ELECTRICAL MACHINES - II

[CODE: LC-EE-208]

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EXPERIMENT No. 1

AIM: To compute the torque vs speed characteristics of three phase induction motor for various stator voltages.

APPARATUS USED: Three phase induction motor (3 hp, 415V), AC voltmeter (0-600V), AC ammeter (0-5A), connecting wires, three phase autotransformer (415/0-470V, 4A), spring balance, ruler.

THEORY: The three-phase induction motor carries a three-phase winding on its stator. The rotor is either a wound type or consists of copper bars short-circuited at each end, in which case it is known as squirrel-cage rotor. The three-phase current drawn by the stator from a three-phase supply produces a magnetic field rotating at synchronous speed in the air-gap. The magnetic field cuts the rotor conductors inducing electromotive forces which circulate currents in them. According to Lenz's Law, the EMFs must oppose the cause which produces them; this implies that the rotor must rotate in the direction of the magnetic field set up by the stator. If the rotor could attain synchronous speed, there would be no induced EMF in it. But on account of losses, the speed is always less than the synchronous speed. The torque developed in induction machines is proportional to the square of applied stator voltage. But, higher voltages are dangerous at the time of starting because of the heavy starting current, so starting torque is not increased using this method.

CIRCUIT DIAGRAM:

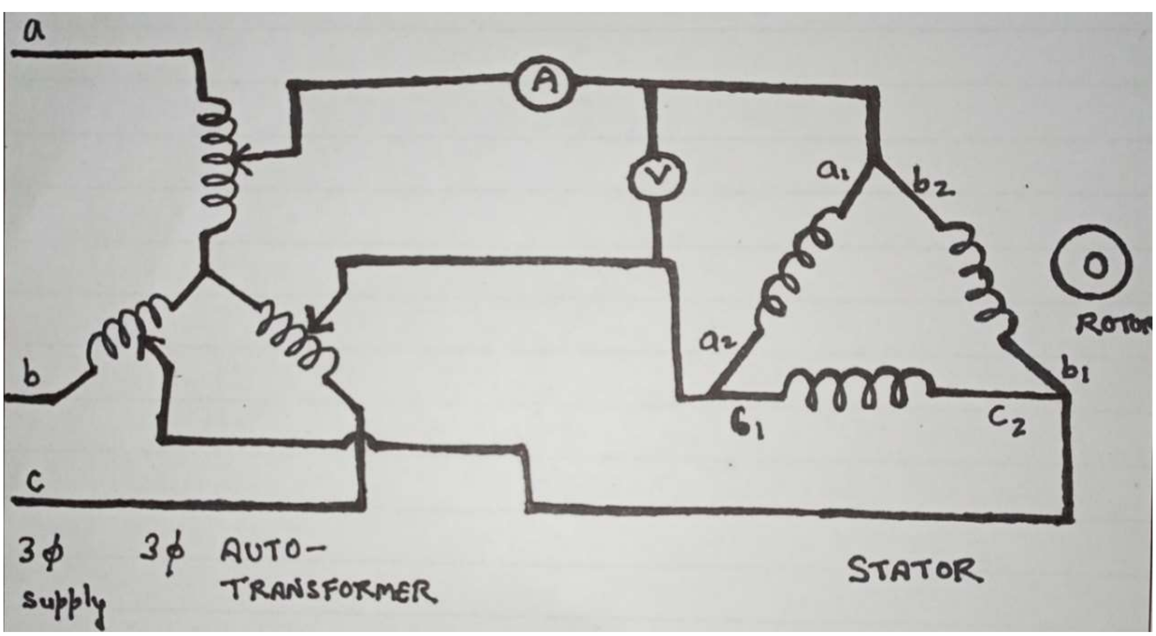

Fig. 1: Experiment setup

PROCEDURE:

- Connected the circuit as per the circuit diagram.
- Set the autotransformer to zero position.
- Switched on the mains supply.
- Put a light load on motor shaft.
- Increased the autotransformer output voltage gradually to 100V.
- Increased the load on the motor shaft in steps (noted down the load), and measured the speed of the motor using tachometer.
- Repeated the above two steps for 200V, 300V and 400V autotransformer output voltages.
- Reduced the autotransformer output voltage gradually to zero.
- Switched off the mains.
- Plotted the torque-speed characteristics for different stator voltages.

OBSERVATIONS AND CALCULATIONS:

Diameter of brake-drum, d = ___________ Radius of brake-drum, r = ___________

S.no.	Stator voltage (V)	Mechanical Load			Force	Torque	Speed (rpm)
		W1 (kg)	W2 (kg)	Total, W = W1 – W2 (kg)	W X g (N)	Force X r (Nm)	
1	100V						
2	200V						
3	300V						
4	400V						

TORQUE VS SPEED CHARACTERISTICS FOR VARIOUS STATOR VOLTAGES:

RESULT:

- As the load is increased, the speed of the motor gets reduced.
- As the stator voltage is increased, the torque of the motor increased as square of the voltage.

PRECAUTIONS:

1. Autotransformer should be varied gradually.
2. The autotransformer should be at zero output position before switching on the supply.
3. The mechanical load on the shaft should be free during starting.
4. The load should not be increased beyond the current rating of the machine.

EXPERIMENT No. 2

AIM: To perform load test on three phase induction motor to determine its performance characteristics.

APPARATUS USED: Three phase induction motor (3 hp, 415V), AC voltmeter (0-600V), AC ammeter (0-5A), wattmeter (600V, 5A)-2, connecting wires, three phase autotransformer (415/0-470V, 4A), spring balance, ruler, tachometer.

