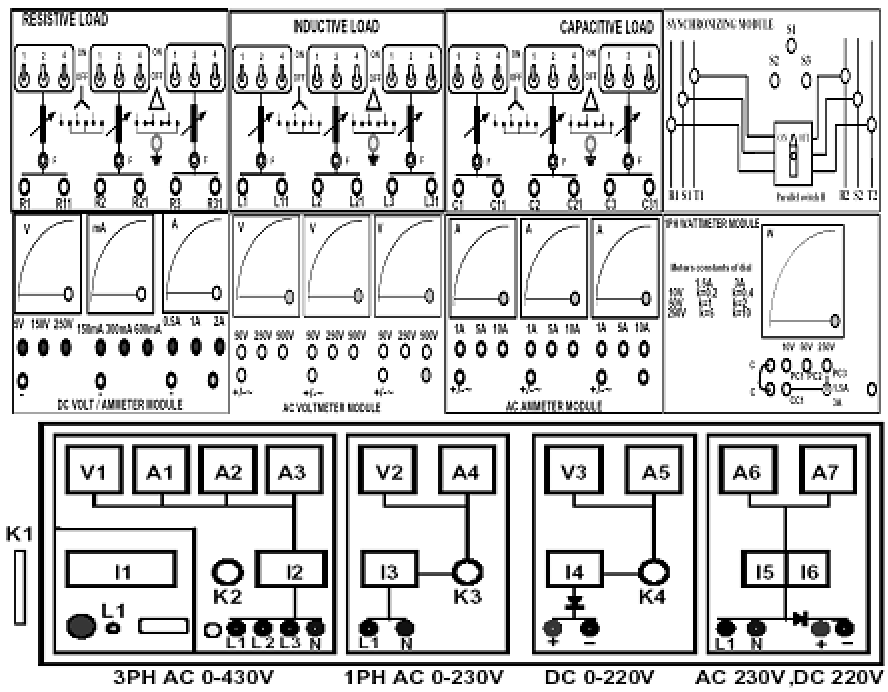
Two theories have been put forward to explain the operation of 1-phase Induction motor. The theories are: 1) Double Revolving Field theory. 2) Cross-field theory.

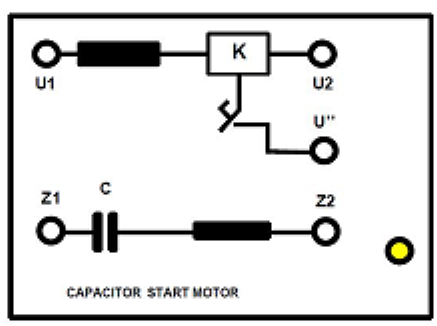
Equipments:

1. LC meter
2. 1-φ Variac
3. Wattmeter
4. AC Voltmeter (0-300 V)
5. AC Ammeter (0-2.5 A)
6. Tachometer
7. Wire for connection



Connection Diagram:





Procedure:

A) To determine the terminals of running and starting winding:
Normally 3 or 4 terminals are available on the motor terminal box. If one terminal of both starting and running windings are internally connected, then 3-terminals are available on the terminal box. The auxiliary winding is designed to have higher resistance/reactance ratio than the main winding so that the current in the auxiliary winding leads the current in the main winding.

1) Take any two-coil terminals and determine its resistance by a sensitive ohm-meter.
R1= ……… ohms.

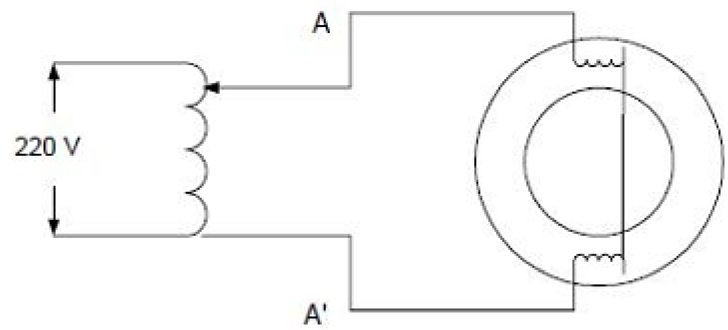
2) Similarly determine the inductance of the coil by an L-C meter.
L1=…………henry, XL1= 2πfL1=…………… ohms.