THEORY: Performance characteristics of the induction motor show graphically the variation of speed, stator current, power factor and efficiency as the shaft power is varied from no-load to full load. These characteristics depend upon the motor rotor resistance, air-gap length, and shape of stator and rotor slots. At no load the speed is near to synchronous speed, as the load increases on motor shaft, the speed falls and the stator working current increases, hence the power factor of motor improves. Also, as the load increases the efficiency increases, it attains maximum value when fixed and variable losses become equal and decreases after that.

FORMULAE USED:

- $P_{in} = P_1 + P_2$; where P_1 and P_2 are the readings of wattmeter in two wattmeter method
- $\phi = tan^{-1}\left\{\sqrt{3}\left|\frac{P_1 - P_2}{P_1 + P_2}\right|\right\}$; where φ is pf angle
- $P_{out} = (W_1 - W_2) \times g \times r \times \frac{2\pi N_r}{60}$; where W_1 and W_2 are the readings from the load balance, g is acceleration due to gravity and N_r is rotor speed in rpm
- $\eta = \frac{P_{out}}{P_{in}} \times 100$

CIRCUIT DIAGRAM:

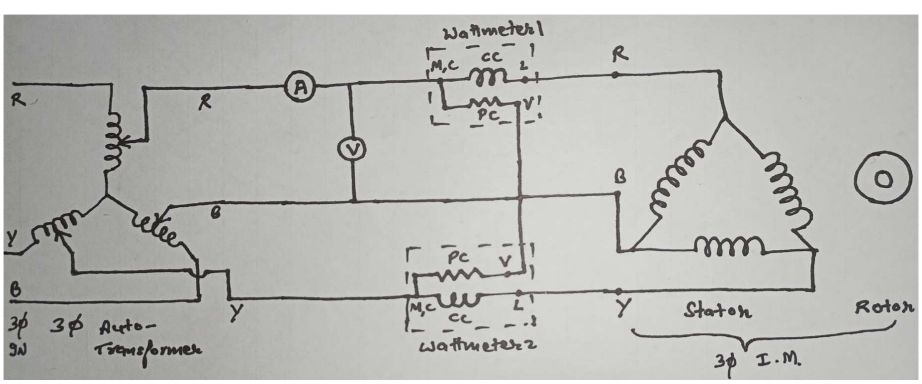

Fig. 1: Experiment setup

PROCEDURE:

- Connected the circuit as per the circuit diagram.
- Set the autotransformer to zero position.
- Switched on the mains supply.
- Keep the motor shaft on no load.
- Increased the autotransformer output voltage gradually to 415V.
- Increased the load on the motor shaft in steps (noted down the load), and measured the speed of the motor using tachometer, stator current, wattmeter readings and shaft load.
- Reduced the autotransformer output voltage gradually to zero.
- Switched off the mains.
- Plotted the speed, efficiency and pf of induction motor with respect to output power of motor.

OBSERVATIONS:

Diameter of brake-drum, d = ___________ Radius of brake-drum, r = ___________

S.no	Mechanical Load			Speed, Nr (rpm)	Wattmeter Readings		Stator Current, I (A)
	W1 (kg)	W2 (kg)	Total, W = W1 – W2 (kg)		Wattmeter 1, P_1 (W)	Wattmeter 2, P_2 (W)	

CALCULATIONS:

S.no.	Force	Torque, T	Output Power, Pout	Input Power, Pin	Power factor angle ϕ	Power factor	Efficiency η
	W X g (N)	Force X r (Nm)	$T \times 2\pi \frac{N_r}{60}$ (W)	P1 + P2 (W)	$tan^{-1}\left\{\sqrt{3}\left\|\frac{P_1 - P_2}{P_1 + P_2}\right\|\right\}$	$cos\phi$	$\frac{P_{out}}{P_{in}} \times 100$

PERFORMANCE CHARACTERISTICS:

RESULT:

- As the load is increased from no load to full load, the speed of induction motor reduced.
- As the load is increased from no load to full load, the stator current increased.
- As the load is increased from no load to full load, the pf improved.
- As the load is increased from no load to full load, the efficiency increased up to a certain load then decreased.

PRECAUTIONS:

1. Autotransformer should be varied gradually.
2. The autotransformer should be at zero output position before switching on the supply.
3. The mechanical load on the shaft should be free during starting.
4. The load should not be increased beyond the current rating of the machine.

EXPERIMENT No. 3

AIM: To perform no load and blocked rotor test on three phase induction motor.

APPARATUS USED: Three phase induction motor (3 hp, 415V), AC voltmeter (0-600V), AC ammeter (0-5A), wattmeter (600V, 5A)-2, multimeter, connecting wires, three phase autotransformer (415/0-470V, 4A).

THEORY: The no load test is performed to obtain the magnetizing branch parameters (shunt parameters) of the induction machine's equivalent circuit. In this test, the motor is allowed to run at no-load at the rated voltage and rated frequency. Machine will rotate at almost synchronous speed, which makes slip nearly equal to zero. This causes the equivalent rotor impedance to be very large. The ammeter gives the no load stator current and wattmeter gives the no load losses which comprise core losses, and friction and windage losses. These losses are constant losses as these are independent of load. The blocked rotor test is performed to obtain the induction motor's full load leakage impedance.

FORMULAE USED:

- No load impedance per phase, $Z_{nl} = \frac{V_{nl}}{I_{nl}}$
- No load resistance per phase, $R_{nl} = \frac{P_{nl}}{I_{nl}^2}$
- No load reactance per phase, $X_{nl} = \sqrt{Z_{nl}^2 - R_{nl}^2}$
- Rotational losses, $P_{rot.loss} = 3(P_{nl} - I_{nl}^2 r_1)$
- Blocked rotor impedance per phase, $Z_{br} = \frac{V_{br}}{I_{br}}$
- Blocked rotor resistance per phase, $R_{br} = \frac{P_{br}}{I_{br}^2}$
- Blocked rotor reactance per phase, $X_{br} = \sqrt{Z_{br}^2 - R_{br}^2}$
- $x_1 = x_2 = \frac{X_{br}}{2}$
- Stator magnetizing reactance, $X_m = X_{nl} - x_1$
- Stator winding resistance per phase, $r_1 = 1.2 \times \frac{3}{2} r_{dc}$

- Rotor resistance per phase, $r_2 = (R_{br} - r_1)\left(\frac{X_2}{X_m}\right)^2$

CIRCUIT DIAGRAM:

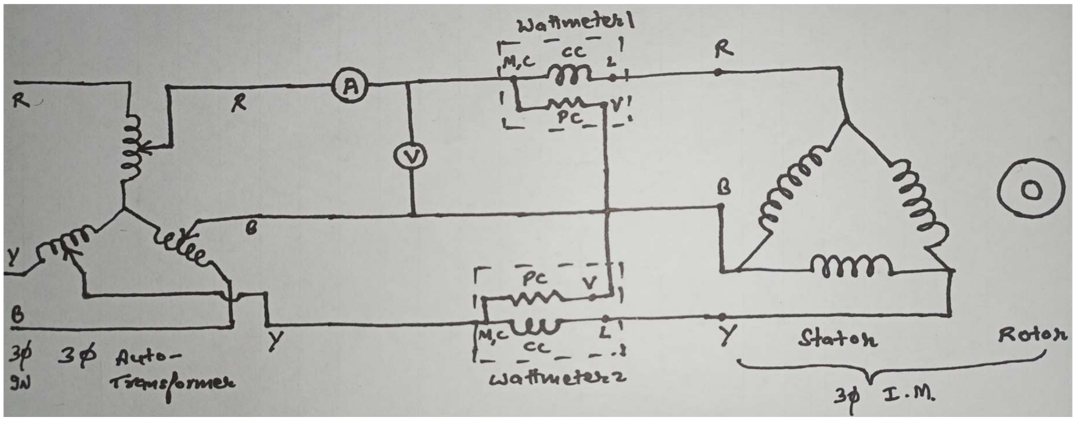

Fig. 1: Experiment setup

PROCEDURE:

No Load Test:

- Connected the circuit as per the circuit diagram.
- Set the autotransformer to zero position.
- Switched on the mains supply.
- Keep the motor shaft on no load.
- Increased the autotransformer output voltage gradually to rated 415V.
- Recorded the ammeter reading (no load current) and wattmeter reading (no load power loss).

Blocked Rotor Test:

- Connected the circuit as per the circuit diagram.
- Set the autotransformer to zero position.
- Switched on the mains supply.
- Blocked the rotor using external means.
- Applied the balanced three phase voltage to the stator windings using variac such that rated stator current flows in the windings.
- Recorded the voltmeter reading (blocked rotor voltage) and wattmeter reading (blocked rotor power loss).
- Measured the dc resistance of the stator windings using multimeter.

OBSERVATIONS:

Test Name	Voltmeter reading (V)	Ammeter reading (A)	Wattmeter 1 reading P_1 (W)	Wattmeter 1 reading P_2 (W)	Total Power $P = P_1 + P_2$ (watts)

No load test	$V_{nl} =$	$I_{nl} =$			$P_{nl} =$
Blocked rotor test	$V_{br} =$	$I_{br} =$			$P_{br} =$

DC resistance of the stator winding (delta connected arrangement), $R_{dc} =$ ____________

CALCULATIONS:

Stator winding resistance per phase, r_1	Stator winding reactance per phase, x_1	Stator magnetizing reactance, X_m	Rotor resistance per phase, r_2	Rotor standstill reactance per phase, x_2	Rotational losses, $P_{rot.loss}$

EQUIVALENT CIRCUIT DIAGRAM:

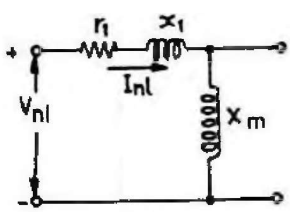

Fig. 2(a): During no load

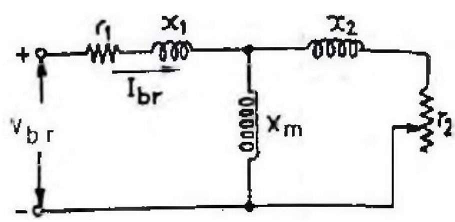

Fig. 2(b): During blocked rotor

RESULT: Within the experimental error, the equivalent circuit parameters of the given 3-phase induction motor were determined.

PRECAUTIONS:
- Autotransformer should be varied gradually.
- The autotransformer should be at zero output position before switching on the supply.
- The load should not be increased beyond the current rating of the machine.

EXPERIMENT No. 4

AIM: To construct and simulate automatic star-delta starter for three phase induction motor.

APPARATUS USED: Computer and electrical control simulating software-EKTS

THEORY: At the time of motor starting the motor inertia is high as slip is equal to 1, thus the machine demands heavy starting current which is quite dangerous for the motor windings. Therefore, starters are used to start the motor safely. The method of starting the induction motor using star-delta starter is used for motors which are designed to operate normally in delta. As, in star connection the phase voltage is $1/\sqrt{3}$ times the applied line voltage, hence the voltage seen by each phase of stator winding is lesser than that during delta connections. With this the starting line current gets reduced to 1/3 times to that of line current when motor started directly on delta.