3) Now take the remaining two coil terminals and measure its resistance and inductance.
R2=…………ohms, L2=…………….henry, XL2=……………ohms.

Determine R/XL1 and R/XL2. From this ratio determine the running winding and starting winding terminals.

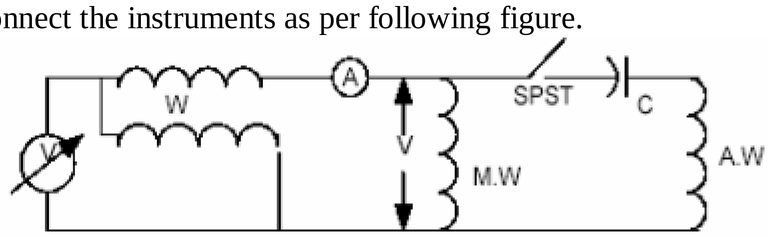
B) Running of the motor by the main winding:

1) Connect the terminals of the main winding as per following figure.



C) Running of the motor with the auxiliary winding:

1) Connect the instruments as per following figure.



Report:

1. In step-B why did the motor rotate in both directions?
2. What is the purpose of capacitor in step-C ? Explain.
3. What have you noticed when you switched-off the SPST in step-C ?
4. Why does the motor continue to run in step-C, when the SPST was switched-off?

Experiment No: 10 **Date:**

Name of Experiment: Measurement of circuit parameters of single phase induction motor and determination of efficiency.

Theory:

As in a polyphase induction motor, the equivalent-circuit parameters of a single-phase induction motor can be measured from No-load and Blocked-rotor tests and from stator winding resistance test.

Blocked rotor test: The single-phase voltage, applied to the stator main winding, is increased gradually from zero so that rated current flows in the main winding. Under these conditions voltmeter, ammeter and wattmeter readings respectively denoted by V_{SC}, I_{SC}, W_{SC}, are recorded. Then DC resistance of main stator winding is measured. This dc resistance should be multiplied by a factor 1.4 so as to obtained effective AC resistance r_1 at line frequency with rotor stationary, the slip S=1, and the voltage required to circulate full load current is very low. Therefore, the flux is small and the magnetizing current flowing through *Xm is* also very low. In view of this magnetizing reactance can be neglected. From the test data, the equivalent impedance referred to stator is

$$Z_{SC}=\frac{V_{SC}}{I_{SC}}$$

The equivalent resistance R_{SC} is given by

$$R_{SC}=r_1+\frac{r_2}{2}\times 2=\frac{W_{SC}}{I_{SC}^2}$$

Since the resistance of main stator winding R_1 is already measured effective rotor resistance r_2 at line frequency is

$$R_2=R_{SC}-r_1=\frac{W_{sc}}{I_{sc}^2}-r_1$$

From equivalent circuit for blocked rotor test ,

$$X_{SC}=x_1+\frac{1}{2}x_2\times 2=x_1+x_2$$

Since the leakage reactance x_1 and x_2 can't be separated out, it is a common practice to assume

So, $x_1=x_2$

$$x_1=x_2=\frac{1}{2}\times X_{sc}$$

or, $x_1=x_2=\frac{1}{2}\times X_{sc}=\frac{1}{2}\times\sqrt{Z_{sc}^2-R_{sc}^2}$

In blocked rotor test , note that only main winding is excited, auxiliary winding is left open.