SCHEMATIC DIAGRAM:

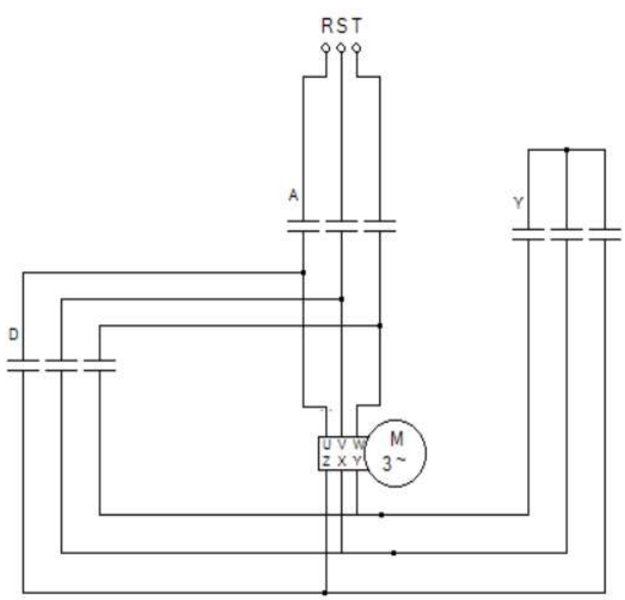

Fig.1 Power Circuit

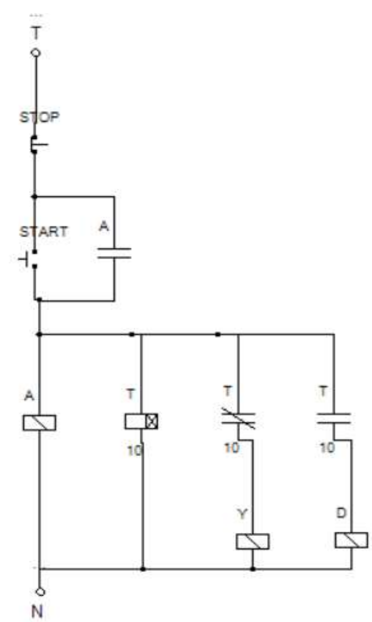

Fig. 2: Control Circuit

ALGORITHM:

Start PB	→	Contactor A on	+	Contactor Y on	+	Timer starts
Timer T on	→	Contactor Y off	+	Contactor D on		
Stop PB	→	Contactor A off	+	Contactor D off		

Table 1: Components Information

Contactor A	Main Contactor
Contactor Y	STAR Connection
Contactor D	DELTA Connection
Timer T	On-Delay Time Relay (set to 10s)
STOP	STOP Push Button
START	START Push Button

RESULT: Star-delta starter is constructed and simulated.

EXPERIMENT No. 5

AIM: To study the speed control of induction motor by rotor resistance control.

APPARATUS USED: Three phase slip-ring induction motor (3 hp, 415V), AC voltmeter (0-600V), AC ammeter (0-5A), connecting wires, slip ring starter, inductive proximity sensor and digital RPM meter.

THEORY: This method of speed control is only possible for slip-ring induction motors. External variable resistances are inserted into the rotor circuit via slip rings. As the rotor resistance is increased, the motor speed falls for a fixed load torque. There is power loss in the external resistance in rotor circuit, hence the efficiency of this method is low. Thus, this method of speed control is adopted for a narrow speed range and usually for a short-time operation.

FORMULAE USED:

- Rotor resistance, $R_2 = \frac{V_r}{\sqrt{3}I_r}$
- Resistance power loss, $P_{loss} = 3(I_r^2 R_2)$

CIRCUIT DIAGRAM:

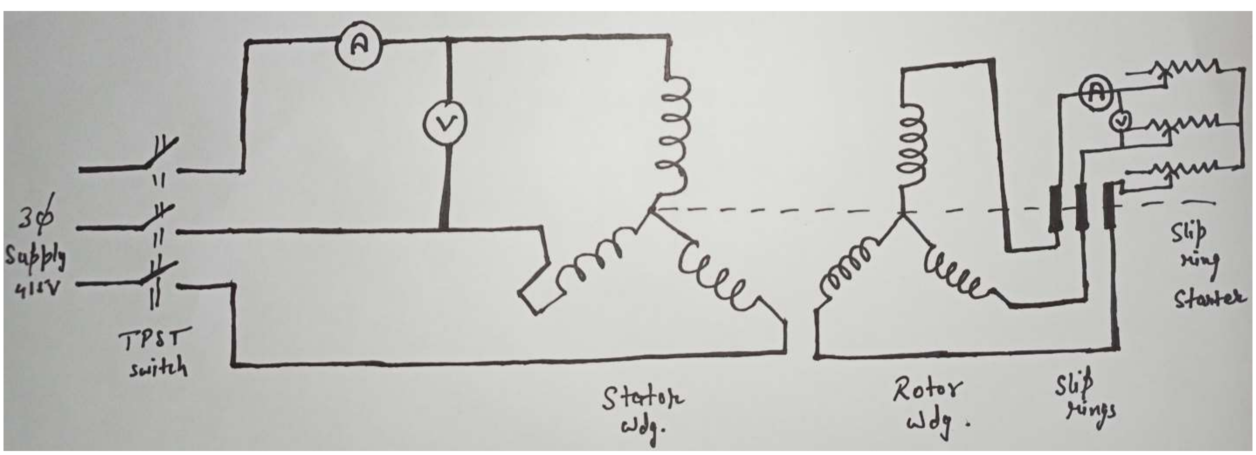

Fig. 1: Experiment setup

PROCEDURE:

- Connected the circuit as per the circuit diagram shown in fig. 1.
- Kept the external rotor resistance to its maximum resistance value.

- Noted down the speed of the rotor using RPM meter, and the stator current, rotor circuit current and voltage.
- Reduced the external rotor resistance in steps and repeated the above step.
- Computed the power loss in the external rotor resistance.

OBSERVATIONS:

S. No.	Stator current (A)	Rotor current (A)	Rotor line voltage (V)	Rotor speed (RPM)	Rotor resistance (Ω)	Rotor resistance power loss (W)

RESULT: It is observed that as the rotor resistance increases, the rotor speed falls and the power loss in the rotor circuit increases.

PRECAUTIONS:

- All the connections should be tight.
- The slip ring starter must be set at maximum resistance at the time of starting the motor.
- The load should not be increased beyond the current rating of the machine.

EXPERIMENT No. 6

AIM: To perform open circuit test on 3-phase alternator and to obtain its open circuit characteristic.

APPARATUS USED: Three-phase alternator (440V, 1.3A, 1500 rpm), DC motor (220V, 2HP), variable DC supply (220V-2 in nos.), AC Voltmeter (0-600V), DC ammeter (0-5A), tachometer, connecting wires.

THEORY: Synchronous alternator is an AC synchronous machine which operates at synchronous speed. Open-circuit characteristic of a synchronous alternator is the plot between generated emf and field current. As the excitation is increased, the emf generated also increases linearly, but as the excitation is increased more and more, the emf gets saturated, i.e., though the field current is increased but generator emf will not increase. Hence, the open circuit characteristics of the alternator becomes non-linear.

CIRCUIT DIAGRAM:

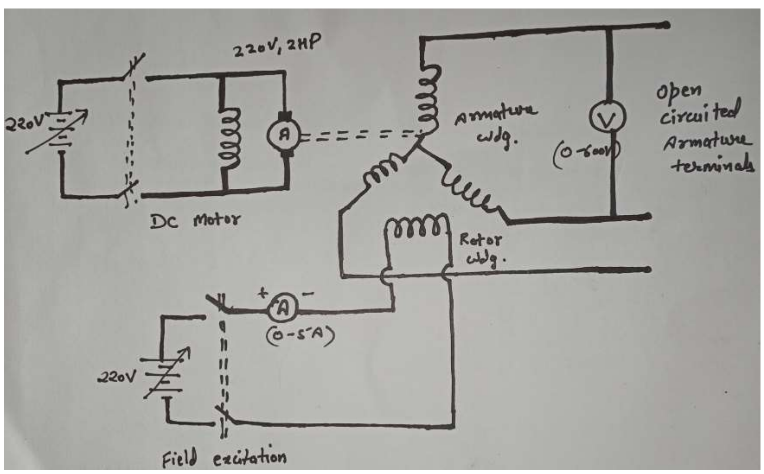

Fig. 1: Experiment setup

PROCEDURE:

- Kept the alternator armature open circuited and connected the circuit as per the fig. 1.
- Kept the field excitation of the alternator to zero.
- Started the DC motor and increase its speed to the rated speed of given three phase alternator using armature voltage speed control method. Tachometer was used to examine the speed of the motor.
- Gradually, the field current to the alternator field winding was increased from zero and the open circuit terminal voltage of the alternator was noted down simultaneously along with the ammeter reading measuring the field current.

- Repeated the above step of increasing the field excitation till 125% of the rated armature voltage was reached.
- Plotted the OCC i.e., curve between open circuit armature voltage and field current.

OBSERVATIONS:

S. No.	Field current (A)	Open circuit armature voltage, E_f (V)

RESULT: Within the experimental error, the open circuit characteristic of the given three phase alternator was obtained.

PRECAUTIONS:

- All the connections should be tight.
- The supply to the motor should be kept at zero before switching on the mains.
- The field excitation should be kept at zero before switching on the mains.
- The applied voltage to the motor should be increased gradually to limit the starting current.
- The open circuit armature voltage of the alternator should not be increased beyond 125% of its rated voltage.

EXPERIMENT No. 7

AIM: To perform short-circuit test on a 3-phase alternator and to obtain its short-circuit characteristic.

APPARATUS USED: Three-phase alternator (440V, 1.3A, 1500 rpm), DC motor (220V, 2 hp), variable DC supply (220V-2 in nos.), AC ammeter (0-2A), DC ammeter (0-5A), tachometer, connecting wires.

THEORY: Synchronous alternator is an AC synchronous machine which operates at synchronous speed. short-circuit characteristic of a synchronous alternator is the plot between armature current and field current. As the excitation is increased, the armature current also increases linearly. As during this case the emf will be very low, hence the alternator will not get saturated, and the short circuit characteristic will remain linear.

CIRCUIT DIAGRAM:

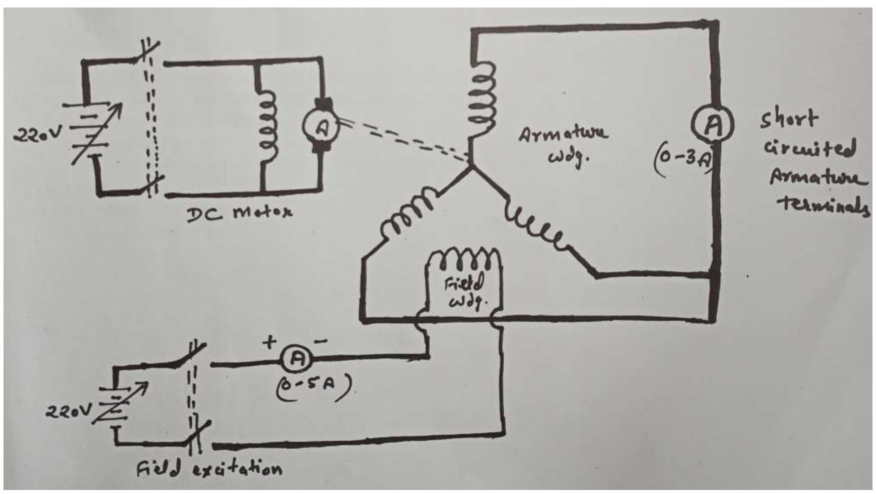

Fig. 1: Experiment setup

PROCEDURE:

- Connected the circuit as per the fig. 1.
- Kept the field excitation of the alternator to zero.
- Started the DC motor and increase its speed to the rated speed of given three phase alternator using armature voltage speed control method. Tachometer was used to examine the speed of the motor.
- Gradually, the field current to the alternator field winding was increased from zero and the short circuit armature current of the alternator was noted down simultaneously along with the ammeter reading measuring the field current.

- Repeated the above step of increasing the field excitation till 125% of the rated armature current was reached.
- Plotted the SCC i.e., curve between short circuit armature current and field current.

OBSERVATIONS:

S. No.	Field current (A)	Short circuit armature current, I_a (A)

RESULT: Within the experimental error, the short circuit characteristic of the given three phase alternator was obtained.

PRECAUTIONS:

- All the connections should be tight.
- The supply to the motor should be kept at zero before switching on the mains.
- The field excitation should be kept at zero before switching on the mains.
- The applied voltage to the motor should be increased gradually to limit the starting current.
- The short circuit armature current should not be increased beyond 125% of the rated current.

EXPERIMENT No. 8

AIM: To measure synchronous impedance, short circuit ratio of a synchronous alternator, and hence obtain the full load voltage regulation of the alternator using synchronous impedance method.

APPARATUS USED: Three-phase alternator (440V, 1.3A, 1500 rpm), DC motor (220V, 2 hp), variable DC supply (220V-2 in nos.), AC ammeter (0-2A), DC ammeter (0-5A), tachometer, multimeter and connecting wires.

THEORY: Synchronous alternator is an AC synchronous machine which operates at synchronous speed. Short circuit ratio (SCR) is defined as the ratio of field current required to produce rated armature voltage at open circuit to the field current required to produce the rated armature current at short circuit. SCR is a measure of the stability of the alternator. Higher the SCR (around 1 to 1.5), greater will be the synchronizing power and hence the stability.

Synchronous impedance method is applied only to cylindrical rotor machines to obtain voltage regulation, because the air gap is almost constant in cylindrical rotor machines and hence the air-gap flux. Thus, mmfs can be replaced by their corresponding emfs. The synchronous impedance is obtained using OCC and SCC.

FORMULAE USED:

- $Z_s = \frac{Open\ circuit\ voltage\ from\ the\ OCC\ at\ a\ certain\ field\ current}{short\ circuit\ armature\ current\ from\ the\ SCC\ at\ the\ same\ field\ current}$
- $SCR = \frac{I_f\ required\ to\ produce\ rated\ armature\ voltage\ at\ open\ circuit}{I_f\ required\ to\ produce\ the\ rated\ armature\ current\ at\ short\ circuit}$
- $r_a^{dc} = \frac{1}{2} \times resistance\ measured\ across\ two\ phases\ of\ armature$
- $ac\ resistance, r_a = 1.2 \times r_a^{dc}$
- $synchronous\ reactance, X_s = \sqrt{Z_s^2 - r_a^2}$
- $\bar{E}_f = \bar{V}_t + \bar{I}_a(r_a + jX_s)$
- $Voltage\ regulation = \frac{|\bar{E}_f| - |\bar{V}_t|}{|\bar{V}_t|} \times 100$

CIRCUIT DIAGRAM:

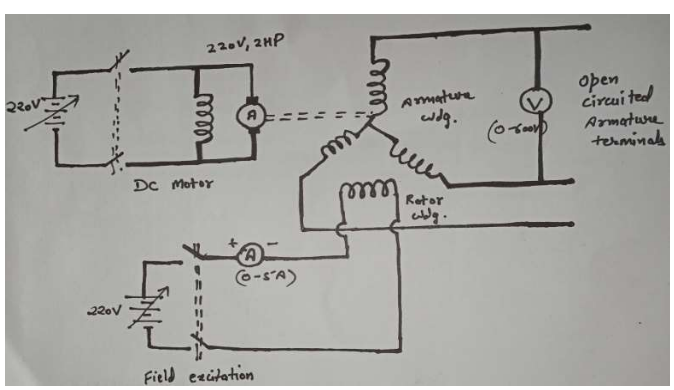

Fig. 1: Open circuit test

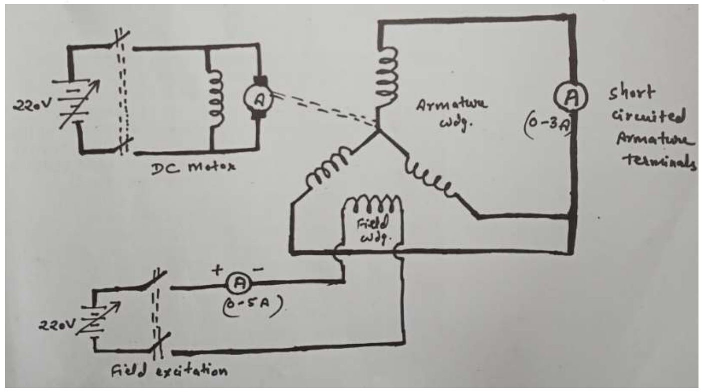

Fig. 2: Short circuit test

PROCEDURE:

- Connected the circuit as per the fig. 1.
- Obtained the open-circuit characteristics of the alternator.
- Connected the circuit as per the fig. 2.
- Obtained the short-circuit characteristic of the alternator.
- Measured the armature winding resistance using the multimeter.
- Synchronous impedance was calculated from the open and short circuit characteristics.
- Noted down the open circuit voltage from OCC corresponding to the field current required to produce full load armature current in SCC.
- Full load voltage regulation was computed using synchronous impedance method.

OBSERVATIONS:

S. No.	Field current (A)	Open circuit armature voltage, E_f (V)

S. No.	Field current (A)	Short circuit armature current, I_a (A)

OCC AND SCC CHARACTERISTICS:

CALCULATIONS:

DC armature resistance between two phases	Armature resistance per phase, r_a	Synchronous impedance per phase, Z_s	Synchronous reactance per phase, X_s	SCR	E_f corresponding to full load armature current	Full load armature current, I_a

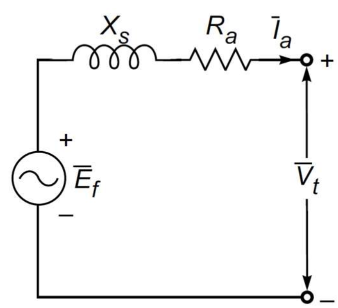

Fig. 3: Equivalent circuit diagram

- $E_f\angle\delta = V_t\angle 0 + I_a\angle 0(r_a + jX_s)$

  on comparing real and imaginary parts:

- $E_f sin\delta = I_a X_s$

  $\delta = sin^{-1}\left(\frac{I_a X_s}{E_f}\right) =$ ____

- $E_f cos\delta = V_t + I_a r_a$

  $V_t = E_f cos\delta - I_a r_a =$ _____

- $full\ load\ voltage\ regulation = \frac{E_f - V_t}{V_t} \times 100 =$ _________

RESULT: Within the experimental error, the synchronous impedance, SCR and full load voltage regulation of the given three-phase alternator were determined.

PRECAUTIONS:

- All the connections should be tight.
- The supply to the motor should be kept at zero before switching on the mains.
- The field excitation should be kept at zero before switching on the mains.
- The applied voltage to the motor should be increased gradually to limit the starting current.
- The short circuit armature current should not be increased beyond 125% of the rated current.

EXPERIMENT No. 9

AIM: To perform load test on a three-phase alternator.

APPARATUS USED: Three-phase alternator (440V, 1.3A, 1500 rpm), DC motor (220V, 2 hp), variable DC supply (220V-2 in nos.), AC ammeter (0-2A), DC ammeter (0-5A), tachometer, connecting wires, three-phase lamp load (440V, 1kW).

THEORY: Synchronous alternator is an AC synchronous machine which operates at synchronous speed. As the dc field excitation of an alternator is increased, its speed being held constant, the magnetic flux, and hence, the output voltage increases up to its saturation of core. Under load because of armature reaction, the field flux is affected by the load pf. Leading pf assists the field flux while lagging pf opposes the field flux. Load test provides the information about the efficiency and regulation. As the electrical load increases on the alternator, its speed gets reduced under constant excitation and terminal voltage reduces.

CIRCUIT DIAGRAM:

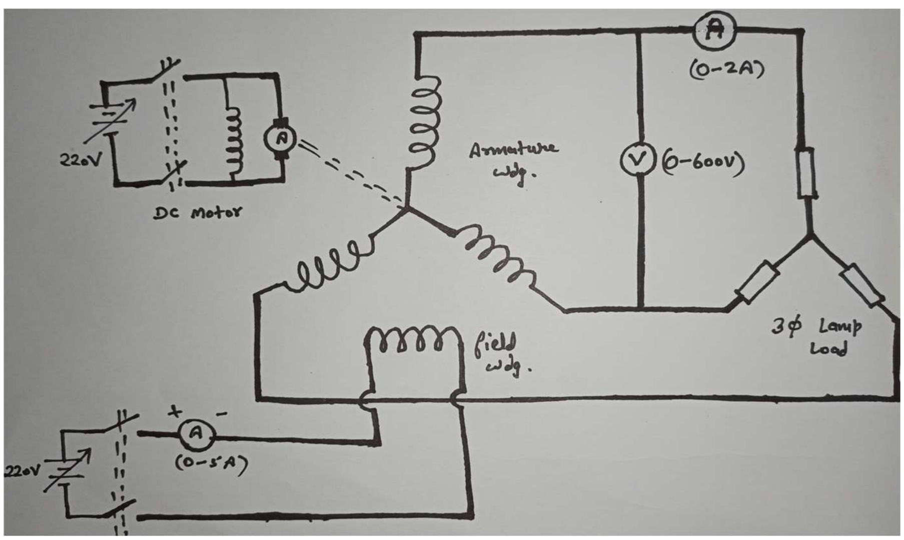

Fig. 1: Experiment setup

PROCEDURE:

- Connected the circuit as per the fig. 1.
- Kept the field excitation of the alternator to zero.
- Started the DC motor and increased its speed to the rated speed of given three phase alternator using armature voltage speed control method. Tachometer was used to examine the speed of the motor.

- Gradually, the field current to the alternator field winding was increased from zero till the rated open circuit voltage gets achieved.
- Now, put load across the alternator armature in steps and noted down the speed, armature current and alternator terminal voltage, without changing the dc excitation.
- After performing the experiment, removed the dc excitation of the alternator and brought the speed to the zero.
- Switched off the mains.

OBSERVATIONS:

S. No.	Alternator terminal voltage, V_t (V)	Alternator armature current, I_a (A)	Speed (rpm)

RESULT: As the load on the alternator is increased, its speed decreases and terminal voltage also decreases. Hence, dc input to the motor is to be also increased to bring back the speed of alternator to rated synchronous speed.

PRECAUTIONS:
- All the connections should be tight.
- The supply to the motor should be kept at zero before switching on the mains.
- The field excitation should be kept at zero before switching on the mains.
- The alternator should not be overloaded.

EXPERIMENT No. 10

AIM: To determine the negative and zero sequence impedances of a three-phase alternator.

APPARATUS USED: Three-phase alternator (440V, 1.3A, 1500 rpm), DC motor (220V, 2 hp), variable DC supply (220V-2 in nos.), AC ammeter (0-2A), wattmeter (5A, 300V), tachometer, connecting wires.

THEORY: When a synchronous generator is carrying an unbalanced load, its operation is analyzed by symmetrical components. The sequence currents flow in the machine. The negative sequence is produced and armature reaction which rotates around armature at synchronous speed in direction to that of field poles and therefore rotates part the field poles at synchronous speed, inducing current in the field damper winding and rotor iron. The impendence encountered by the negative sequence is called the negative sequence impedance of the generator. The zero-sequence current produces flux in each phase but their combined armature reaction at the air gap is zero. The impedance encountered by their currents is called zero sequence impedance of alternator. Zero sequence current only flows when alternator neutral is earthed and it is equal to the one-third of the neutral current.

FORMULAE USED:

- $Z_2 = \frac{V_o}{\sqrt{3}I_{sc}}$; where V_o is open circuit voltage between one opened phase and two shorted phases and I_{sc} is short circuit current in the shorted phases
- $\phi = cos^{-1}\left(\frac{P}{V_o I_{sc}}\right)$
- $X_2 = Z_2\ sin\phi$
- $Z_o = \frac{3V_o}{I_o}$; where V_o is the voltage applied to and I_o is the total current input to the parallel connected armature windings

CIRCUIT DIAGRAM:

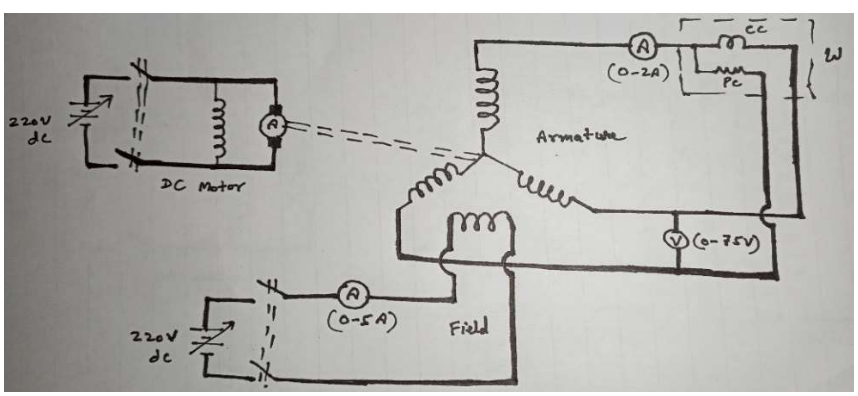

Fig. 1: Determination of negative sequence impedance

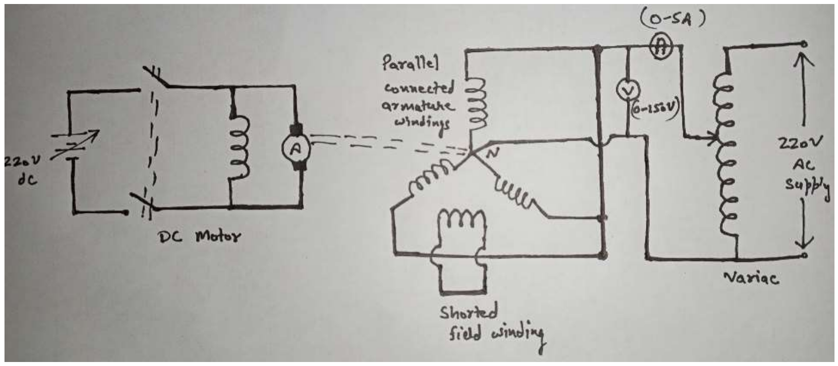

Fig. 2: Determination of zero sequence impedance

PROCEDURE:

Determination of negative sequence impedance

- Connected the circuit as per the fig. 1.
- Kept the field excitation of the alternator to zero.
- Started the DC motor and increased its speed to the rated speed of given three phase alternator using armature voltage speed control method. Tachometer was used to examine the speed of the motor.
- Gradually, the field current to the alternator field winding was increased from zero such that the short circuit current did not exceed its full load value.
- Noted down the readings of voltmeter, ammeter and wattmeter.
- Reduced the excitation to zero, and brought down the speed to zero.

Determination of zero sequence impedance

- Connected the circuit as per the fig. 2.
- The machine was made to run at rated speed.
- Applied low voltage from a variac at the parallel connected armature windings in steps such that the current should not exceed the rated armature winding current, and measured the voltage and current.
- Reduced the voltage to zero, brought the speed down to zero and switched off the mains.

OBSERVATIONS AND CALCULATIONS:

Table 1: Negative sequence impedance

S. No.	Open circuit voltage, V_o (V)	Short circuit current, I_{sc} (A)	Wattmeter reading, P (W)	$Z_2 = \frac{V_o}{\sqrt{3}I_{sc}}$	$X_2 = Z_2 \sin\phi$	Average Z_2 and X_2

Table 2: Zero sequence impedance

S. No.	Applied voltage, V_o (V)	Ammeter reading, I_o (A)	$Z_o = \frac{3V_o}{I_o}$	Average Z_o

RESULT: Within the experimental error, the negative and zero sequence impedances of the given three-phase alternator were determined.

PRECAUTIONS:

- All the connections should be tight.
- The supply to the motor should be kept at zero before switching on the mains.
- The field excitation should be kept at zero before switching on the mains.
- The alternator armature winding current should not be increased beyond its rated value.