No-Load Test: The single phase induction motor, under no load condition is run at rated voltage and frequency. With the motor running at no load, the slip is very close to zero. It may therefore assumed that $S\cong 0$. Under this condition, $\frac{r_2}{2S}$ become infinity and $\frac{r_2}{2(2-S)}=\frac{r_2}{4}$ becomes several time smaller than $\frac{X_m}{2}$ In view of this approximation $\frac{r_2}{2S}+j\frac{x_2}{2}$ and $\frac{X_m}{2}$ (across $\frac{r_2}{4}+j\frac{x_2}{2}$) may be neglected.

Under no load test let the voltmeter, ammeter, and wattmeter readings be V_1 , I_{nl} and W_{nl} respectively.

Then no load power factor is

$$\cos\theta_{nl}=\frac{W_{nl}}{V_{nl}I_{nl}}$$

No load equivalent impedance is $Z_{nl}=\frac{V_1}{I_{nl}}$

$$X_{nl}=Z_{nl}\sqrt{1-\cos^2\theta_{nl}}$$
$$=Z_{nl}\sin\theta_{nl}$$

Again, $Z_{nl}=R_{nl}+jX_{nl}$

$$=\left(r_1+\frac{r_2}{4}\right)+j\left[x_1+\frac{1}{2}(x_2+X_m)\right]\ r_1$$

$$\therefore\quad x_1+\frac{1}{2}(x_2+X_m)=X_{nl}$$

Since x_1 and x_2 are already known from blocked rotor test , magnetizing reactance X_m can be calculated from the above equation.

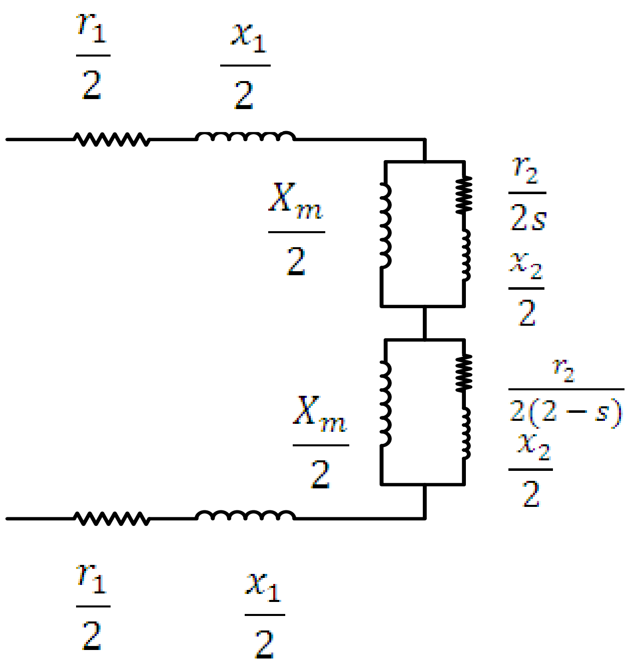


Fig. Electrical equivalent circuit of single phase induction motor :

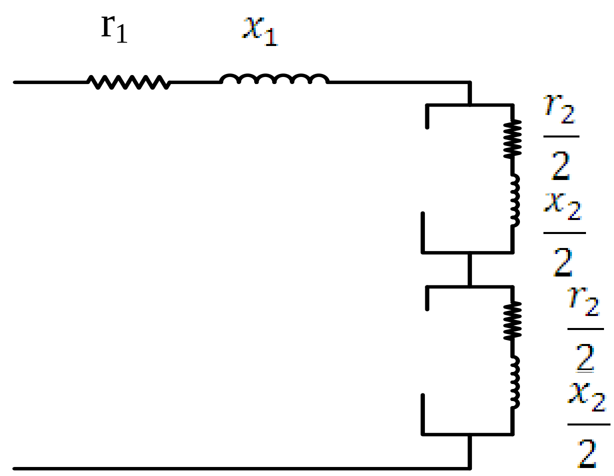


Fig. for blocked rotor test

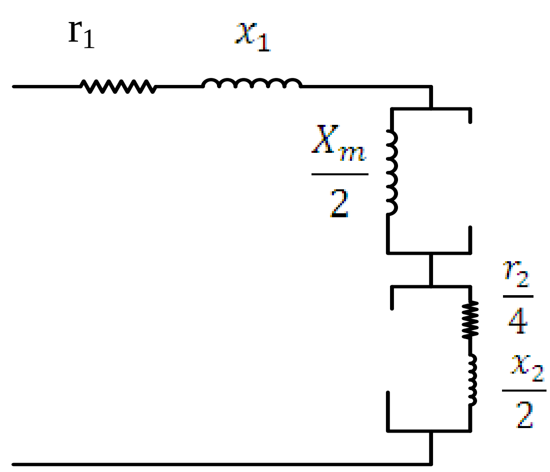


Fig. for No load test

Apparatus:

1) Single phase induction motor(220V, 6.6 A , 1 kW, 2820 rpm, p.f. 0.90).
2) Ammeter (0-5 A).
3) Wattmeter (0-10A, 0-450v).
4) Voltmeter (0-450v).
5) Variac(0 -250V)

Circuit Diagram:

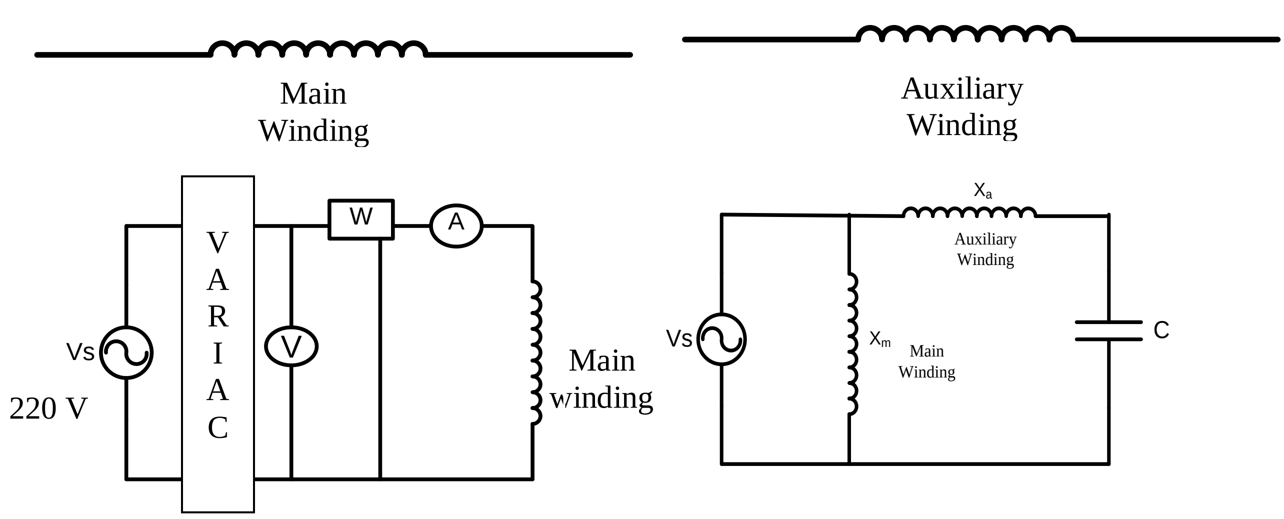


Fig: Circuit diagram of single phase induction motor.

Data Table:

Test	V (v)	I (A)	P (W)	Pin (W)	Pout (W)	η= Pout / Pin
No Load Test	220	3.3	180			
Blocked Rotor Test	96	6.5	400			

Calculation:

From blocked rotor test:

$$Z_{SC} = \frac{V_{SC}}{I_{SC}} = 14.77\ \Omega$$

$$R_{SC} = r_1 + r_2 = \frac{P_{SC}}{I_{SC}^2} = 9.47\ \Omega$$

$$X_{SC} = x_1 + x_2 = \sqrt{Z_{SC}^2 - R_{SC}^2} = 11.33\ \Omega$$

$$x_1 = x_2 = \frac{1}{2} X_{SC} = 5.67\ \Omega$$

$$r_{1dc} = 3.95 \qquad \therefore \quad r_1 = 3.95 \times 1.4 = 5.53\ \Omega$$

$$r_2 = R_{SC} - r_1 = 3.94\ \Omega$$

From no load test:

$$\cos\theta_{nl} = \frac{P_{nl}}{V_{nl} I_{nl}} = 0.248$$

$$\sin\theta_{nl} = \sqrt{1 - \cos\theta_{nl}^2} = 0.97$$

$$Z_{nl} = \frac{V_{nl}}{I_{nl}} = 66.67\ \Omega$$

$$X_{nl} = Z_{nl} \sin\theta_{nl} = 64.67$$

$$\text{Now, } X_{nl} = x_1 + \frac{1}{2}(x_2 + X_m)$$

$$\therefore \quad X_m = 112.33\ \Omega$$

Now the rated core and friction & windage losses $= W_{nl} - I_{nl}^2 \left(r_1 + \frac{r_2}{4}\right)$

= 109.05 Watt.

$\therefore$ Rated Cu loss and core, friction & wnidage losses = 400+109.05 Watt

= 509.05 Watt.

Rated p.f. =0.90

Rated input = $220 \times 6.5 \times 0.9$ = 1287 Watt

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{P_{in} - P_{losses}}{P_{in}} \times 100\% = 60.45\ \%$$

Precautions:

1. the connection of C.C and P.C should be correct.
2. The readings of the various meters should be taken carefully.

Discussion:

Experiment No: **11** **Date:**

Name of Experiment: Determination of value of capacitor for maximum starting torque of capacitor split-phase induction motor.

Theory: A single phase induction motor with main stator winding has no inherent starting torque, since main winding produces only stationary, pulsating air-gap flux wave. For the development of starting torque, rotating air-gap field must be produced. Several methods which have been developed for starting of single phase induction motor, ma be classified as follows;

1) split-phase starting.
2) Shaded-pole starting.
3) Repulsion motor starting and
4) Reluctance starting.

All the split-phase motors have two stator winding, a main (or running) winding and an auxiliary (or starting) winding. Both this windings are connected in parallel but there magnetic axes are spaced displaced by $90°$ electrical. There are four types of split-phase motor

a) Resistor split-phase motor
b) Capacitor split-phase motor
c) Capacitor start and run motor.
d) Capacitor run motor.

In capacitor split phase motor the main winding is designed by taking into consideration the required performance of this motor. The time phase displacement between auxiliary winding current I_a and main winding current I_m is obtained by putting a suitable capacitor in series with the auxiliary winding . A centrifugal switch CS is placed in the auxiliary winding which disconnect the auxiliary winding when the motor reaches at about 70 to 80% of synchronous speed. By use of suitable starting capacitor, the highest possible starting torque can be achieved. But size and hence cost of the starting capacitor; then, would be quite high. The auxiliary winding and starting capacitor are in circuit for a short time only, these can therefore, be designed for a minimum cost.
The maximum starting torque can be obtained if the value of capacitor (C) is such that

$$X_c = \frac{1}{2\pi f C} = X_a + \frac{r_a r_m}{Z_m + X_m}$$

Where ,

X_c= Capacitive reactance for maximum starting torque.
X_a=Inductive reactance of the auxiliary winding
X_m= reactance of the main winding.
Z_m=Impedance of the main winding.
r_m=resistance of main winding.
r_a=resistance of main winding.

In this experiment a reduced voltage is applied at the auxiliary winding and main winding is applied separately. Then current and voltage reading are taken.

Apparatus:

1) Single phase induction motor(220V, 6.6 A , 1 kW, 2820 rpm, p.f.-0.90).
2) Ammeter (0-5 A).
3) Wattmeter (0-10A, 0-450v).
4) voltmeter (0-450v).
5) Variac (0 -250V)

Circuit Diagram:

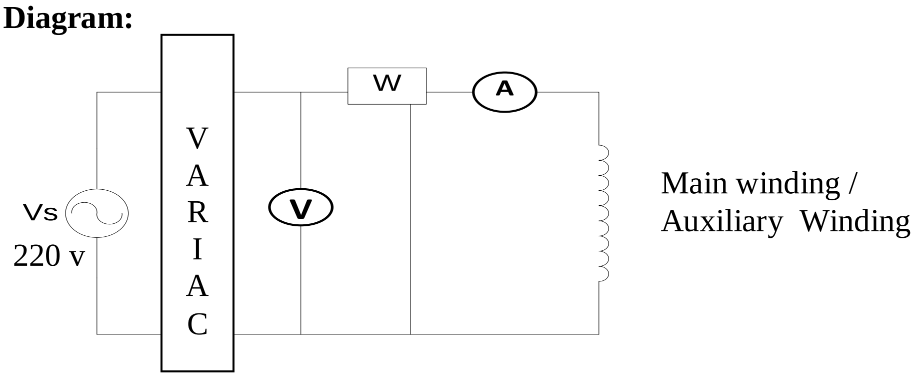


Fig: Circuit diagram of single phase induction motor

Data Table:

Winding	V	I	P	$r=P/I^2$	$Z=V/I$	$X=\sqrt{Z^2-R^2}$	$X_c = X_a + \frac{r_a r_m}{Z_m + X_m}$	$C = \frac{1}{2\pi f X_C}$ μF
Main	100	7.25	430	8.18	13.79	11.11	27.54	115.58
Aux	100	3.7	200	14.61	27.03	22.74		

Calculation:

$$r_a = \frac{P}{I_a^2} = 14.61$$

$$r_m = \frac{P}{I_m^2} = 8.18$$

$$Z_a = \frac{V_a}{I_a} = 27.03$$

$$Z_m = \frac{V_m}{I_m} = 13.79$$

$$X_a = \sqrt{Z_a^2 - X_a^2} = 22.74$$

$$X_m = \sqrt{Z_m^2 - X_m^2} = 11.11$$

$$X_c = X_a + \frac{r_a r_m}{Z_m + X_m} = 27.54\ \Omega$$

$$C = \frac{1}{2\pi f X_C} = 115.58\ \mu F \qquad (f=50\text{ Hz})$$

Discussion:

Apparatus:

6) Single phase induction motor(220V, 6.6 A , 1 kW, 2820 rpm, p.f.-0.90).
7) Ammeter (0-5 A).
8) Wattmeter (0-10A, 0-450v).
9) voltmeter (0-450v).
10) Variac (0 -250V)

Circuit Diagram:

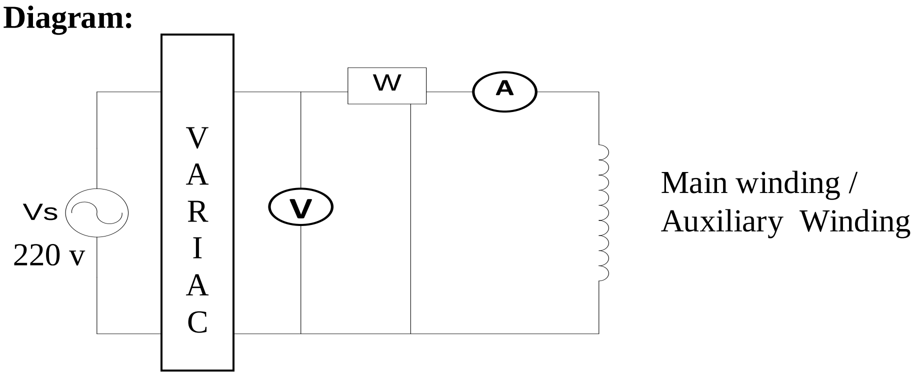


Fig: Circuit diagram of single phase induction motor

Data Table:

Winding	V	I	P	$r=P/I^2$	$Z=V/I$	$X=\sqrt{Z^2-R^2}$	$X_c = X_a + \frac{r_a r_m}{Z_m + X_m}$	$C = \frac{1}{2\pi f X_C}$ μF
Main								
Aux								

Calculation:

$$r_a = \frac{P}{I_a^2} =$$

$$r_m = \frac{P}{I_m^2} =$$

$$Z_a = \frac{V_a}{I_a} =$$

$$Z_m = \frac{V_m}{I_m} =$$

$$X_a = \sqrt{Z_a^2 - X_a^2} =$$

$$X_m = \sqrt{Z_m^2 - X_m^2} =$$

$$X_c = X_a + \frac{r_a r_m}{Z_m + X_m} =$$

$$C = \frac{1}{2\pi f X_C} = \qquad (f=50\ \text{Hz})$$

Discussion:

Now the rated core and friction & windage losses $= W_{nl} - I_{nl}^2 (r_1 + \frac{r_2}{4})$

=

∴ Rated Cu loss and core, friction & wnidage losses =

.

Rated p.f. =0.90

Rated input = $220 \times 6.5 \times 0.9 =$

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{P_{in} - P_{losses}}{P_{in}} \times 100\%$$

Precautions:

3. the connection of C.C and P.C should be correct.
4. The readings of the various meters should be taken carefully.

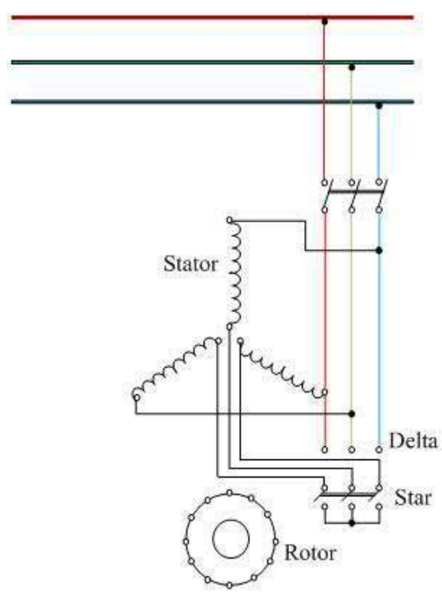
Discussion:

Experiment No: **12** **Date:**

Name of Experiment: Starting an Induction Motor by applying star-delta starter.

Theory: The induction motor must be built to run normally with a mesh-connected stator winding. At starting, the winding is connected temporarily in star. The phase voltage is thus reduced to $\mathbf{1/\sqrt{3} = 0.58}$ of normal, and the motor behaves as if the auto-transformer were employed with a ratio $\mathbf{x = 0.58}$. The starting current per phase is $\mathbf{I_s = 0.58 I_x}$, the line current is $\mathbf{(0.58)^2 I_x = 0.33 I_x}$, the starting torque is one-third of short-circuit value.

The method is cheap and effective, so long as the starting torque is not required to exceed about 50 percent of full load torque. It can therefore be used for machine-tools, pumps, motor generators etc. The method is unsuitable for motors at voltages exceeding 3000 V. because of the excessive number of stator turns needed for delta running. Where induction motors are required to run for considerable periods on small loads, a star-delta switch permits the machine to be star-connected during these periods, with reduction of magnetizing current and increase in efficiency.



Star-Delta Starting

This is a starting method that reduces the starting current and starting torque. At starting the Induction motor is star connected after it reached the approximate operational speed it is switch to delta. The motor must be delta connected during a normal run, in order to be able to use this starting method. This starting method only works when the application is light loaded during the start. If the motor is too heavily loaded, there will not be enough torque to accelerate the motor up to speed before switching over to the delta position.

Apparatus:

1) 3-φ Induction Motor
2) Star-Delta Starter
3) Connecting Wires
4)

Table: (Readings)

Conclusion: