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LAB MANUAL

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Branch : *B.E.* – ECE

Year & Semester : II Year / IV Semester

EE6461- ELECTRICAL ENGINEERING AND CONTROL SYSTEM LABORATORY

ANNA UNIVERSITY : CHENNAI
REGULATION – 2013

EE6461 ELECTRICAL ENGINEERING AND CONTROL SYSTEM LABORATORY

LIST OF EXPERIMENTS:

1. Study of DC & AC motor starters
2. Study of three phase circuits
3. Speed Control of DC shunt motor
4. Load Test on DC shunt motor
5. OCC & Load Characteristics of DC shunt generator
6. Transfer Function of separately excited D.C Generator.
7. Regulation of three phase alternator
8. Open Circuit and Short Circuit test on single phase transformer to draw its equivalent circuit
9. Load test on single-phase transformer
10. Load test on single phase and three-phase Induction motor
11. Measurement of passive elements using Bridge Networks.
12. Study of transducers and characterization.
13. Digital simulation of linear systems.
14. Stability Analysis of Linear system using MATLAB or equivalent Software.
15. Study the effect of P, PI, PID controllers using MATLAB or equivalent Software.
16. Design of Lead and Lag compensator.

TOTAL: 45 PERIODS

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3		Open Circuit Characteristics of Self Excited DC Shunt Generator		
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5		Load Test on Single Phase Transformer		
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INTRODUCTION

SYSTEM

The number of elements or components connected in sequence to form a group and that group is said to be a system.

CONTROL SYSTEM

The output quantity is controlled by varying the input quantity. This system is said to be control system.

Control systems are ubiquitous. They appear in our homes, in cars, in industry and in systems for communication and transport, just to give a few examples. Control is increasingly becoming mission critical; processes will fail if the control does not work. Control has been important for design of experimental equipment and instrumentation used in basic sciences and will be even more so in the future. Principles of control also have an impact on such diverse fields as economics, biology, and medicine.

Controls, like many other branches of engineering science, have developed in the same pattern as natural science. Although there are strong similarities between natural science and engineering science it is important to realize that there are some fundamental differences. The inspiration for natural science is to understand phenomena in nature. This has led to a strong emphasis on analysis and isolation of specific phenomena, so called reductionism. A key goal of natural science is to find basic laws that describe nature. The inspiration of engineering science is to understand, invent, and design man-made technical systems. This places much more emphasis on interaction and design. Interaction is a key feature of practically all manmade systems. It is therefore essential to replace reductionism with a holistic systems approach. The technical systems are now becoming so complex that they pose challenges comparable to the natural systems.

A fundamental goal of engineering science is to find system principles that make it possible to effectively design complex systems. Feedback, which is at the heart of automatic control, is an example of such a principle.

A simple form of feedback consists of two dynamical systems connected in a closed loop which creates an interaction between the systems. Simple causal reasoning about such a system is difficult because, the first system influences the second and the second system influences the first, leading to a circular argument.

This makes reasoning based on cause and effect difficult and it is necessary to analyze the system as a whole. A consequence of this is that the behavior of a feedback system is often counterintuitive.

To understand feedback systems it is therefore necessary to resort to formal methods. Feedback has many advantages. It is possible to create linear behavior out of nonlinear components. Feedback can make a system very resilient towards external influences. The total system can be made very insensitive to external disturbances and to variations in its individual components. Feedback has one major disadvantage; it may create instability, which is intrinsically a dynamic phenomenon. To understand feedback systems it is therefore necessary to have a good insight into dynamics. The wide applicability of control has many advantages.

Since control can be used in so many different fields, it is a very good vehicle for technology transfer. Ideas invented in one field can be applied to another technical field. Control is inherently multi-disciplinary. A typical control system contains sensors, actuators, computers and software. Analysis of design of control systems require knowledge about the particular process to be controlled, knowledge of the techniques of control and specific technology used in sensors and actuators. Controllers are typically implemented using digital computers.

EX.NO : 01	LOAD TEST ON DC SHUNT MOTOR
DATE	

AIM:

To conduct load test on DC shunt motor and to find efficiency.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-20)A	MC	1
2	Voltmeter	(0-300)V	MC	1
3	Rheostat	1250Ω, 0.8A	Wire Wound	1
4	Tachometer	(0-1500) rpm	Digital	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

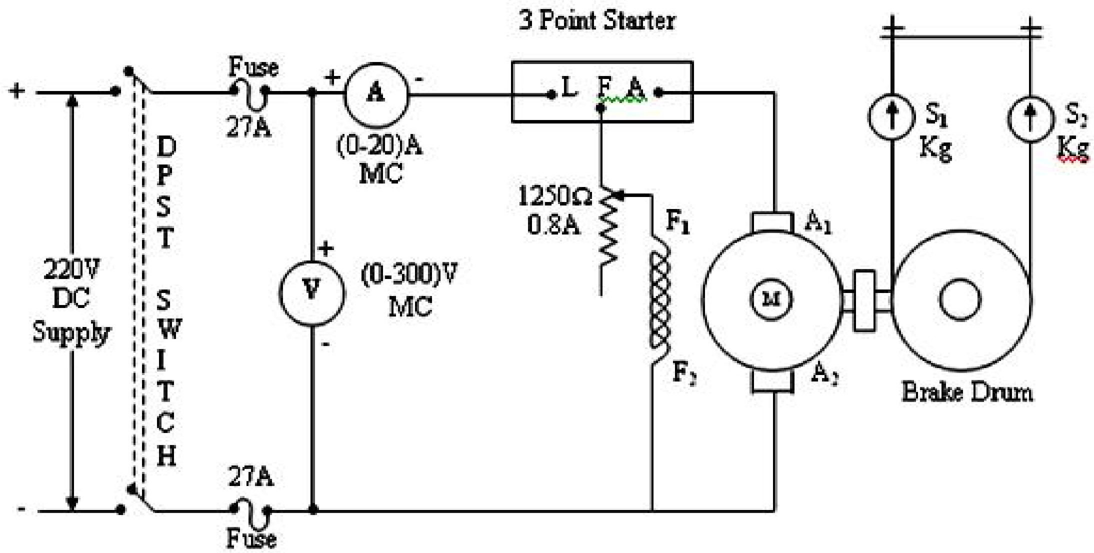
PRECAUTIONS:

1. DC shunt motor should be started and stopped under no load condition.
2. Field rheostat should be kept in the minimum position.
3. Brake drum should be cooled with water when it is under load.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. After checking the no load condition, and minimum field rheostat position, DPST switch is closed and starter resistance is gradually removed.
3. The motor is brought to its rated speed by adjusting the field rheostat.
4. Ammeter, Voltmeter readings, speed and spring balance readings are noted under no load condition.
5. The load is then added to the motor gradually and for each load, voltmeter, ammeter, spring balance readings and speed of the motor are noted.
6. The motor is then brought to no load condition and field rheostat to minimum position, then DPST switch is opened.

CIRCUIT DIAGRAM: (Load Test on DC Shunt Motor)

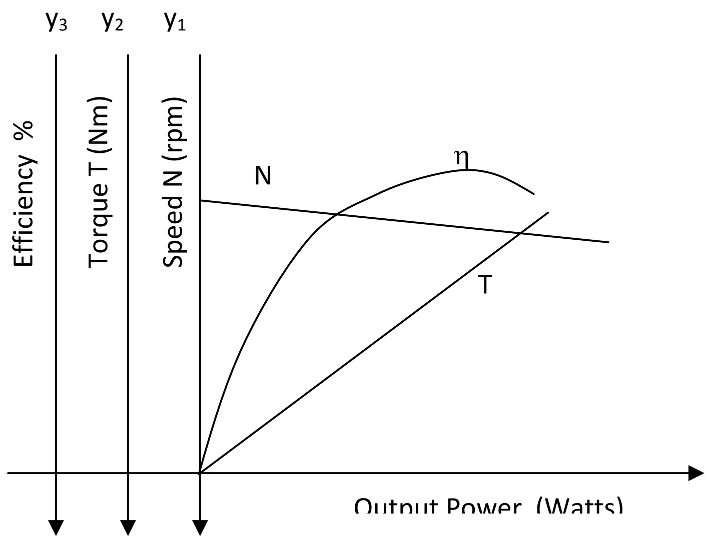


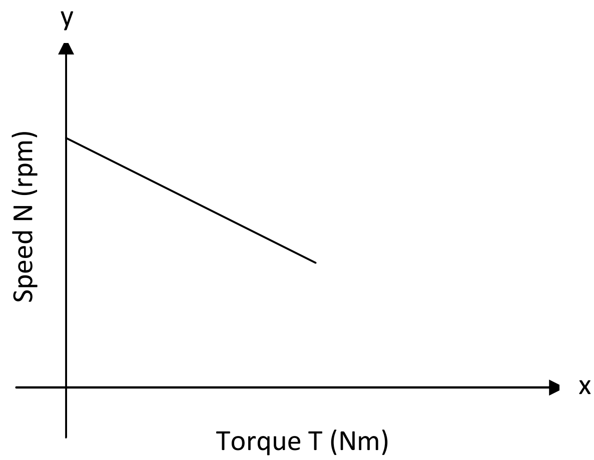
TABULAR COLUMN: **(LOAD TEST ON DC SHUNT MOTOR)**

S. No.	Voltage (V_L)	Current (I_L)	Spring Balance Reading		(S_1¼S_2)	Speed (N)	Torque (T)	Output Power (Po)	Input Power (P_i)	Efficiency (¦)
			S_1	S_2						
	Volts	*Amps*	*Kg*	*Kg*	*Kg*	*rpm*	*Nm*	*Watts*	*Watts*	%

Circumference of the Brake drum = **cm.**

MODEL GRAPHS: (Load Test on DC Shunt Motor)





FORMULAE:

1. Radius of brake drum(**R**) $= \dfrac{\boldsymbol{Circumference\ of\ the\ brake\ drum\ in\ CM}}{\mathbf{100*2}\boldsymbol{n}}$ **m**
2. Torque T = $(S_1 \sim S_2)$ x R x 9.81 Nm
3. Input Power $P_i = V*I$ Watts
4. Output Power $P_0 = \dfrac{2nNT}{60}$ Watts
5. Efficiency η % $= \dfrac{Output\ power}{Input\ power}$ x 100%

MODEL CALCULATIONS:

RESULT:

Thus the efficiency of the DC shunt motor with the load is tested.

EX.NO :02	SPEED CONTROL OF DC SHUNT MOTOR
DATE	

AIM:

To obtain speed control of DC shunt motor by

a. Varying armature voltage with field current constant.
b. Varying field current with armature voltage constant

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-20) A	MC	1
2	Voltmeter	(0-300) V	MC	1
3	Rheostats	1250Ω, 0.8A 50Ω, 3.5A	Wire Wound	Each 1
4	Tachometer	(0-3000) rpm	Digital	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS:

1. Field Rheostat should be kept in the minimum resistance position at the time of starting and stopping the motor.
2. Armature Rheostat should be kept in the maximum resistance position at the time of starting and stopping the motor.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. After checking the maximum position of armature rheostat and minimum position of field rheostat, DPST switch is closed

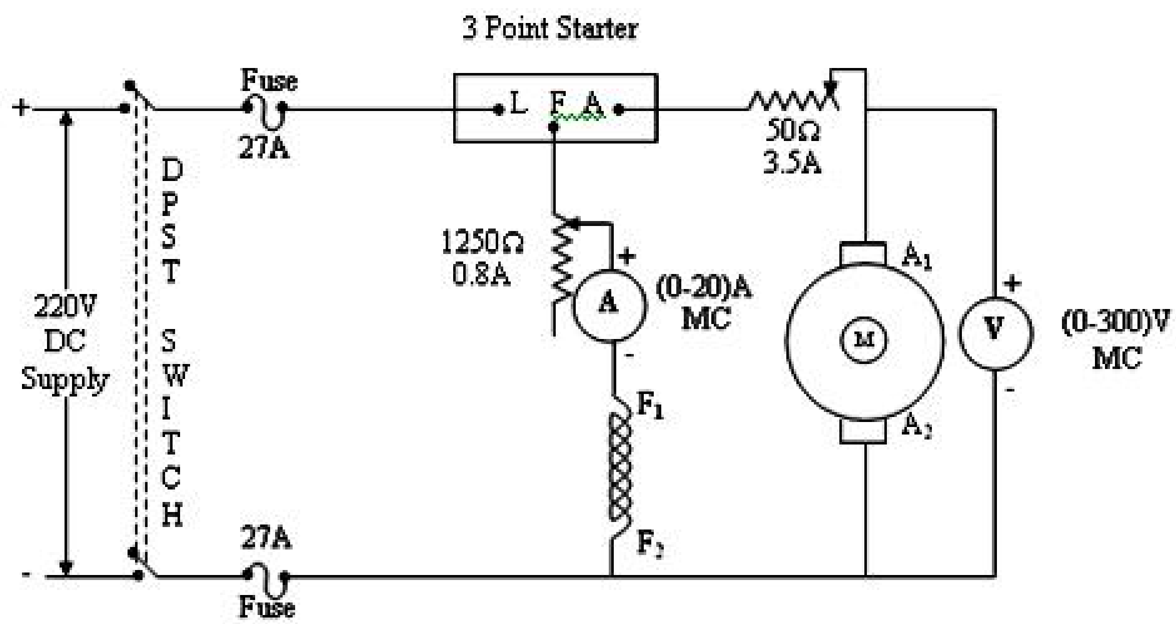
(i) Armature Control:

Field current is fixed to various values and for each fixed value, by varying the armature rheostat, speed is noted for various voltages across the armature.

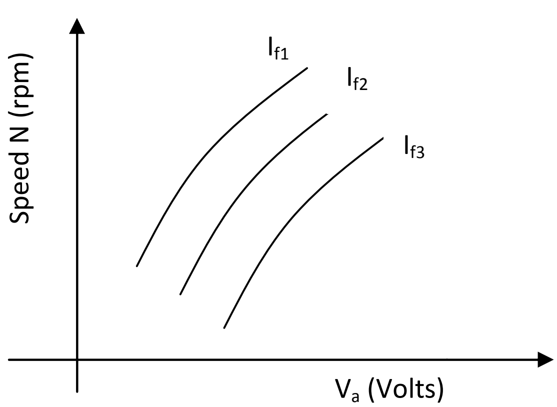
(ii) Field Control:

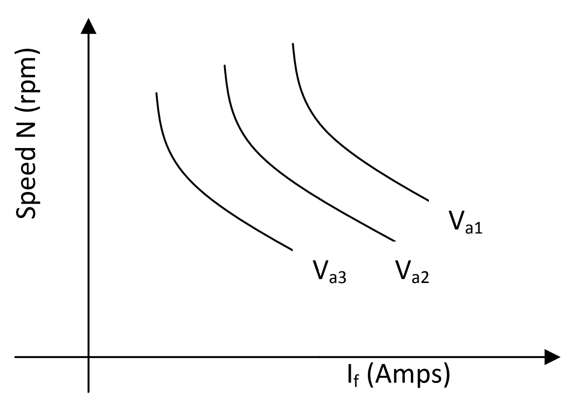
1. Armature voltage is fixed to various values and for each fixed value, by adjusting the field rheostat, speed is noted for various field currents.
2. Bringing field rheostat to minimum position and armature rheostat to maximum position DPST switch is opened.

CIRCUIT DIAGRAM(Speed Control of DC Shunt Motor)



MODEL GRAPHS: (Speed Control of DC Shunt Motor)





TABULAR COLUMN:

(i) Armature Voltage Control:

S. No.	I_{f1} =		I_{f2} =		I_{f3} =	
	Armature Voltage (V_a) *Volts*	**Speed (N)** *rpm*	**Armature Voltage (V_a)** *Volts*	**Speed (N)** *rpm*	**Armature Voltage , (V_a)** *Volts*	**Speed (N)** *rpm*

(ii) Field Control:

S. No.	V_{a1} =		V_{a2} =		V_{a3} =	
	Field Current (I_f) *Amps*	**Speed (N)** *rpm*	**Field Current (I_f)** *Amps*	**Speed (N)** *rpm*	**Field Current (I_f)** *Amps*	**Speed (N)** *rpm*

RESULT:

Thus the speed control of DC shunt motor by Varying armature voltage with field current constant and Varying field current with armature voltage constant is verified.

EX.NO :03	OPEN CIRCUIT CHARACTERISTICS OF SELF EXCITED DC SHUNT GENERATOR
DATE	

AIM:

To obtain open circuit characteristics of self excited DC shunt generator and to find its critical resistance.

APPARATUS REQUIRED:

SL. NO.	APPARATUS	RANGE	TYPE	QUANTITY
1	Ammeter	(0-2)A	MC	1
2	Voltmeter	(0-300) V	MC	1
3	Rheostats	1250Ω, 1A	Wire Wound	Each 1
4	Tachometer	(0-3000) rpm	Digital	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

FUSE RATING

125% of rated current (full load current)

PRECAUTIONS:

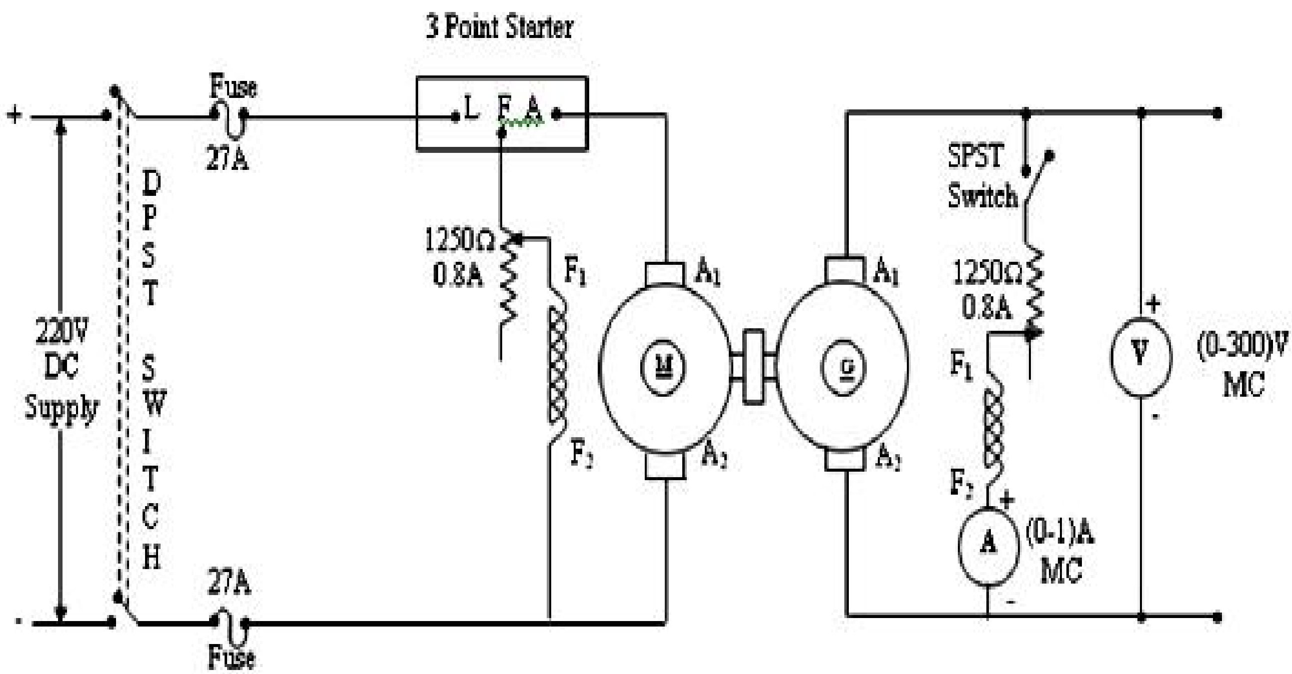
1. The field rheostat of motor should be in minimum resistance position at the time of starting and stopping the machine.
2. The field rheostat of generator should be in maximum resistance position at the time of starting and stopping the machine.
3. SPST switch is kept open during starting and stopping.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. After checking minimum position of motor field rheostat, maximum position of generator field rheostat, DPST switch is closed and starting resistance is gradually removed.
3. By adjusting the field rheostat, the motor is brought to rated speed.

4. Voltmeter and ammeter readings are taken when the SPST switch is kept open.
5. After closing the SPST switch, by varying the generator field rheostat, voltmeter and ammeter readings are taken.
6. After bringing the generator rheostat to maximum position, field rheostat of motor to minimum position, SPST switch is opened and DPST switch is opened.

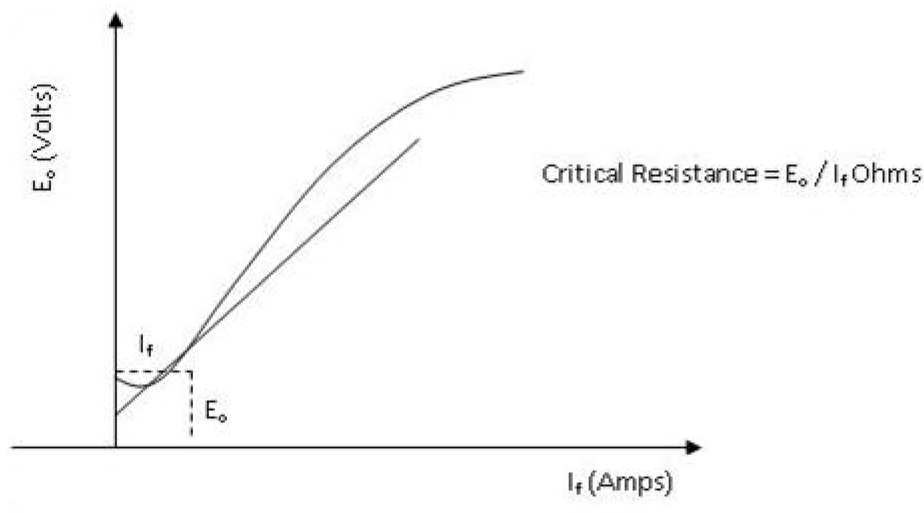
CIRCUIT DIAGRAM: (Open Circuit Characteristics of Self Excited DC Shunt Generator)



TABULAR COLUMN: (Open Circuit Characteristics of Self Excited DC Shunt Generator)

SL.NO	**Field Current** (I_f) *Amps*	**Armature Voltage** (E_0) *volts*

MODEL GRAPH: (Open Circuit Characteristics of Self Excited DC Shunt Generator)



RESULT

Thus the self excited DC shunt generator open circuit characteristics are obtained and the critical resistance is found.

EX.NO :04	LOAD CHARACTERISTICS OF SELF EXCITED DC SHUNT GENERATOR
DATE	

AIM:

To obtain internal and external characteristics of DC shunt generator.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-2)A (0-20A)	MC	Each 1
2	Voltmeter	(0-300) V	MC	1
3	Rheostats	1250Ω, 1A	Wire Wound	Each 1
4	Tachometer	(0-3000) rpm	Digital	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS:

1. The field rheostat of motor should be at minimum position.
2. The field rheostat of generator should be at maximum position.
3. No load should be connected to generator at the time of starting and stopping.

PROCEDURE:

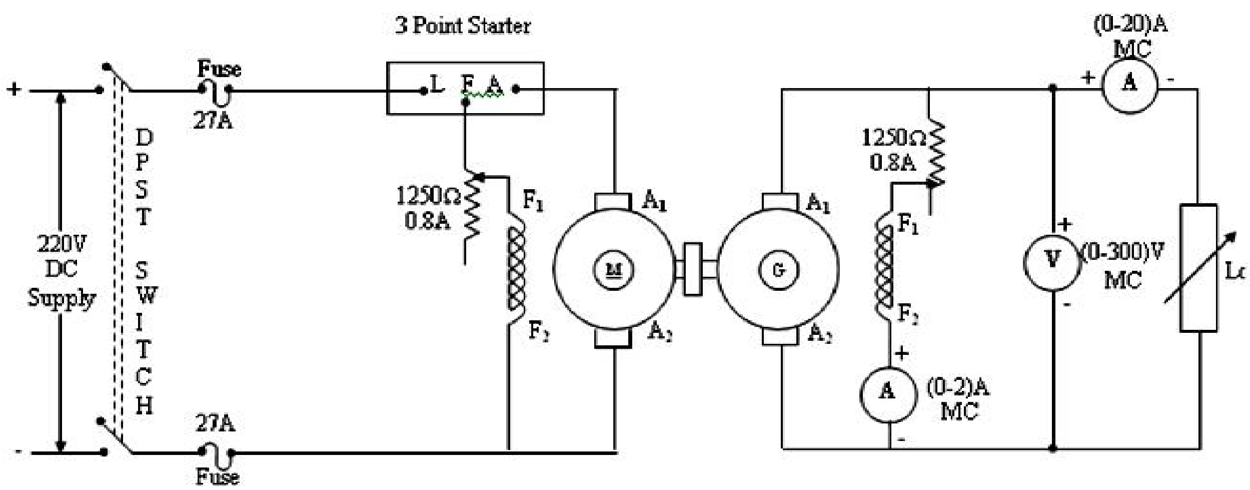
1. Connections are made as per the circuit diagram.
2. After checking minimum position of DC shunt motor field rheostat and maximum position of DC shunt generator field rheostat, DPST switch is closed and starting resistance is gradually removed.
3. Under no load condition, Ammeter and Voltmeter readings are noted, after bringing the voltage to rated voltage by adjusting the field rheostat of generator.
4. Load is varied gradually and for each load, voltmeter and ammeter readings are noted.

5. Then the generator is unloaded and the field rheostat of DC shunt generator is brought to maximum position and the field rheostat of DC shunt motor to minimum position, DPST switch is opened.

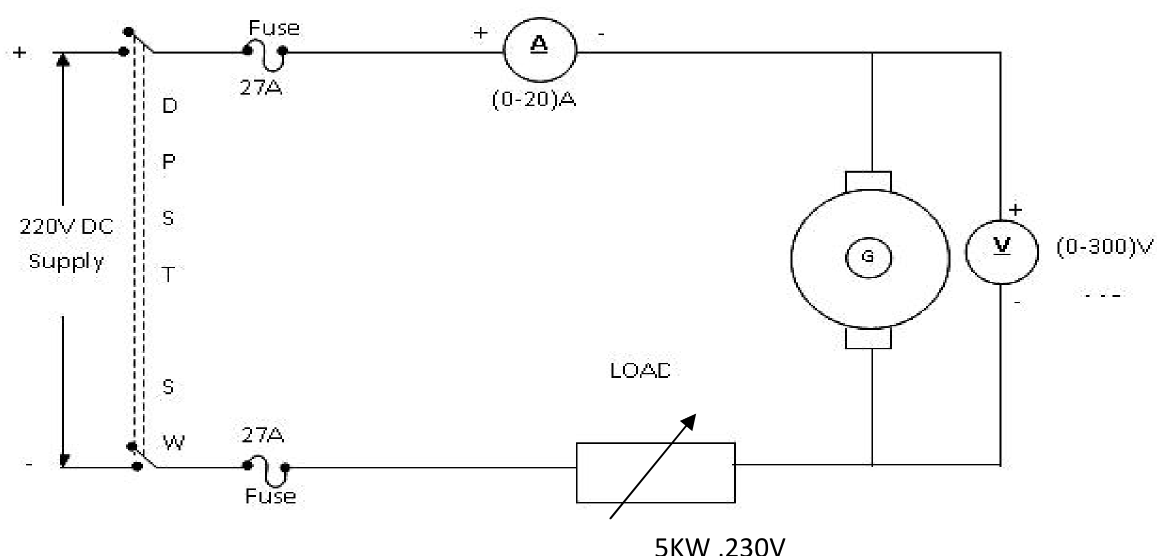
PROCEDURE TO FIND ARMATURE RESISTANCE:

1. Connections are made as per the circuit diagram.
2. Supply is given by closing the DPST switch.
3. Readings of Ammeter and Voltmeter are noted.
4. Armature resistance in Ohms is calculated as Ra = (Vx1.5) /I

CIRCUIT DIAGRAM: (Load Circuit Characteristics Of Self Excited Dc Shunt Generator)



CIRCUIT DIAGRAM to Find Ra:



TABULATION: (Load Circuit Characteristics of Self Excited DC Shunt Generator)

S.L.NO	**Field Current (I_f)** ***Amps***	**Load Current (I_L)** ***Amps***	**Terminal Voltage (V)** ***volts***	**$I_a=I_f+I_L$** ***Amps***	**Eg=V+IaRa** ***volts***

FORMULAE:

Eg = V + Ia Ra (Volts)

Ia = IL + If (Amps)

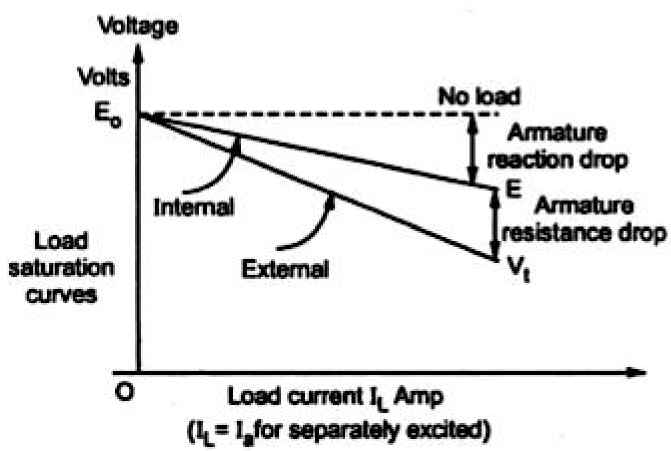
Where,

Eg	:	Generated emf in Volts
V	:	Terminal Voltage in Volts
Ia	:	Armature Current in Amps
I_L	:	Line Current in Amps
I_f	:	Field Current in Amps
Ra	:	Armature Resistance in Ohms

TABULATION : (Load Circuit Characteristics of Self Excited DC Shunt Generator)

S.LNO	Voltage (V) *Volts*	Current (I) *Amps*	Armature Resistance (Ra) *ohms*

MODEL GRAPH: (Load Circuit Characteristics of Self Excited DC Shunt Generator)



RESULT:

Thus the internal and external characteristics of DC shunt generator are verified.

EX.NO :05	LOAD TEST ON A SINGLE PHASE TRANSFORMER
DATE	

AIM:

To conduct load test on single phase transformer and to find efficiency and percentage regulation.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-10)A (0-5)A	MI	Each 1
2	Voltmeter	(0-150) V (0-300) V	MI	Each1
3	Wattmeter	300V,5A 300V,5A	UPF LPF	Each 1
4	Resistive Load	5KW,230V	-	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS:

1. Auto Transformer should be in minimum position.

2. The AC supply is given and removed from the transformer under no load condition.

PROCEDURE:

1. Connections are made as per the circuit diagram.

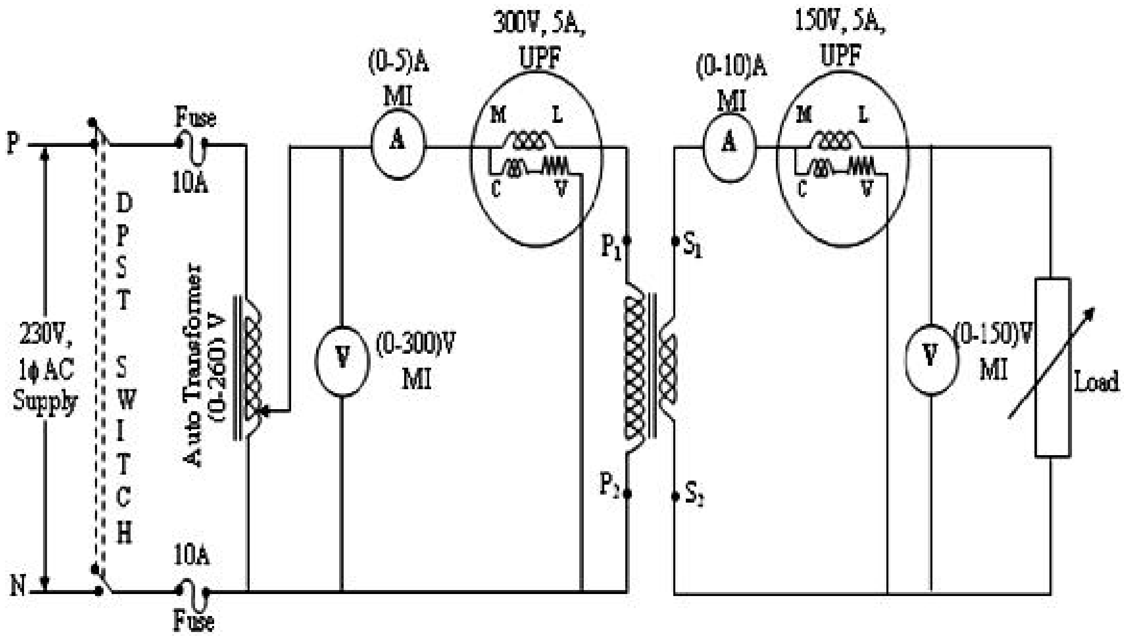
2. After checking the no load condition, minimum position of auto transformer and DPST switch is closed.

3. Ammeter, Voltmeter and Wattmeter readings on both primary side and secondary side are noted.

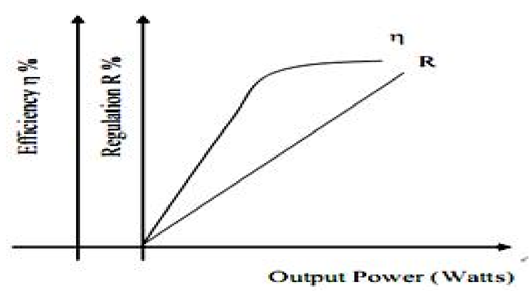
4. The load is increased and for each load, Voltmeter, Ammeter and Wattmeter readings on both primary and secondary sides are noted.

5. Again no load condition is obtained and DPST switch is opened.

CIRCUIT DIAGRAM: (Load Test on A Single Phase Transformer)



MODEL GRAPH: (Load Test on A Single Phase Transformer**)**



TABULATION: (Load Test on A Single Phase Transformer)

(MF – Multiplication factor)

Sl. NO	**Load**	**Primary**			**Secondary**			**Inpur power W_1 X MF**	**Outpur power W_2 X MF**	**%Efficiency**	**% Regulation**
		V_1 ***Volt***	**I_1** ***Amp***	**W_1** ***Watts***	**V_2** ***Volt***	**I_2** ***Amp***	**W_2** ***Watts***	**P_{in}** ***Watts***	**P_{out}** ***Watts***	**ŋ (%)**	**%**

FORMULAE:

1.Output Power(P_{out})= W_2 x Multiplication factor

2.Input Power(P_{in})= W_1 x Multiplication factor

$$3.\text{Efficiency in } \eta\ \% = \frac{\text{Output Power}}{\text{Input Power}} \times 100\%$$

$$4.\text{Regulation R } \% = \frac{V_{NL} - V_{FL}\ (\text{Secondary})}{V_{NL}} \times 100\%$$

Where,

V_{NL} – No load voltage in volts

V_{FL}- Full load voltage in volts

W_1- Primary watt meter reading in watts

W_2- Secondary watt meter reading in watts

RESULT:

Thus the load test on single phase transformer and to find efficiency and percentage regulation is conducted.

EX.NO :06	OPEN CIRCUIT & SHORT CIRCUIT TEST ON A SINGLE PHASE TRANSFORMER
DATE	

AIM:

To predetermine the efficiency and regulation of a transformer by conducting open circuit test and short circuit test and to draw equivalent circuit.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-2)A (0-5)A	MC	Each 1
2	Voltmeter	(0-300) V	MC	1
3	Wattmeter	150V,5A 150V,5A	UPF LPF	Each 1
5	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS:

1. Auto Transformer should be in minimum voltage position at the time of closing & opening DPST Switch.

PROCEDURE:

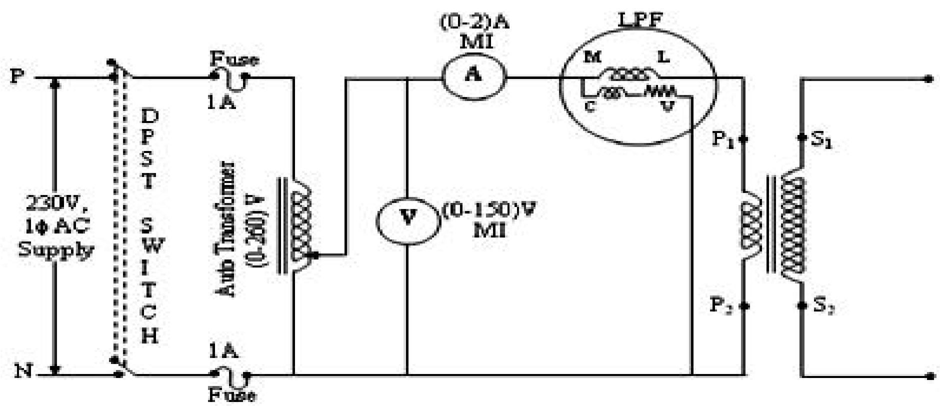
Open Circuit Test:

1. Connections are made as per the circuit diagram.
2. After checking the minimum position of Autotransformer, DPST switch is closed.
3. Auto transformer is adjusted get the rated primary voltage.
4. Voltmeter, Ammeter and Wattmeter readings on primary side are noted.
5. Auto transformer is again brought to minimum position and DPST switch is opened

SHORT CIRCUIT TEST:

1. Connections are made as per the circuit diagram.
2. After checking the minimum position of Autotransformer, DPST switch is closed.
3. Auto transformer is adjusted get the rated primary current.
4. Voltmeter, Ammeter and Wattmeter readings on primary side are noted.
5. Auto transformer is again brought to minimum position and DPST switch is opened.

CIRCUIT DIAGRAM: (Open Circuit Test)



TABULATION: (Open Circuit Test)

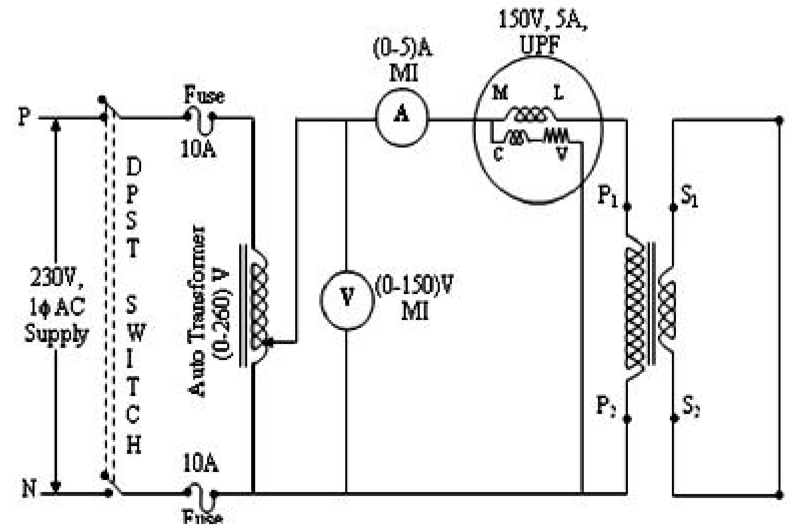
SL.NO	Voltage (V_0) *Volts*	Current (I_0) *Amps*	Power (W_0) *Watts*

V_0 – Open circuit voltage in volts

I_0 – Open circuit current in Amps

W_0– Open circuit power in watts

CIRCUIT DIAGRAM: (Short Circuit Test)



TABULATION FOR SHORT CIRCUIT:

SL.NO	Voltage (V_{sh}) *Volts*	Current (I_{sh}) *Amps*	Power (W_{sh}) *Watts*

V_{sh}– Short circuit voltage in volts

I_{sh}– Short circuit current in Amps

W_{sh}– Short circuit power in watts

FORMULA USED:

1.No load power factor $Cos\acute{Ø}_0 = W_0 / V_0 I_0$

Where V_0 - Open circuit voltage in volts

I_0 - Open circuit current in amps

W_0 - No load power in watts(Iron loss)

2.Working component of no load current $Iw = I_o \cos \acute{Ø}_0$

3.Magnetizing component of no load current $I\mu = I_o \sin\acute{Ø}_0$

4.$R_O = V_0 / Iw$

5.$X_O = V_0 / I\mu$

6.Equivalent impedence of transformer w.r.t HV side $Z_{o2} = V_{sc} / I_{sc}$

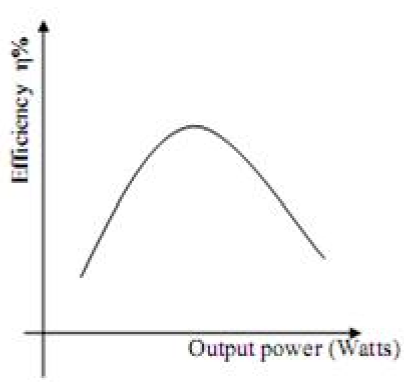
7. Equivalent resistance of transformer w.r.t HV side $R_{o2} = W_{sc} / I_{sc}^2$

8. Equivalent reactance of transformer w.r.t HV side $X_{o2} = \sqrt{Z_{o2}^2 - R_{o2}^2}$ 9.Transformer ratio $K = V_2 / V_1$

10. Equivalent resistance of transformer w.r.t LV side $R_{o1} = R_{o2} / K^2$

11. Equivalent reactance of transformer w.r.t LV side $X_{o1} = X_{o2} / K^2$

MODEL GRAPH: (Short Circuit Test)



TO PREDETERMINE PECENTAGE EFFICIENCY :

1.Q = KVA of the given transformer

2.X= Fraction of load

3.Total Losses= $X^2 W_{sc} + W_0$

4.Input= Output + Losses

5.Percentage Efficency=(Output/ Input)*100

TO CALCULATE PERCENTAGE REGULATION:

1.For lagging power factor, Percentage Regulation = $(X* I_{sc} / V_0)*(R_{o2} \cos\theta + X_{o2} \sin\theta) *100$

2.For lagging power factor, Percentage Regulation=$(X* I_{sc} / V_0)*(R_{o2} \cos\theta - X_{o2} \sin\theta) *100$

RESULT:

Thus the efficiency and regulation of a transformer by conducting open circuit test and short circuit test and to draw equivalent circuit is determined.

EX.NO :07	LOAD TEST ON SINGLE PHASE INDUCTION MOTOR
DATE	

AIM:

To conduct the direct load test on a given 3-phase induction motor and plot the performance characteristics of the machine.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-10)A	MI	1
2	Voltmeter	(0-300) V	MI	1
3	Wattmeter	300V,10A	UPF	Each 1
4	Single phase auto transformer	0-230v	AC	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

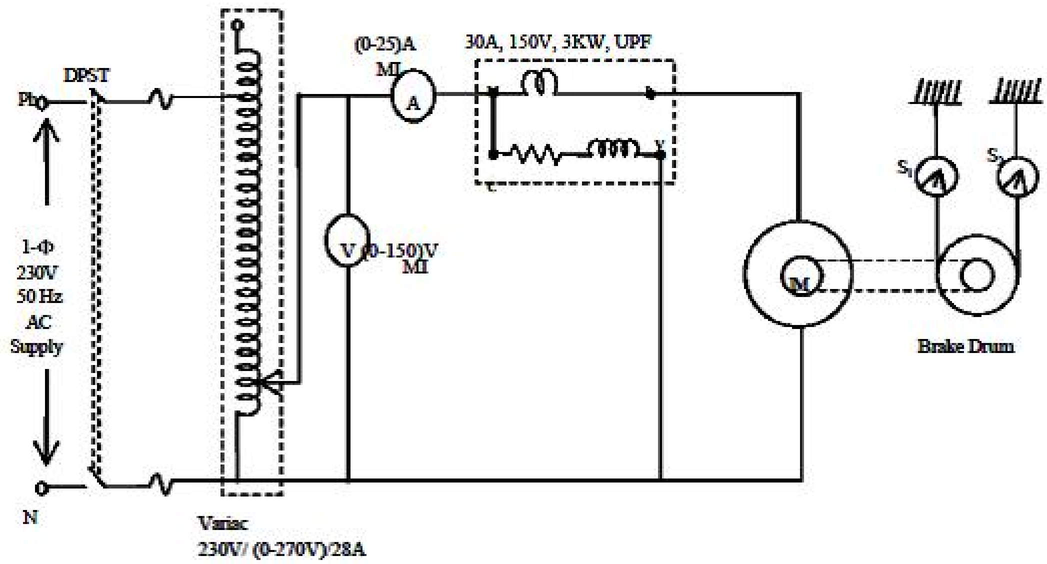
PRECAUTIONS:

1. Motor should be started and stopped under no load condition.
2. Brake drum should be cooled with water when it is under load.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. The DPST switch is closed. The autotransformer is adjusted to get rated voltage and corresponding no load readings are noted down.
3. Gradually increase the load upto the rated current and for each load the corresponding meter readings are tabulated
4. Then load is removed and autotransformer reduced to zero. Then DPST switch opened.

CIRCUIT DIAGRAM (Load Test on Single phase Induction Motor)



TABULATION: (Load Test on Single phase Induction Motor)

S. NO	Voltage (V_L)	Current (I_L)	Spring Balance Reading		(S_1¼S_2)	Speed (N)	Torque (T)	Output Power (Po)	Input Power (P_i)	Efficiency (¦)	Slip	Power factor
			S_1	S_2								
	Volts	*Amps*	*Kg*	*Kg*	*Kg*	*rpm*	*Nm*	*Watts*	*Watts*	%	%	*Cos Ø*

Circumference of the Brake drum =___________meter

FORMULAE:

1. Radius of brake drum(**R**) $= \frac{\textit{Circumference of the brake drum in CM}}{100*2n}$ **m**
2. Torque T = ($S_1 \sim S_2$) x R x 9.81 Nm
3. Input Power P_i = V*I Watts
4. Output Power $P_0 = \frac{2nNT}{60}$ Watts
5. Efficiency η % $= \frac{\textit{Output power}}{\textit{Input power}}$ x 100%
6. Slip N_s% $= \frac{N_S - N}{N}$ x 100%

Where , N_s(synchronous speed) = 1500 rpm, N = Actual speed for motor

CALCULATIONS:

RESULTS:

Thus the direct load test on a given 3-phase induction motor and plot the performance characteristics of the machine is conducted.

EX.NO :08	LOAD TEST ON THREE PHASE INDUCTION MOTOR
DATE	

AIM:

To conduct the direct load test on a given 3-phase induction motor and plot the performance characteristics of the machine.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-10)A	MI	1
2	Voltmeter	(0-300) V	MI	1
3	Wattmeter	600 V,10A (double element)	UPF	1
4	Three phase auto transformer	0-270v		1
5	Tachometer	-	-	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS: (Not to be included in the Record)

1. Remove the fuse carrier before starting wiring
2. Fuse rating calculation: Since this is load test, the required fuse rating is only 120% of the rated current of the motor
3. Before switching on the supply ensure the motor in on no load condition and the autotransformer is in the minimum position
4. Replace the fuse carriers with appropriate fuse wires after the circuit connections are checked by the staff in charge

PROCEDURE:

1. The connections are given as shown in circuit diagram.

2. The 3Φ ac supply is switched ON to the motor using the starter.

3. Under this load condition, one set of readings of the ammeter (IL), voltmeter (VL), wattmeter (W), spring balance and the speed (N) of motor are noted down.

4. Now the mechanical load on motor is increased in regular steps in such a way that the current drawn by the motor increases in steps of 1A.

5. At each step of loading, the entire meter readings are noted down in the tabular column.

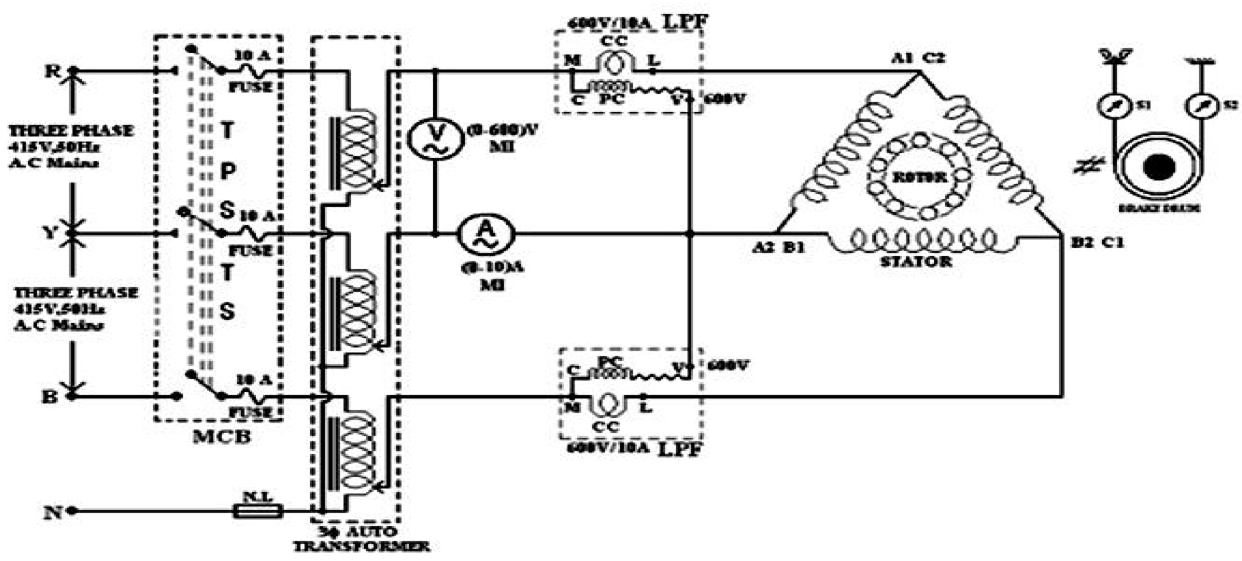
6. This procedure is continued until the current drawn by the motor equals 120% of its rated value.

7. After the experiment is completed, the main supply is switched OFF.

8. After completing the experiment, Torque, Output Power, Power Factor, % Slip and % efficiency are calculated by using the given formulae.

9. Using the obtained data, the plot of % efficiency Vs Output power, .% Slip vs Output power, Speed vs Output power, power factor vs Output power, Line current vs Output power and Slip vs torque

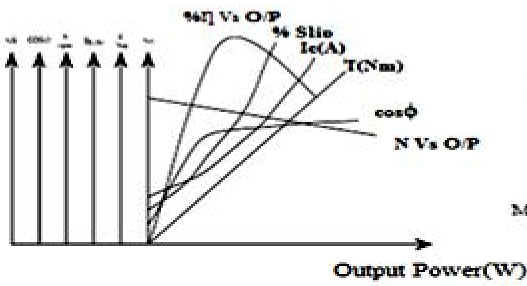
CIRCUIT DIAGRAM:(Load Test on Three Phase Induction Motor)

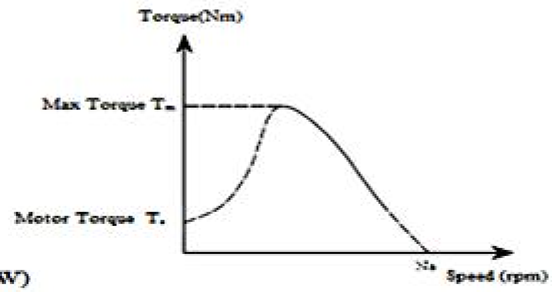


<u>TABULATION:</u>(Load Test on Three Phase Induction Motor)

S. No.	Voltage (V_L)	Current (I_L)	Spring Balance Reading		(S_1¼S_2)	Speed (N)	Torque (T)	Output Power (Po)	Input Power (P_i)	Efficiency (¦)	Slip	Power factor
			S_1	S_2								
	Volts	*Amps*	*Kg*	*Kg*	*Kg*	*rpm*	*Nm*	*Watts*	*Watts*	%	%	*Cos Ø*

MODEL GRAPH:(Load Test on Three Phase Induction Motor)





FORMULA:

1. Radius of brake drum(**R**) = ________________ **m**
2. Torque $T = (S_1 \sim S_2) \times R \times 9.81$ Nm
3. Input Power $P_i = V*I$ Watts
4. Output Power P_0 = ____ Watts
5. Efficiency η % = ________ x 100%
6. Slip N_s% = ____ x 100%

   Where , N_s(synchronous speed) = 1500 rpm, N = Actual speed for motor

RESULT :

Thus the direct load test on a given 3-phase induction motor and plot the performance characteristics of the machine is verified.

EX.NO :09	TRANSFER FUNCTION OF SEPARATELY EXCITED DC SHUNT GENERATOR
DATE	

AIM:

To obtain internal and external characteristics of DC separately excited DC shunt generator.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-2)A (0-20) A	MC MC	1 1
2	Voltmeter	(0-300)V	MC	1
3	Rheostats	1200Ω, 0.8A	Wire Wound	2
4	Loading Rheostat	5KW, 230V	-	1
5	Tachometer	(0-1500)rpm	Digital	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS:

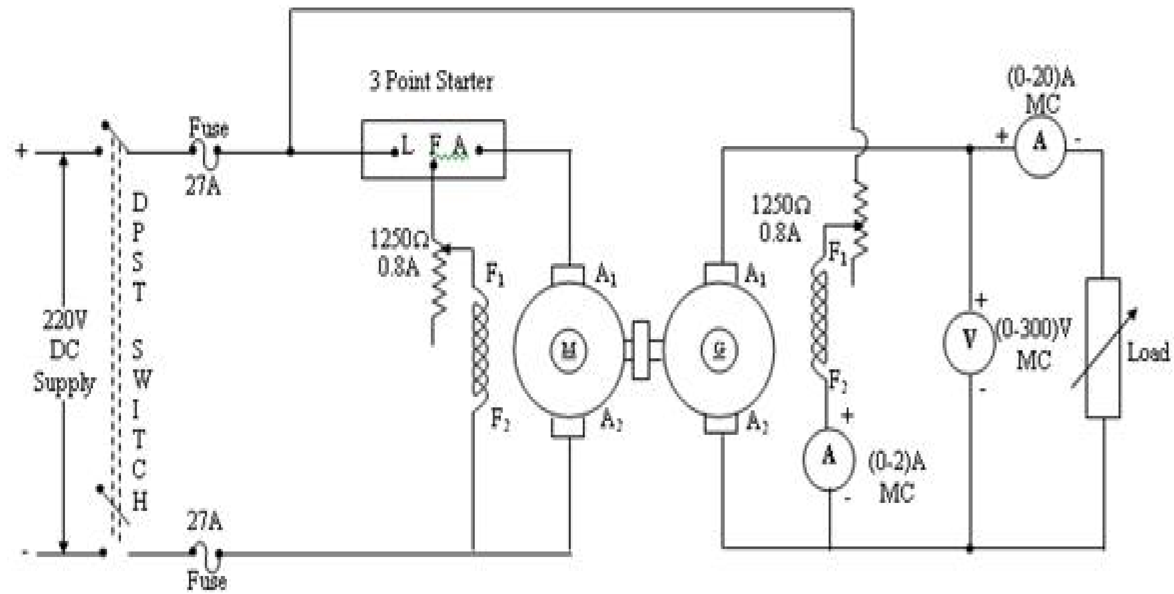
1. The field rheostat of motor should be at minimum position.
2. The field rheostat of generator should be at maximum position.
3. No load should be connected to generator at the time of starting and stopping.

PROCEDURE:

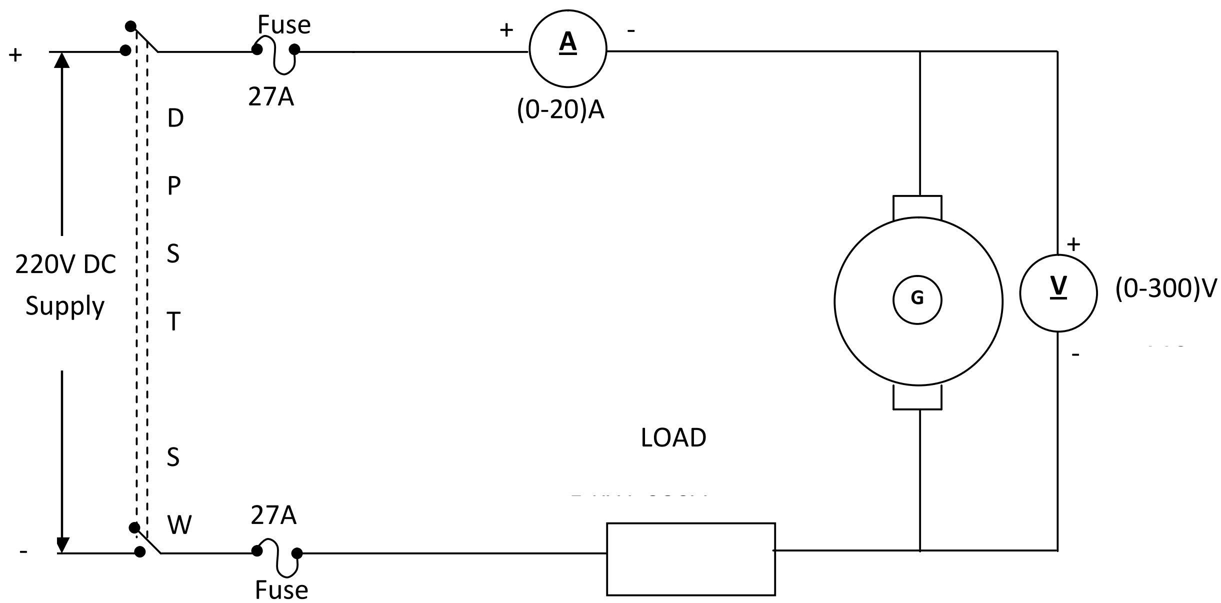
1. Connections are made as per the circuit diagram.
2. After checking minimum position of DC shunt motor field rheostat and maximum position of DC shunt generator field rheostat, DPST switch is closed and starting resistance is gradually removed.
3. Under no load condition, Ammeter and Voltmeter readings are noted, after bringing the voltage to rated voltage by adjusting the field rheostat of generator.
4. Load is varied gradually and for each load, voltmeter and ammeter readings are noted.

5. Then the generator is unloaded and the field rheostat of DC shunt generator is brought to maximum position and the field rheostat of DC shunt motor to minimum position, DPST switch is opened.

CIRCUIT DIAGRAM: (Transfer Function of Separately Excited DC Shunt Generator)



DETERMINATION OF ARMATURE RESISTANCE:

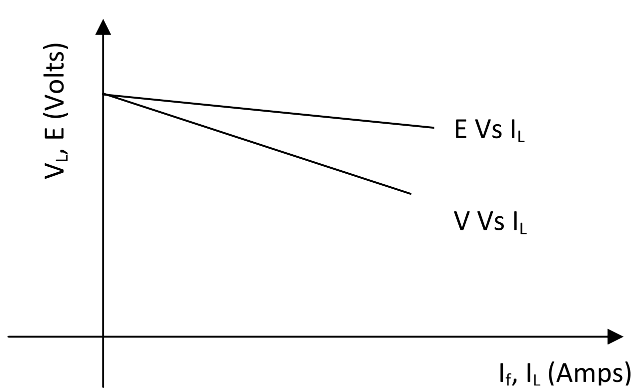


TABULATION: (Transfer Function of Separately Excited DC Shunt Generator)

S. No.	**Voltage (V) *Volts***	**Current (I) *Amps***	**Armature Resistance (R_a) *Ohms***

S. No.	**Field Current (I_f) *Amps***	**Load Current (I_L) *Amps***	**Terminal Voltage (V) *Volts***	**$I_a = I_L + I_f$ *Amps***	**$E_g = V + I_a R_a$ *Volts***

MODEL GRAPH: (Transfer Function of Separately Excited DC Shunt Generator)



FORMULAE:

1. $E_g = V + I_a R_a$ (Volts)
2. $I_a = I_L + I_f$ (Amps)

Where as

E_g	:	Generated emf in Volts
V	:	Terminal Voltage in Volts
I_a	:	Armature Current in Amps
I_L	:	Line Current in Amps
I_f	:	Field Current in Amps
R_a	:	Armature Resistance in Ohms

RESULT:

Thus the internal and external characteristics of DC separately excited DC shunt generator is obtained.

EX.NO :10	TRANSFER FUNCTION OF SELF EXCITED DC SHUNT GENERATOR
DATE	

AIM:

To obtain internal and external characteristics of DC shunt generator.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-2)A (0-20) A	MC MC	1 1
2	Voltmeter	(0-300)V	MC	1
3	Rheostats	400Ω, 0.8A	Wire Wound	2
4	Loading Rheostat	5KW, 230V	-	1
5	Tachometer	(0-1500)rpm	Digital	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

PRECAUTIONS:

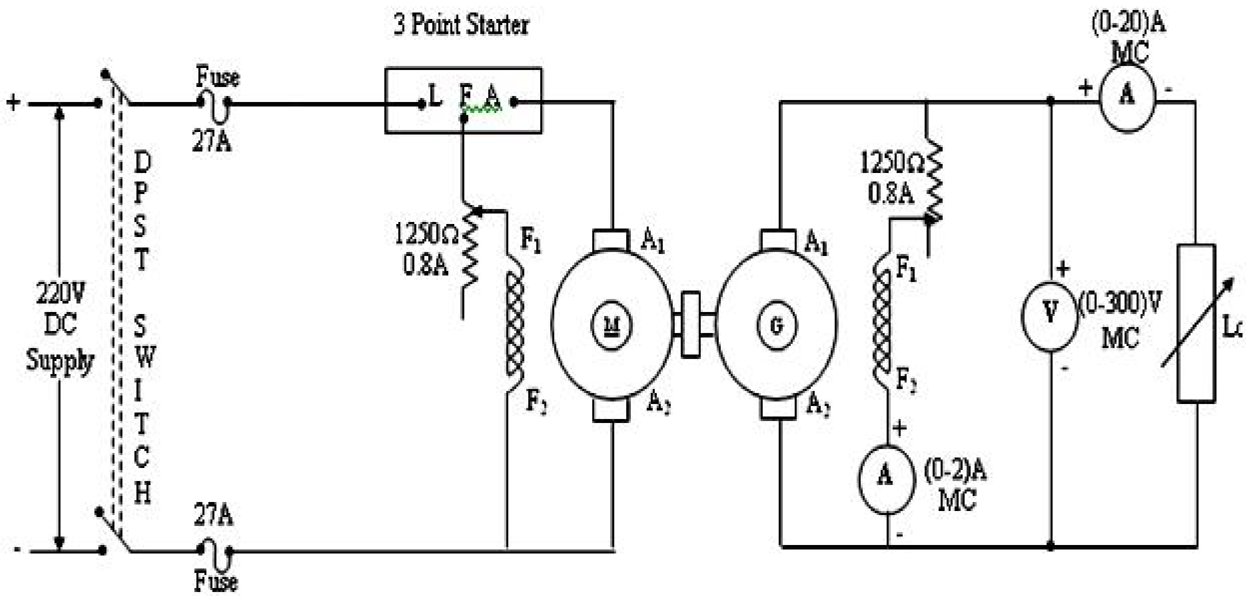
1. The field rheostat of motor should be at minimum position.
2. The field rheostat of generator should be at maximum position.
3. No load should be connected to generator at the time of starting and stopping.

PROCEDURE:

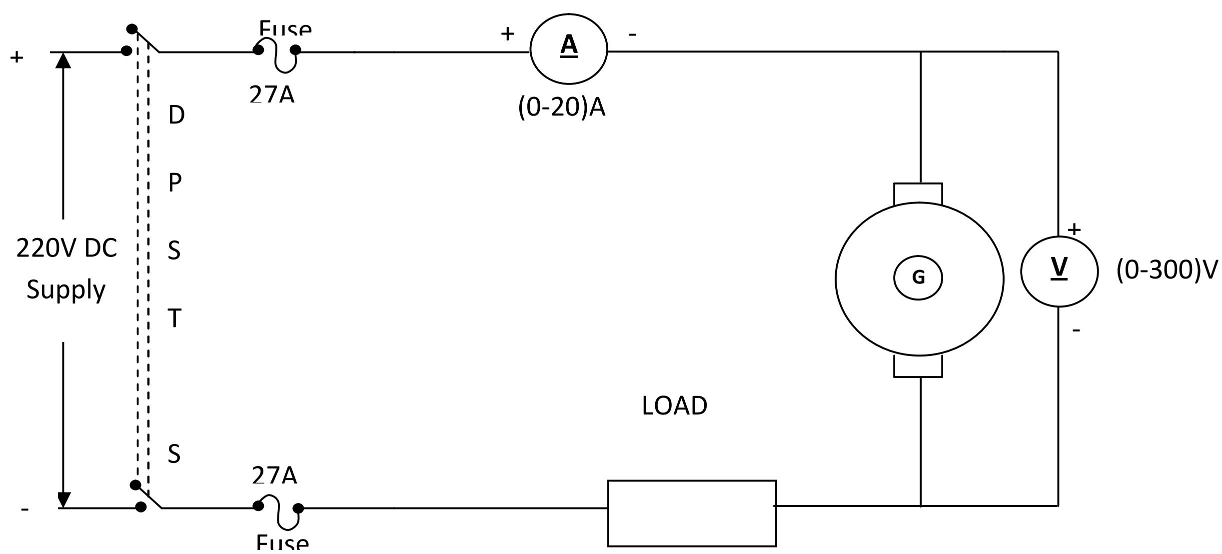
1. Connections are made as per the circuit diagram.
2. After checking minimum position of DC shunt motor field rheostat and maximum position of DC shunt generator field rheostat, DPST switch is closed and starting resistance is gradually removed.
3. Under no load condition, Ammeter and Voltmeter readings are noted, after bringing the voltage to rated voltage by adjusting the field rheostat of generator.

4. Load is varied gradually and for each load, voltmeter and ammeter readings are noted. Then the generator is unloaded and the field rheostat of DC shunt generator is brought to maximum position and the field rheostat of DC shunt motor to minimum position, DPST switch is opened.

CIRCUIT DIAGRAM: (Transfer Function of Self Excited DC Shunt Generator)



DETERMINATION OF ARMATURE RESISTANCE:



PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Supply is given by closing the DPST switch.
3. Readings of Ammeter and Voltmeter are noted.
4. Armature resistance in Ohms is calculated as $R_a = (Vx1.5) / I$

FORMULAE:

1. $E_g = V + I_a R_a$ (Volts)

2. $I_a = I_L + I_f$ (Amps)

Where as

$.E_g$: Generated emf in Volts

V : Terminal Voltage in Volts

I_a : Armature Current in Amps

I_L : Line Current in Amps

I_f : Field Current in Amps

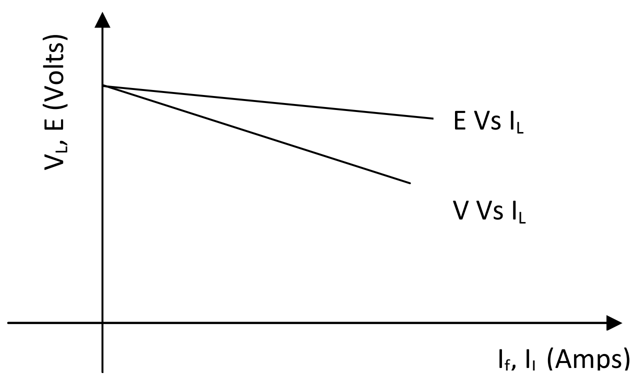
R_a: Armature Resistance in Ohms

TABULAR COLUMN: (Transfer Function of Self Excited DC Shunt Generator)

S. No.	Voltage (V) *Volts*	Current (I) *Amps*	Armature Resistance (R_a) *Ohms*

S. No.	Field Current (I_f) *Amps*	Load Current (I_L) *Amps*	Terminal Voltage (V) *Volts*	$I_a = I_L + I_f$ *Amps*	$E_g = V + I_a R_a$ *Volts*

MODEL GRAPH: (Transfer Function of Self Excited DC Shunt Generator)



RESULT:

Thus the open circuit characteristics of self excited DC shunt generator are obtained.

EX.NO :11	STUDY OF D.C MOTOR STARTERS
DATE	

AIM:

To study the different kinds of D.C motor starters

EQUIPMENT AND APPARATUS REQUIRED:

Sl. No.	Name of the apparatus	Quantity
1	Two Point starter	1
2	Three Point starter	1
3	Four Point starter	1

THEORY :

The value of the armature current in a D.C shunt motor is given by

$$I_a = (V - E_b)/ R_a$$

Where V = applied voltage.

Ra = armature resistance.

E_b = Back .e.m.f .

In practice the value of the armature resistance is of the order of 1 ohms and at the instant of starting the value of the back e.m.f is zero volts. Therefore under starting conditions the value of the armature current is very high. This high inrush current at the time of starting may damage the motor. To protect the motor from such dangerous current the D.C motors are always started using starters.

The types of D.C motor starters are
i) Two point starters
ii) Three point starters
iii) Four point starters.
The functions of the starters are
i) It protects the dangerous high speed.
ii) It protects the motor from overloads.

i) <u>TWO POINT STARTERS:</u> (refer fig 11.1)

It is used for starting D.C. series motors which has the problem of over speeding due to the loss of load from its shaft. Here for starting the motor the control arm is moved in clock-wise direction from its OFF position to the ON position against the spring tension. The control arm is held in the ON position by the electromagnet E. The exciting coil of the hold-on electromagnet E is connected in series with the armature circuit. If the motor loses its load, current decreases and hence the strength of the electromagnet also decreases. The control arm returns to the OFF position due to the spring tension, Thus preventing the motor from over speeding. The starter also returns to the OFF position when the supply voltage decreases appreciably. L and F are the two points of the starter which are connected with the motor terminals.

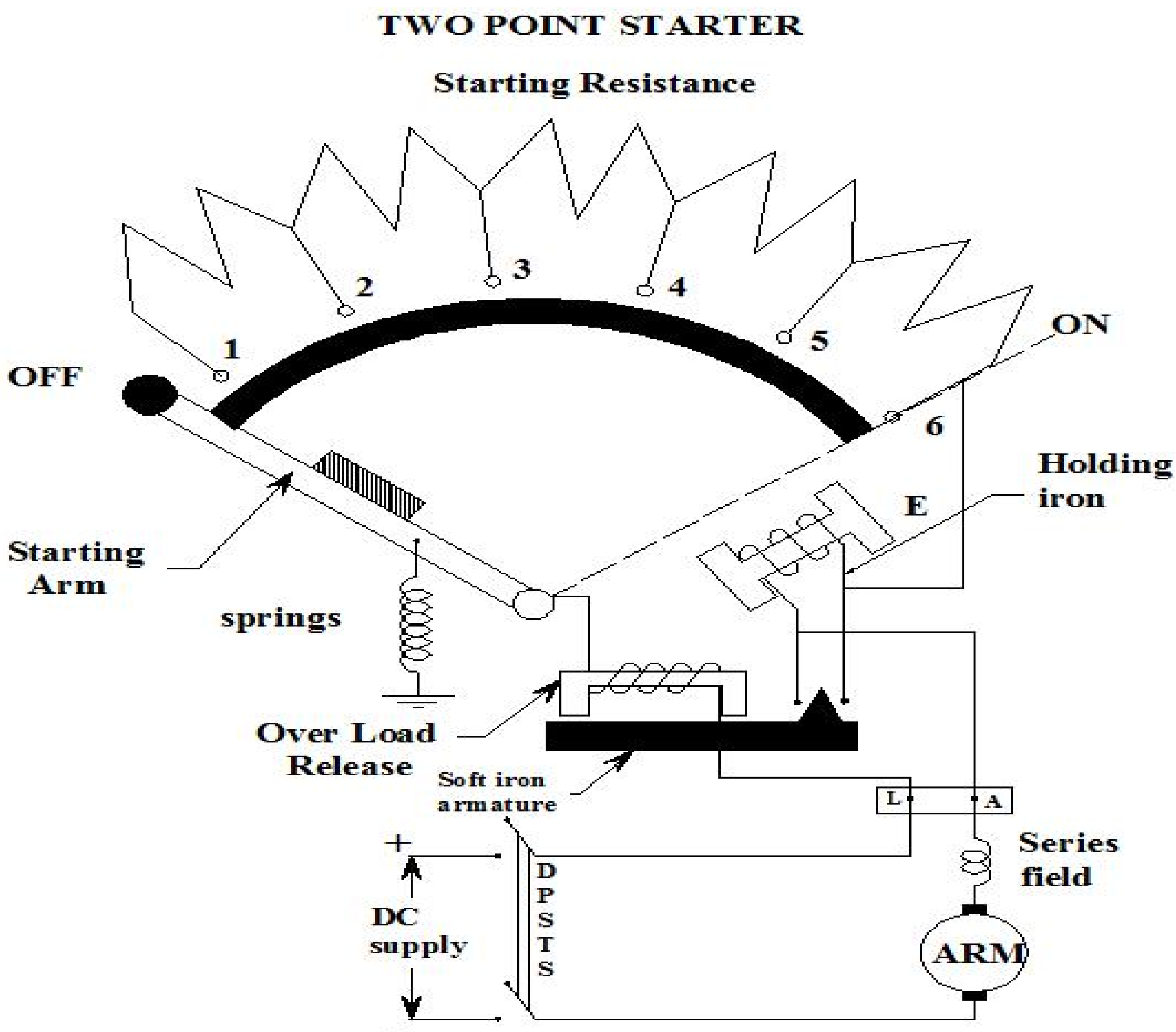


FIGURE 11.1

ii) <u>THREE POINT STARTER:</u> (refer fig 11.2)

It is used for starting the shunt or compound motor. The coil of the hold on electromagnet E is connected in series with the shunt field coil. In the case of disconnection in the field circuit the control arm will return to its OFF position due to spring tension. This is necessary because the shunt motor will over speed if it loses excitation. The starter also returns to the OFF position in case of low voltage supply or complete failure of the supply. This protection is therefore is called No Volt Release (NVR).

OVER LOAD PROTECTION:

When the motor is over loaded it draws a heavy current. This heavy current also flows through the exciting coil of the over load electromagnet (OLR). The electromagnet then pulls an iron piece upwar6.ds which short circuits the coils of the NVR coil. The hold on magnet gets de-energized and therefore the starter arm returns to the OFF position, thus protecting the motor against overload. L, A and F are the three terminals of the three point starter.

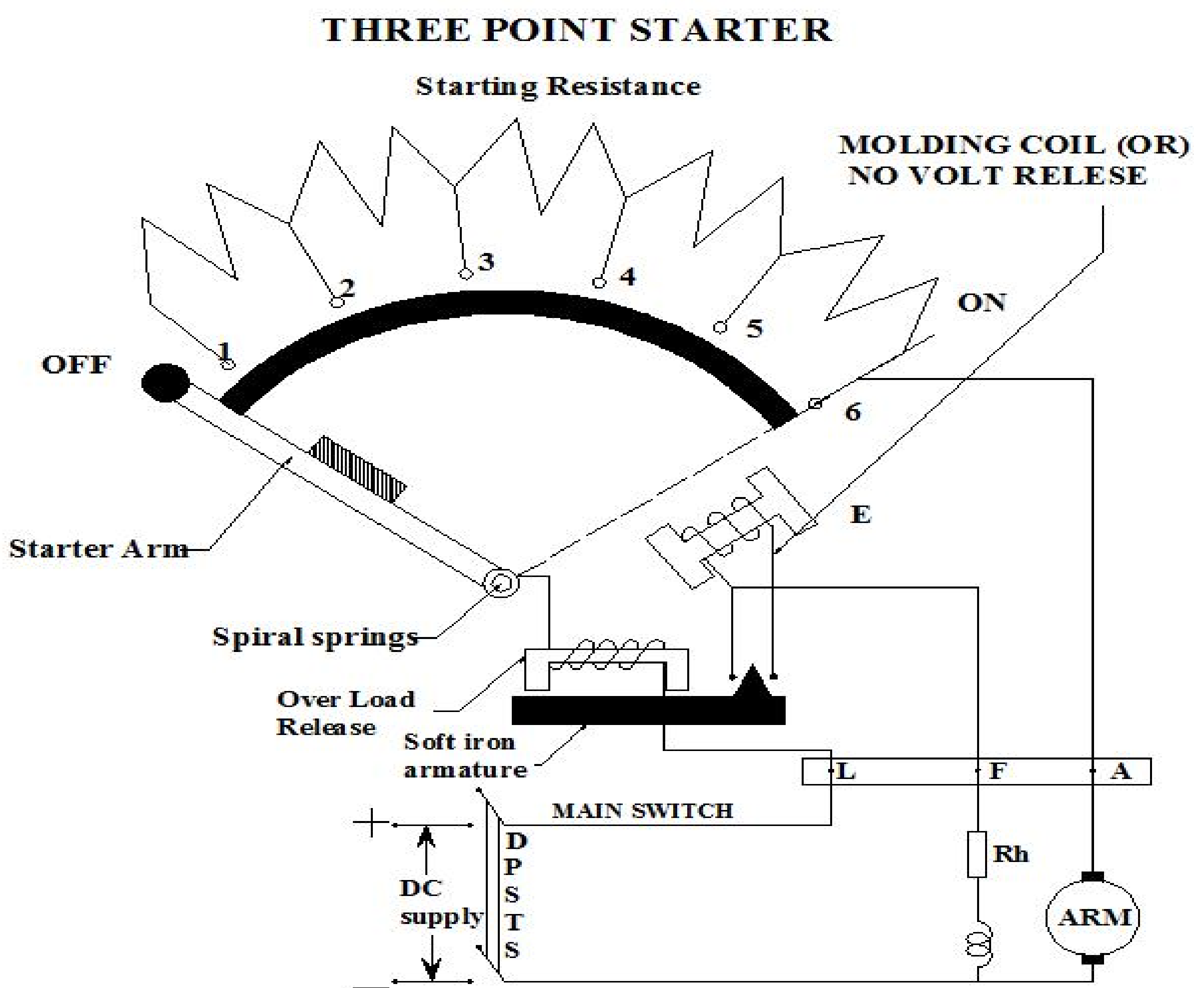


FIGURE 11.2

iii) FOUR POINT STARTER: (refer fig 11.3)

The connection diagram of the four point starter is shown in fig 3. In a four point starter arm touches the starting resistance, the current from the supply is divided into three paths. One through the starting resistance and the armature, one through the field circuit, and one through the NVR coil. A protective resistance is connected in series with the NVR coil. Since in a four point starter the NVR coil is independent of the of the field circuit connection , the DC motor may over speed if there is a break in the field circuit. A D.C motor can be stopped by opening the main switch. The steps of the starting resistance are so designed that the armature current will remain within the certain limits and will not change the torque developed by the motor to a great extent.

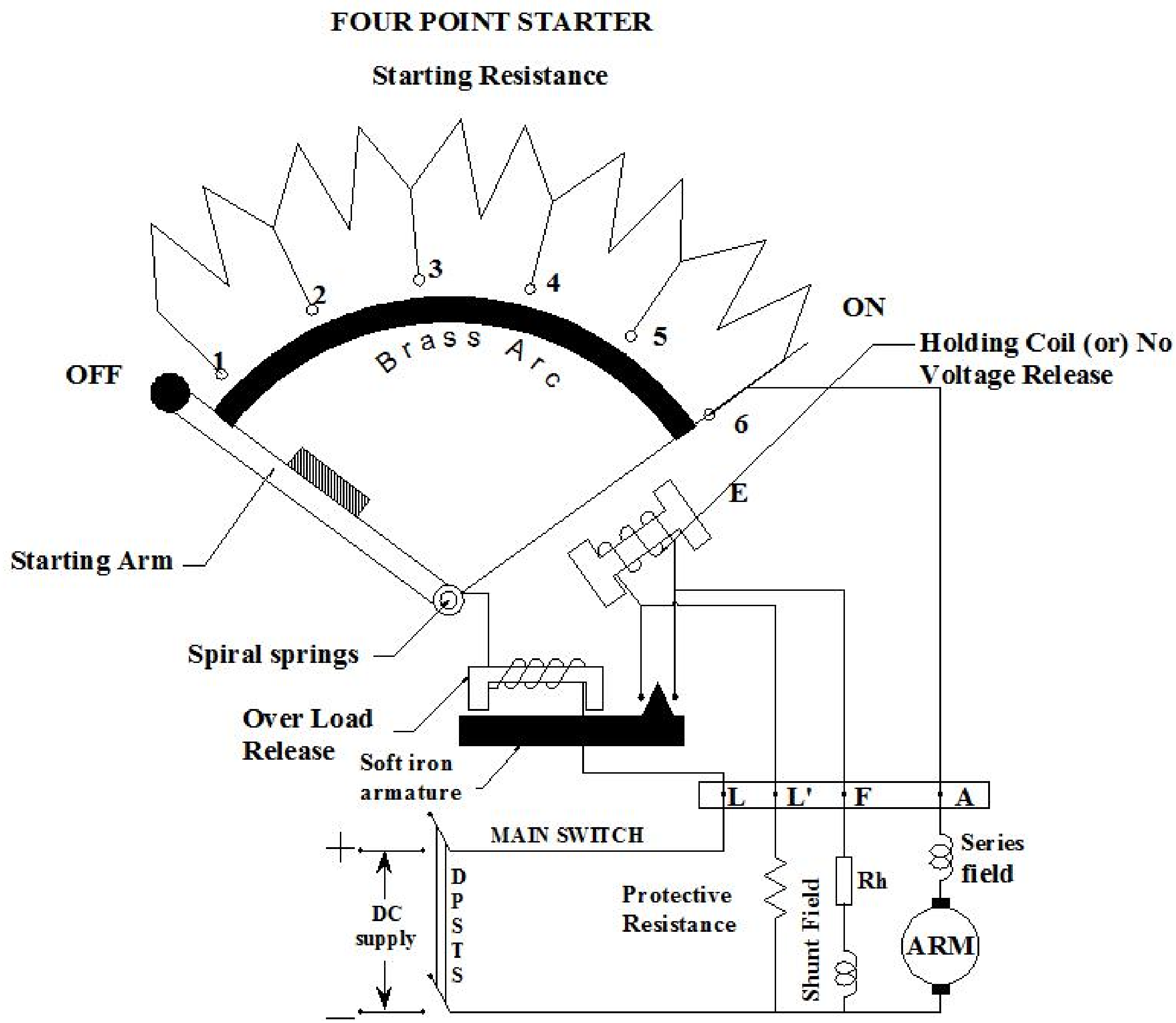


FIGURE 11.3

RESULT:

Thus the construction and working of different starters for starting D.C series, shunt, compound and three phase induction motors are studied.

EX.NO :12	STUDY OF INDUCTION MOTOR STARTERS
DATE	

AUTO –TRANSFORMER STARTING(refer fig 12.1)

An auto transformer starter consists of an auto transformer and a switch as shown in the fig. When the switch S is put on START position, a reduced voltage is applied across the motor terminals. When the motor picks up speed, say to 80 per cent of its normal speed, the switch is put to RUN position. Then the auto-transformer is cut out of the circuit and full rated voltage gets applied across the motor terminals.

The circuit diagram in the fig is for a manual auto-transformer starter. This can be made push button operated automatic controlled starter so that the contacts switch over from start to run position as the motor speed picks up to 80% of its speed. Over-load protection relay has not been shown in the figure. The switch S is air-break type for small motors and oil break type for large motors. Auto transformer may have more than one tapping to enable the user select any suitable starting voltage depending upon the conditions. Series resistors or reactors can be used to cause voltage drop in them and thereby allow low voltage to be applied across the motor terminals at starting. These are cut out of the circuit as the motor picks up speed.

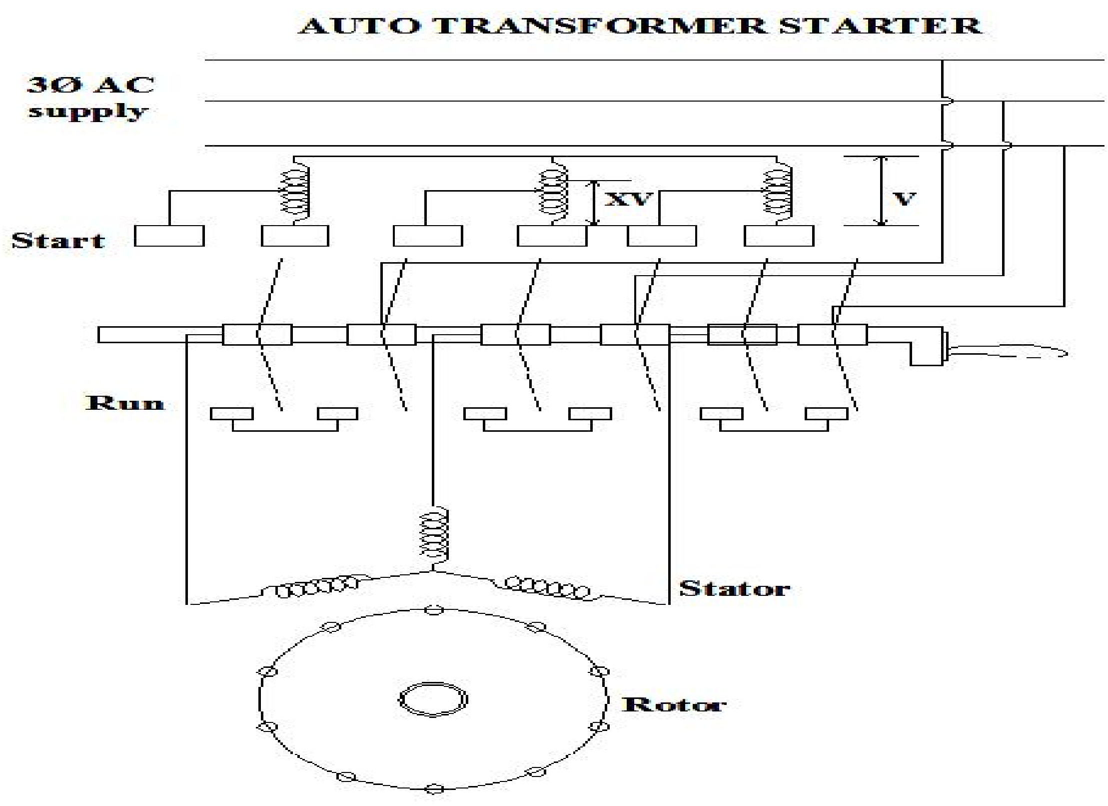


FIGURE 12.1

STAR- DELTA METHOD OF STARTING: (refer fig 12.2)

The startor phase windings are first connected in star and full voltage is connected across its free terminals. As the motor picks up speed, the windings are disconnected through a switch and they are reconnected in delta across the supply terminals. The current drawn by the motor from the lines is reduced to as compared to the current it would have drawn if connected in delta.The motor windings, first in star and then in delta the line current drawn by the motor at starting is reduced to one third as compared to starting current with the windings delta-connected.

In making connections for star-delta starting, care should be taken such that sequence of supply connections to the winding terminals does not change while changing from star connection to delta connection. Otherwise the motor will start rotating in the opposite direction, when connections are changed from star to delta. Star-delta starters are available for manual operation using push button control. An automatic star – delta starter used time delay relays(T.D.R) through which star to delta connections take place automatically with some pre-fixed time delay. The delay time of the T.D.R is fixed keeping in view the starting time of the motor.

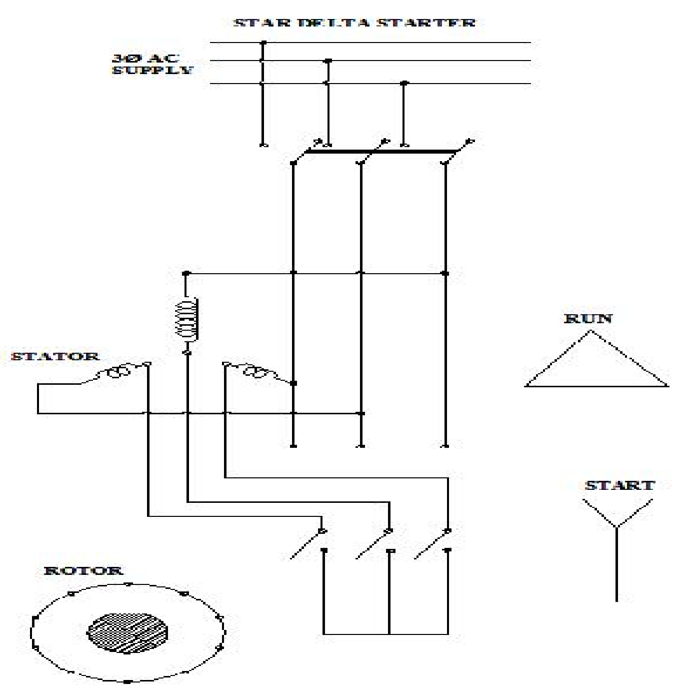


FIGURE 12.2

FULL VOLTAGE OR DIRECT –ON-LINE STARTING(refer fig 12.3)

When full voltage is connected across the stator terminals of an induction motor, large current is drawn by the windings. This is because, at starting the induction motor behaves as a short circuited transformer with its secondary, i.e. the rotor separated from the primary, i.e. the stator by a small air-gap. At starting when the rotor is at stand still, *emf* is induced in the rotor circuit exactly similar to the *emf* induced in the secondary winding of a transformer. This induced e*mf* of the rotor will circulate a very large current through its windings.

The primary will draw very large current from the supply mains to balance the rotor ampere-turns. To limit the stator and rotor currents at starting to a safe value, it may be necessary to reduce the stator supply voltage to a low value. If induction motors are started direct-on-line such a heavy starting current of short duration may not cause harm to the motor since the construction of induction motors are rugged.

Other motors and equipment connected to the supply lines will receive reduced voltage. In industrial installations, however, if a number of large motors are started by this method, the voltage drop will be very high and may be really objectionable for the other types of loads connected to the system. The amount of voltage drop will not only be dependent on the size of the motor but also on factors like the capacity of the power supply system, the size and length of the line leading to the motors etc. Indian Electricity Rule restricts direct on line starting of 3 phase induction motors above 5 hp.

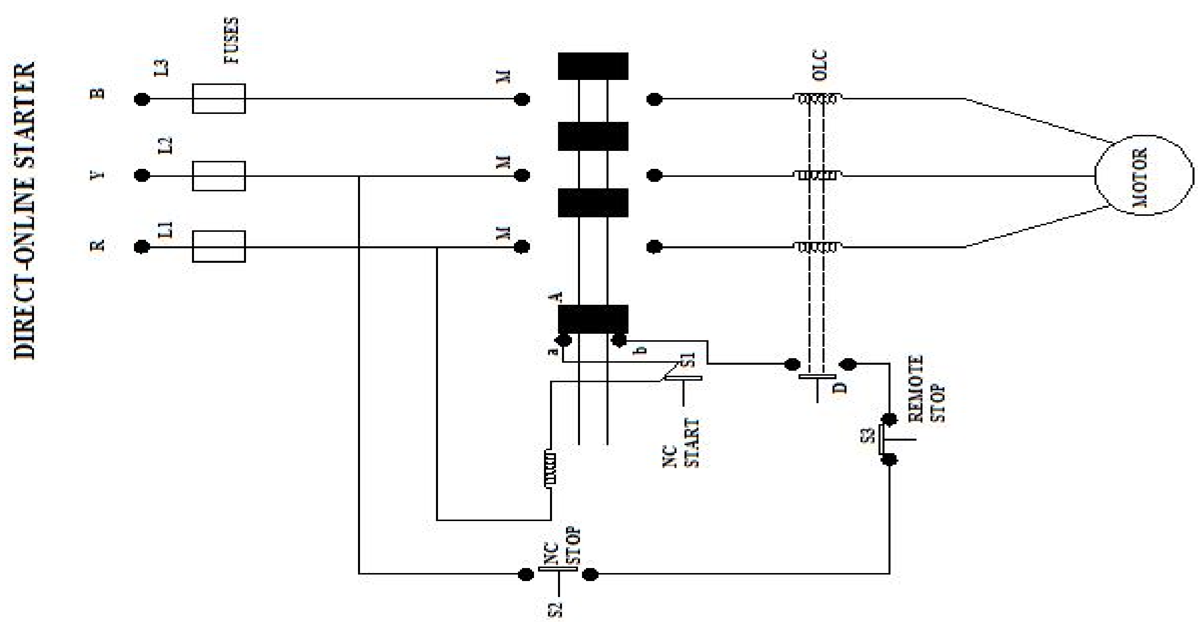


FIGURE 12.3

RESULT:

Thus the construction and working of different starters for starting three phase induction motors are studied.

EX.NO :13	Digital Simulation of Linear Systems
DATE	

AIM:

To digitally simulate the time response characteristics of higher-order MIMO linear systems using state – variable formulation

EQUIPMENTS REQUIRED:

PC system with mat lab

THEORY:

INTRODUCTION TO MATLAB & SIMULINK

MATLAB® is a **high-performance language for technical computing**. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

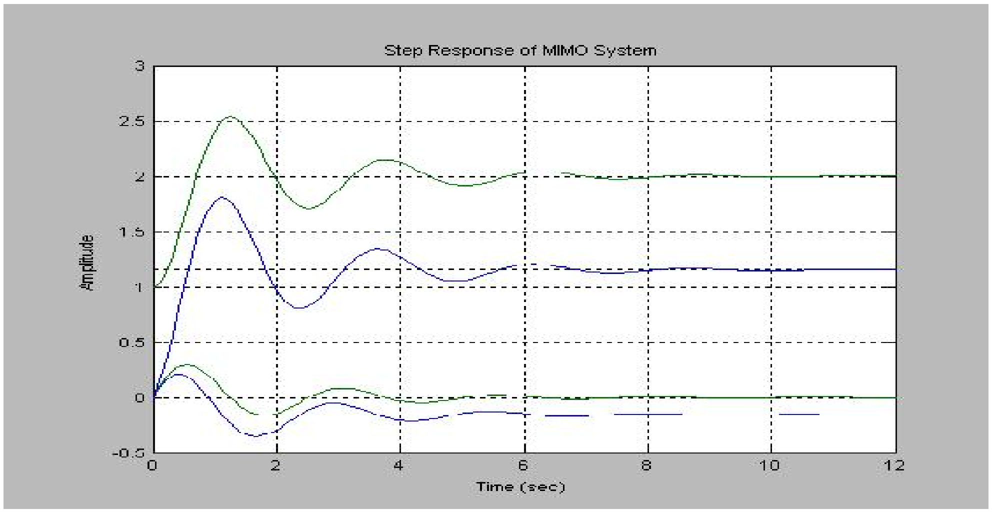
MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

The name **MATLAB** stands for **matrix laboratory**. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

MATLAB PROGRAM:

Open new m file and type the given program

```
% State Space Analysis of MIMO System
%-----X^ = Ax+Bu; y =Cx+Du -------%
A=[-1 -1; 6.5 0];   %----State Matrix-----%
B=[1 1;1 0];   %----Input Matrix------%
C=[1 0;0 1];   %----Output Matrix ------%
D=[0 0;0 1];   %----Transistion Matrix---%
step(A,B,C,D,1)
hold
step(A,B,C,D,2)
title('Step Response of MIMO System')
grid
[num1,den1]=ss2tf(A,B,C,D,1)
[num2,den2]=ss2tf(A,B,C,D,2)
n1=num1(1,:)
n2=num1(2,:)
n3=num2(1,:)
n4=num2(2,:)
d1=den1(1,:)
d2=den2(1,:)
tf1=tf(n1,d1)
tf2=tf(n2,d1)
tf3=tf(n3,d2)
tf4=tf(n4,d2)
```



MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

Starting MATLAB

Instructions for starting MATLAB® depend on your platform. For a list of supported platforms, see the system requirements in the installation documentation, or the Products section of the MathWorks . Starting MATLAB on Windows Platforms To start MATLAB on a Microsoft Windows platform, select the Start -> Programs -> MATLAB 7.0 -> MATLAB 7.0, or double-click the MATLAB shortcut icon on your Windows desktop. The shortcut was automatically created by the installer.

Transfer function of the given 4 systems

Transfer function:

```
      s - 1
  -------------
  s^2 + s + 6.5
```

Transfer function:

```
     s + 7.5
  -------------
  s^2 + s + 6.5
```

Transfer function:

```
  s + 3.553e-015
  --------------
  s^2 + s + 6.5
```

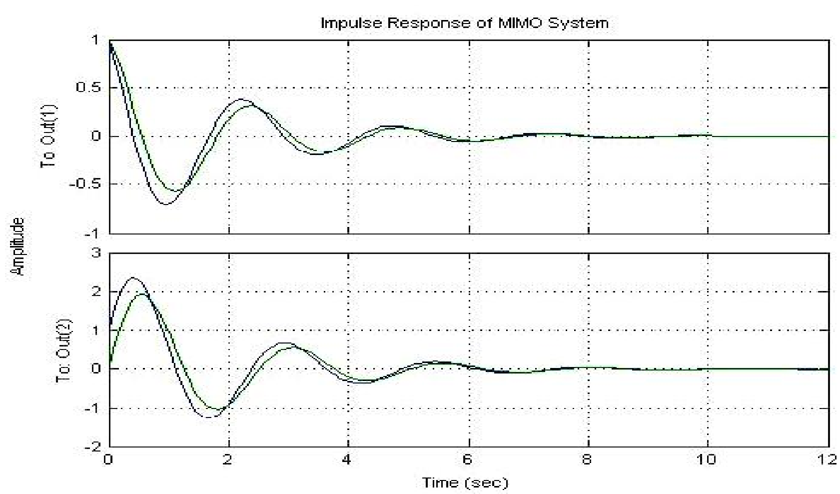
Transfer function:

```
  s^2 + s + 13
  -------------
  s^2 + s + 6.5
```

FOR IMPULSE RESPONSE

response MIMO system

```
% State Space Analysis of MIMO System
%-----X^ = Ax+Bu; y =Cx+Du -------%
A=[-1 -1; 6.5 0];%----State Matrix-----%
B=[1 1;1 0];%----Input Mtrix------%
C=[1 0;0 1];%----Output Matrix ------%
D=[0 0;0 1];%----Transistion Matrix---%
impulse(A,B,C,D,1)
hold
impulse(A,B,C,D,2)
title('Impulse Response of MIMO System')
grid
[num1,den1]=ss2tf(A,B,C,D,1)
[num2,den2]=ss2tf(A,B,C,D,2)
n1=num1(1,:)
n2=num1(2,:)
n3=num2(1,:)
n4=num2(2,:)
d1=den1(1,:)
d2=den2(1,:)
tf1=tf(n1,d1)
tf2=tf(n2,d1)
tf3=tf(n3,d2)
tf4=tf(n4,d2)
```



RESULT:

Thus the time response characteristics of higher-order MIMO linear systems using state – variable formulation is simulated.

EX.NO :14	Stability Analysis of Linear Systems
DATE	

AIM:

To analyze the stability of linear systems using Bode, Root locus, Nyquist plots

EQUIPMENTS REQUIRED:

PC system with mat lab

PROGRAM:

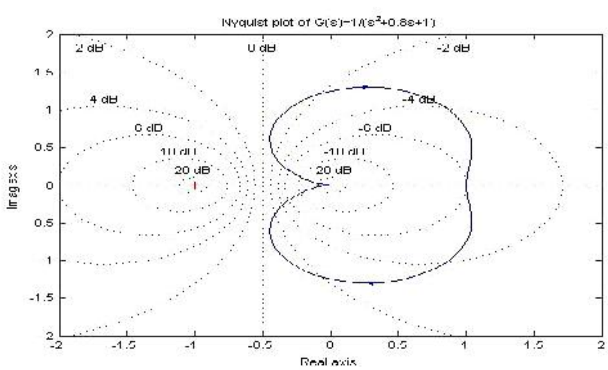
STABILITY ANALYSIS

Program For Nyquist Plot.

```
%---Given System G(s)=1/(s^2+0.8s+1)-----%
%--------Nyquist plot-----------%
num=[0 0 1];
den=[1 0.8 1];
nyquist(num,den);
axis(v)
grid
title('Nyquist plot of G(s)=1/(s^2+0.8s+1)')
xlabel('Real axis')
ylabel('Imag axis')
hold on
```

RESPONSE OF VARIOUS SYSTEMS:

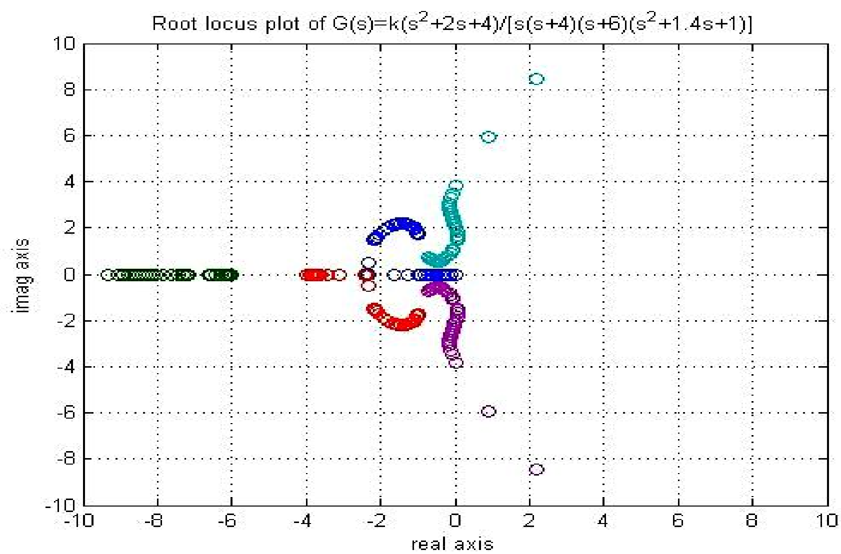
Nyquist plot of $G(s) = \dfrac{1}{(s^2 + 0.8s + 1)}$



PROGRAM FOR ROOT LOCUS

```
%---conditionally stable system--%
%---Given System G(s)=k(s^2+2s+4)/[s(s+4)(s+6)(s^2+1.4s+1)-----%
clc;
close all;
clear all;
%--------Root Locus----------%
numz=[0 0 0 1 2 4];
denp=[1 11.4 39 43.6 24 0];
r=rlocus(numz,denp);
plot(r,'o');
axis(v)
grid
title('Root locus plot of
G(s)=k(s^2+2s+4)/[s(s+4)(s+6)(s^2+1.4s+1)]')
xlabel('real axis')
ylabel('imag axis')
hold
```

ROOT LOCUS

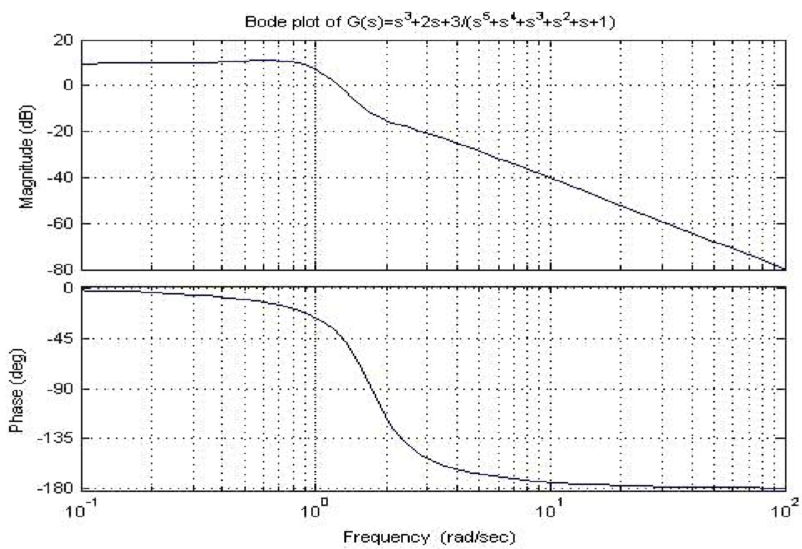


Root locus plot of $G(s) = \dfrac{k\left(s^2 + 2s + 4\right)}{s(s+4)(s+6)(s^2 + 1.4s + 1)}$

PROGRAM FOR BODE PLOT

```
%---Given System=s^3+2s+3/(s^5+s^4+s^3+s^2+s+1)---%
%--------Bode Plot ----------%
numg=[1 0 2 3];
deng=[1 1 1 1 1 1 ];
'G(s)'
u=tf(numg,deng);
bode(u)
grid
hold
title('Bode plot of G(s)=s^3+2s+3/(s^5+s^4+s^3+s^2+s+1)')
[Gm,Pm,Wcg,Wcp] = margin(u)
Gm_dB = 20*log10(Gm)
```

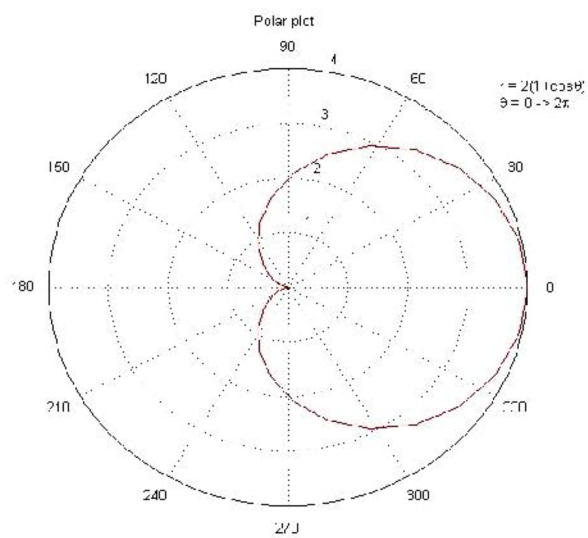
BODE PLOT



PROGRAM FOR POLAR PLOT

```
format compact
set (gcf,'Toolbar','none','Name','Polar Plot', ...
    'Number Title','off','Position',[10,350,350,300]);
theta = 2*pi*linspace(0,1,30);
r = 2*(1 + cos(theta));
Polar (theta,r,'r-')
Set (gca,'Position',[0.1 0.1 0.75 0.75]);
Title ('\bf\itA Polar
Plot','Color','k','VerticalAlignment','bottom')
textstr (1)={'r = 2(1+cos\theta)'};
textstr(2)={'\theta = 0 -> 2\pi'};
text(5*cos(pi/4),5*sin(pi/4), ...
    strcat(textstr))
title('Polar plot ')
    hold
```

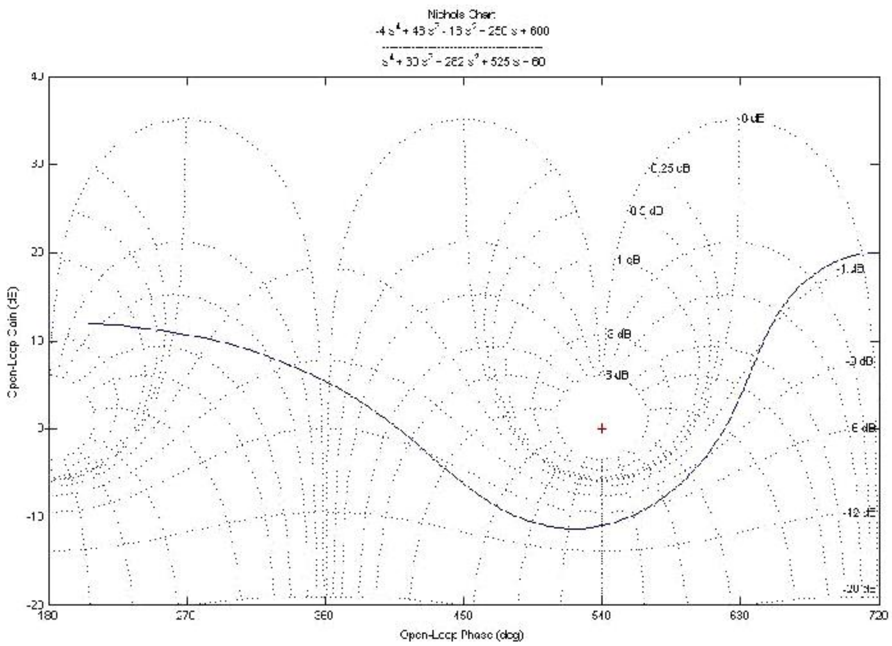
POLAR PLOT



PROGRAM FOR NICHOLS CHART

```
%Plot the Nichols response of the system
num = [-4 48 -18 250 600];
den = [1 30 282 525 60];
H = tf(num,den)
nichols(H); ngrid
```

NICHOLS CHART



RESULT:

Thus the stability of linear systems using Bode, Root locus, Nyquist plots is analysed.

EX.NO :15	STUDY THE EFFECT OF P, PI, PID CONTROLLERS USING MAT LAB
DATE	

AIM:

To Study the effect of P, PI, PID controllers using Mat lab**.**

THEORY

1 Choice of the Controller type

In so far were described proportional, integrative and derivative modes of the controllers and a rational behind their use was explained. However, excerpt for a few tips, an attention was not given to a question when to use different types of controllers. The rest of this section will give some answers on that particular topic.

1.1 On-off Controller

On-off controller is the simplest controller and it has some important advantages. It is economical, simple to design and it does not require any parameter tuning. If oscillations will hamper the operation of the system and if controller parameter tuning is to be avoided, on-off controller is a good solution. In addition, if actuators work in only two modes (on and off), then it is almost always only controller that can be used with such actuators. That is a reason why on-off controllers are often used in home appliances (refrigerators, washers etc.) and in process industry when control quality requirements are not high (temperature control in buildings etc.). Additional advantage of on-off controllers is that they in general do not require any maintenance.

1.2 P Controller

When P controller is used, large gain is needed to improve steady state error. Stable system do not have a problems when large gain is used. Such systems are systems with one energy storage (1st order capacitive systems). If constant steady state error can be accepted with such processes, than P controller can be used. Small steady state errors can be accepted if sensor will give measured value with error or if importance of measured value is not too great anyway. Example of such system is liquid level control in tanks when exact approximate level of liquid suffice for the proper plant operation. Also, in cascade control sometime it is not important if there is an error inside inner loop, so P controller can a good solution in such cases.

Derivative mode is not required if the process itself is fast or if the control system as whole does not have to be fast in response. Processes of 1st order react immediately on the reference signal change, so it is not necessary to predict error (introduce D mode) or compensate for the steady state error (introduce I mode) if it is possible to achieve satisfactory steady state error using only P controller.

1.3 PD controller

It is well known that thermal processes with good thermal insulation act almost as integrators. Since insulation is good and thermal losses are small, the most significant art of the energy that is led to the system is used temperature rise. Those processes allow 18 for large gains so that integral mode in the controller is not needed. These processes can be described as different connections of thermal energy storages. Thermal energy is shifted from one storage into another. In general, with such processes there is present a process dynamics with large inertia. Since dynamics is slow, derivative mode is required for control of such processes. Integral mode would only already slow dynamics make more slowly. The other reason for using PPD controllers in such systems are that is possible to measure temperature with low level of noise in the measured signal.

PD controller is often used in control of moving objects such are flying and underwater vehicles, ships, rockets etc. One of the reason is in stabilizing effect of PD controller on sudden changes in heading variable y(t). Often a "rate gyro" for velocity measurement is used as sensor of heading change of moving object.

1.3 PI controller

PI controllers are the most often type used today in industry. A control without D mode is used when:

a) fast response of the system is not required

b) large disturbances and noise are present during operation of the process

c) there is only one energy storage in process (capacitive or inductive)

d) there are large transport delays in the system

If there are large transport delays present in the controlled process, error prediction is required. However, D mode cannot be used for prediction because every information is delayed till the moment when a change in controlled variable is recorded. In such cases it is better to predict the output signal using mathematical model of the process in broader sense (process + actuator). The controller structures that can be used are, for example, Otto-Smith predictor (controller), PIP controller or so called Internal Model Controller (IMC).

An interesting feature of IMC is that when the model of the process is precise (A = AM and B = BM), then a feedback signal eM = y – yM is equal to disturbance:

It follows that a control signal is not influenced by the reference signal and control systems behaves as open loop. A usual problems with stability that arrise when closed loop systems are used are then avoided. Control system with IMC controller will be stable and if IMC and process are stable. With the exact model of process IMC is actually a feed forward controller and can designed as such, but, unlike feed forward controllers, it can compensate for unmeasured disturbances because feedback signal is equal to disturbance, which allows suitable tuning of the reference value of the controller.

If model of the process is not exact5 (AM =A, BM =B), then feedback signal eM will contain not only disturbance d but a modeling error, $\left[\left(\frac{B}{A}-\frac{B_M}{A_M}\right)u_{IMC}\right]$ also. Thus, a feedback will have its usual role, and stability problem can arise. This requires for parameters6 to be tuned again so the stability is not lost.

1.4 PID controller

Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot are for the most part PID type controllers.

1.5 Topology of PID controllers

Problem of topology (structure) of controller arises when:

- designing control system (defining structure and controller parameters)
- tuning parameters of the given controller

There are a number of different PID controller structures. Different manufacturers design controllers in different manner. However, two topologies are the most often case:

- parallel (non-interactive)
- serial (interactive)

Parallel structure is most often in textbooks, so it is often called "ideal" or "textbook type". This non-interactive structure because proportional, integral and derivative mode are independent on each other. Parallel structure is still very rare in the market. The reason for that is mostly historical. First controllers were pneumatic and it was very difficult to build parallel structure using pneumatic components. Due to certain conservatism in process industry most of the controller used there are still in serial structure, although it is relatively simple to realize parallel structure controller using electronics. In other areas, where tradition is not so strong, parallel structure can be found more often.

1.5.1 Parallel PID topology

A parallel connection of proportional, derivative and integral element is called parallel or non-interactive structure of PID controller. Parallel structure is shown in Fig.

It can be seen that P, I and D channels react on the error signal and that they are unbundled. This is basic structure of PID controller most often found in textbooks. There are other non-interactive structures.

CIRCUIT DIAGRAM (EFFECT OF P, PI, PID CONTROLLERS)

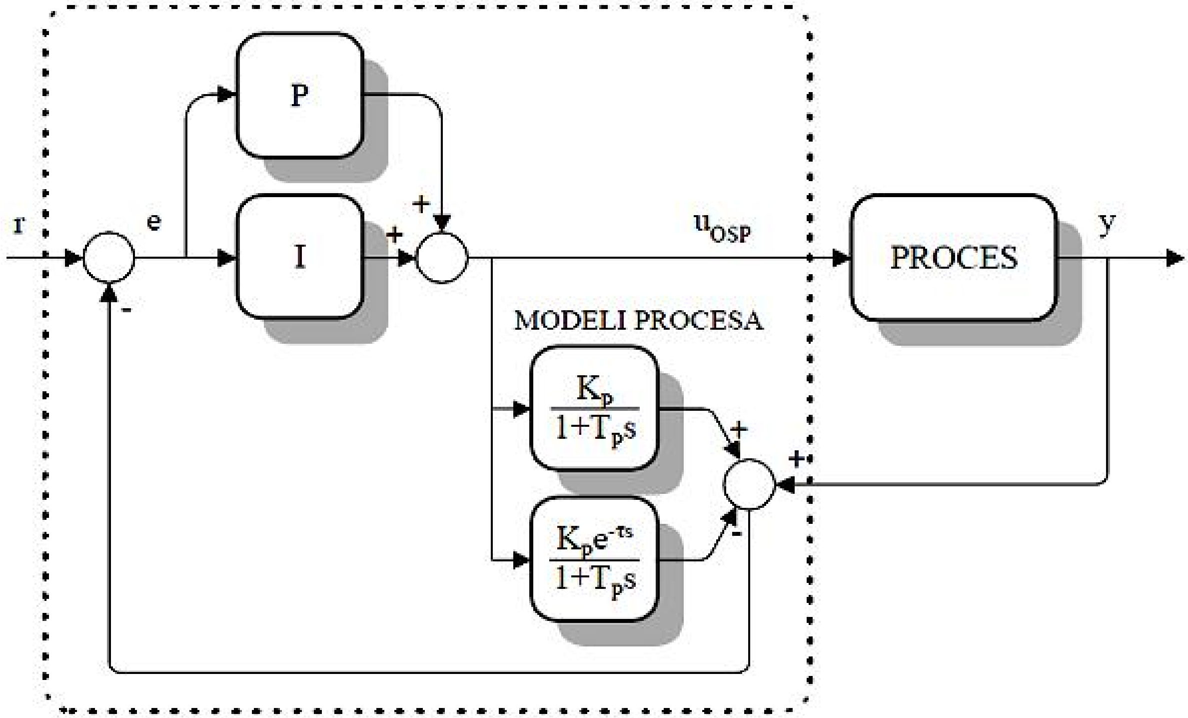


Fig. Otto-Smith controller for systems with transport delay

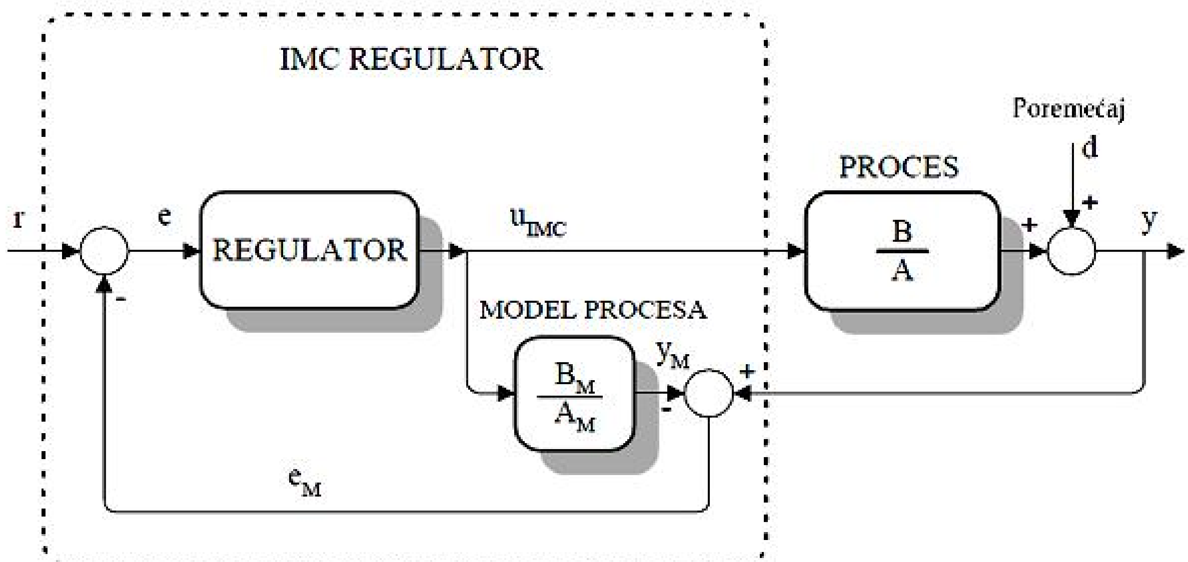


Fig. Structure of IMC

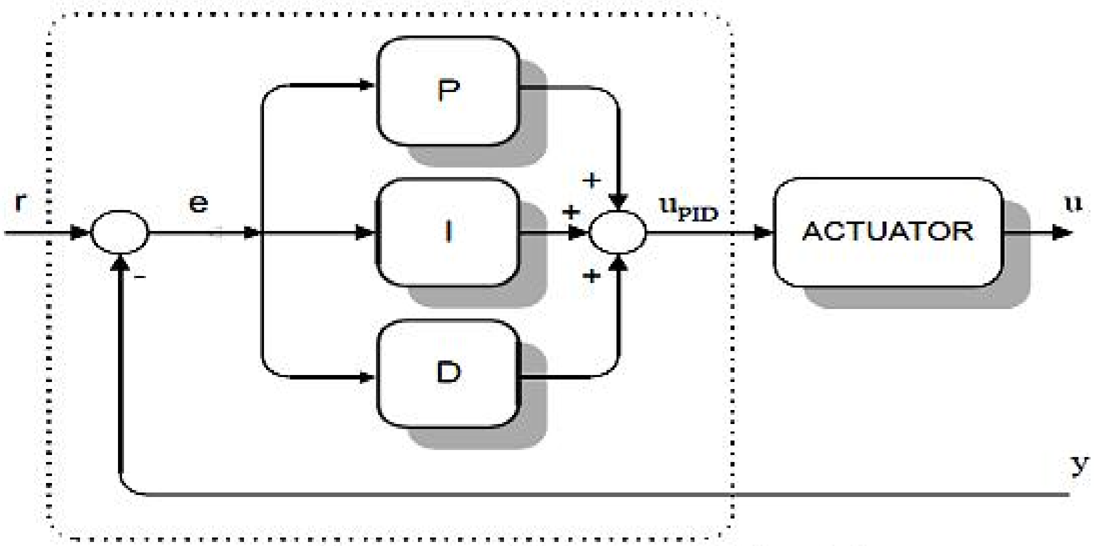


Fig. : Parallel structure of PID controller

RESULT:

Thus the effect of P, PI, PID controllers using Mat lab are studied.

EX.NO :16	DESIGN AND IMPLEMENTATION OF COMPENSATORS
DATE	

AIM:

To study the compensation of the second order process by using lead – Lag Compensator

EQUIPMENT REQUIRED:

1. LEAD – Lag network system kit
2. Capacitors – 0.1µF
3. Decade Resistance Box
4. CRO

DESIGN:

1. Lead – Lag network using operational amplifier:
2. An electronic lead –lag network using operational Amplifier is shown in Fig.

PROCEDURE:

3. Switch ON the power to the instrument.
4. Connect the individual blocks using patch chords bypassing the compensating network and gain as shown in fig. 4.2.
5. Give a sinusoidal input as the set value to the error detector.
6. Measure the amplitude and frequency of the input signal.
7. Measure the amplitude and phase difference of the output signal with respect to the input signal using DSO.
8. Using the technique explained previously, calculate the values of R1, R2, C2, and C1 to compensate for the phase shift of the output signal.
9. Connects the components at the points provided.
10. Now include the compensation block in the forward path before the process using patch chords as shown in fig.4.2.
11. Observe the compensated wave form through DSO.

The transfer function for this circuit can be obtained as follows:

Let

$$Z_1 = R_1 \parallel C_1$$

$$Z_2 = R_2 \parallel C_2$$

The second op-amp acts as a sign inverter with a variable gain to compensate for the magnitude. The transfer function of the entire system is given by G(jω).

$$G(s) = \frac{R_4 R_2 (1 + R_1 C_1 s)}{R_3 R_1 (1 + R_2 C_2 s)}$$

We have

$$\left|G(j\omega)\right| = \frac{R_2 R_4 \sqrt{(1 + T_1^2 \omega^2)}}{R_1 R_3 \sqrt{(1 + T_2^2 \omega^2)}}$$

Where

$T_1 = R_1 C_1$

$T_2 = R_2 C_2$ and

Thus the steady state output is

$$Y_{ss}(t) = \frac{R_2 R_4 \sqrt{(1 + T_1^2 \omega^2)}}{R_1 R_3 \sqrt{(1 + T_2^2 \omega^2)}} Sin(\omega t - \tan^{-1} T_1 \omega - \tan^{-1} T_2 \omega)$$ for an input Esinωt.

From this expression, we find that if $T_1 > T_2$, then $\tan^{-1} T_1\omega - \tan^{-1} T_2\omega > 0$. Thus if $T_1 > T_2$, then the network is a lead network. If $T_1 < T_2$, the network is a lag network.

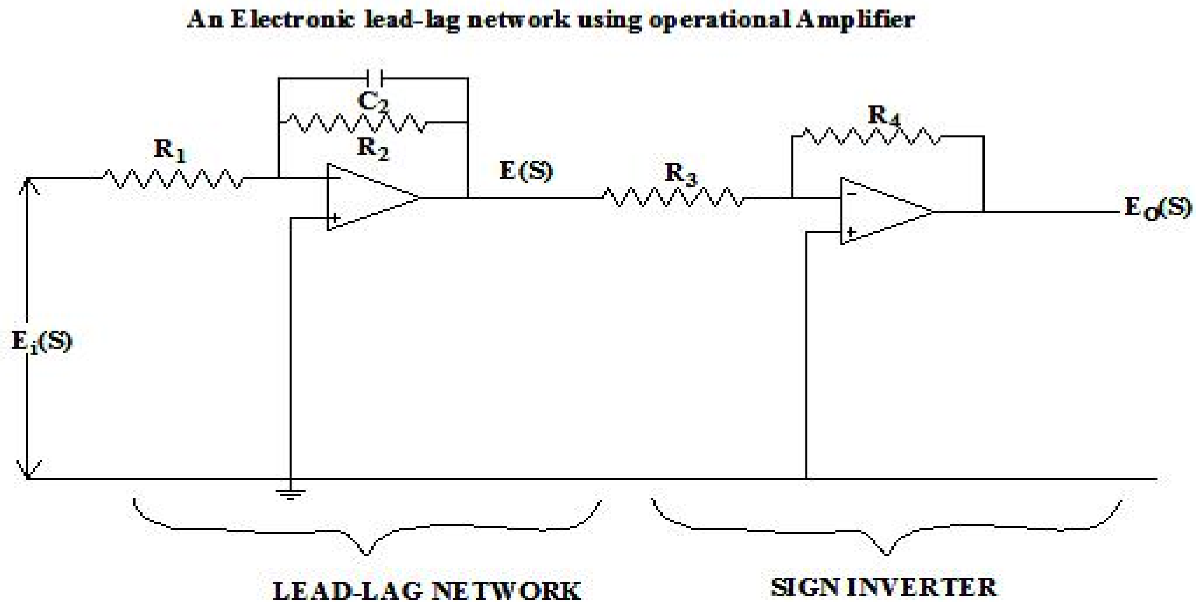
<u>Determination of values for angle compensation:</u>

Frequency of sine wave (f)= 20Hz.

Phase angle to be compensated $= 14.5^0$

$$\phi = \tan^{-1}(2\pi f T_1) - \tan^{-1}(2\pi f T_2)$$
$$Let\, T_1 = 0.1\text{sec}$$
$$14.5 = \tan^{-1}(2\pi * 20 * 0.1) - \tan^{-1}(2\pi * 20 * T_2)$$
$$T_2 = 0.023\text{sec}$$

CIRCUIT DIAGRAM:(Lead-Lag Compensators)



TABULATION: (Lead-Lag Compensators)

Si No	Amplitude *V*	Frequency *Hz*	Phase Shift ¤	Resistance (R_1) *Ohms*	Capacitance (C_1) *Farad*	Resistance (R_2) *Ohms*	Capacitance (C_2) *Farad*

CALCULATION: (frequency = Hz)

Hence the values of T_1 and T_2 are chosen from which the values of R_1, R_2, C_1, and C_2 can be determined. For Example,

$T_1 = R_1C_1 = 0.1$;

If $C_1 = 0.1\mu F$, $R_1 = 1M\Omega$

$T_2 = 0.023sec$

If $C_2 = 0.1\ \mu F$, $R_2 = 230K\Omega$.

These values produce a phase lead of 14.5^o, which is the desired compensation angle.

RESULT:

Thus the compensator is designed for the given process and the performance of the compensated system is found to work satisfactorily.

Frequency :	Hz	R_1 =	C_1 =
		R_2 =	C_2 =
Frequency :	Hz	R_1 =	C_1 =
		R_2 =	C_2 =

EX.NO :17	Predetermination of Regulation of Three Phase Alternator by EMF and MMF Methods
DATE	

AIM:

To predetermine the regulation of three phase alternator by EMF and MMF method and also to draw the vector diagrams.

APPARATUS REQUIRED:

sl. no	Name of the apparatus	Type	Range	Quantity
1	Ammeter	MI	0-10A	2
2	Voltmeter	Mi	0-230V	2
3	Three point starter			1
4	Rheostat	Wire wound	1250Ω, 0.8A	2

FUSE RATING:

125 % of current (Full load current)

For dc shunt motor.

For alternator

PRECAUTION:

i. The motor field rheostat should be kept in the minimum resistance position.
ii. The alternator field potential divider should be in the maximum voltage position.
iii. Initially all switches are in open position.

Procedure for both emf and MMF method:

1. Note down the nameplate details of motor and alternator.
2. Connections are made as per the circuit diagram.
3. Give the supply by closing the dust switch.
4. Using the three point starter, start the motor to run at the synchronous speed by varying the motor filed rheostat.
5. Conduct an open circuit test by varying the potential divider for various values of field current and tabulate the corresponding open circuit voltage readings.

6. Conduct a short circuit test by closing the TPST switch and adjust the potential divider to set the rated armature current, tabulate the corresponding field current.
7. Conduct a stator resistance test by giving connection as per the circuit diagram and tabulate the voltage and current readings for various resistive loads.

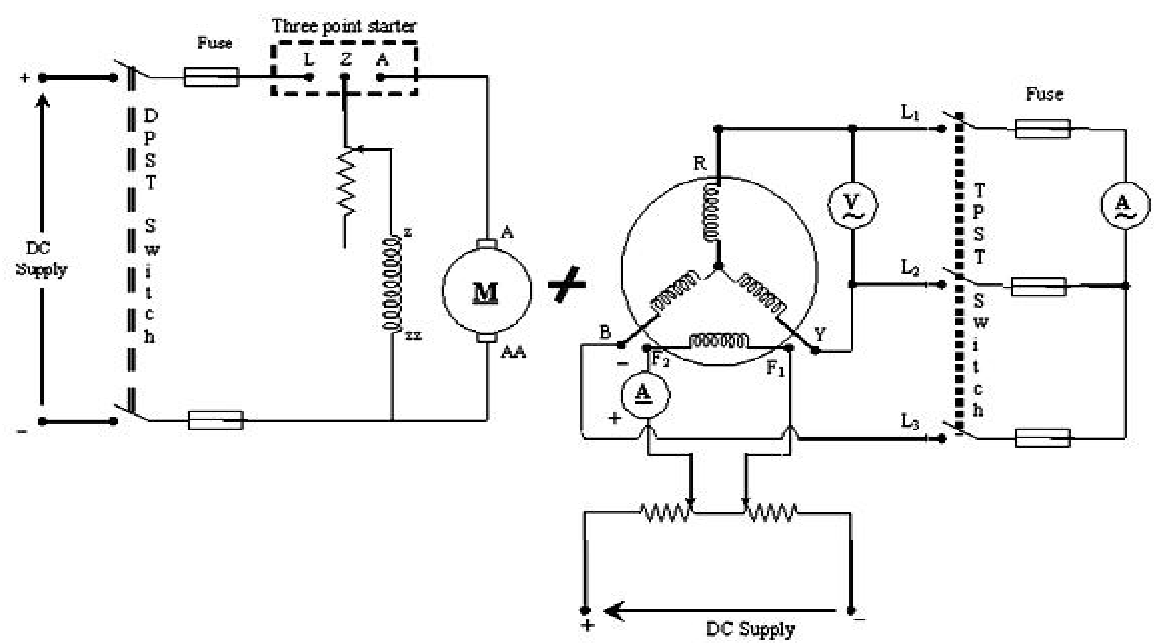
Procedure to draw the graph for EMF method:

1. Draw the open circuit characteristics curve (generator 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 (E_1 (ph)) for the rated short circuit current (**Isc**).
4. By using respective formulae find the **Zs, Xs, Eo** and percentage regulation.

Procedure to draw the graph for MMF method:

1. Draw the open circuit characteristics curve (generator voltage per phase Vs field current)
2. Draw the short circuit characteristics curve (short circuit current Vs field current)
3. Draw the line **OL** to represent **I_f'** which gives the rated generated voltage **(V)**.
4. Draw the line **LA** at an angle (**90ïΦ**) to represent **I_f"** which gives the rated full load current.(**Isc**) on short circuit [(**90ïΦ**) for lagging power factor and (**90- Φ**) for leading power factor].
5. Join the points O and A and find the field current (**I_f**) measuring the distance **OA** that gives the open circuit voltage (**E_0**) from the open circuit characteristics.
6. Find the percentage regulation by using suitable formula.

CIRCUIT DIAGRAM(Regulation of Three Phase Alternator by EMF and MMF Methods)



FORMULAE USED:

emf method:

Armature resistance **Ra = 1.6 Rdc** where - Rdc is the resistance in DC supply.

Synchronous impedance Zs = $(V_{OL}/\sqrt{3}) / (Isc)$

Synchronous impedance Xs = $\sqrt{(Zs^2 - Ra^2)}$

Open circuit voltage E_o = $\sqrt{((V_{rated}\cos\phi + I_a R_a)^2 + (V_{rated}\sin\phi + I_a X_s)^2)}$(For lagging power factor)

Open circuit voltage Eo = $\sqrt{((V_{rated}\cos\phi + I_a R_a)^2 + (V_{rated}\sin\phi - I_a X_s)^2)}$ (For leading power factor)

Open circuit voltage Eo = $\sqrt{((V_{rated}\cos\phi + I_a R_a)^2 + (I_a X_s)^2)}$ (For unity power factor)

Percentage regulation = $(Eo - V_{rated}/V_{rated})*100$(For both EMF and MMF methods)

TABULATION:(Open Circuit Test)

S.NO	**Field current (I_f)** *Amps*	**Open circuit line Voltage-V_{OL}** *Volts*	**Open circuit phase voltage ($V_{o(ph)}$)** *Volts*

TABULATION:(Short circuit test)

S.No	**Field current (I_f)** *Amps*	**Short Circuit Current (120 to 150 % of rated current) (I_{sc})** *Amps*

Tabulation to find out the armature resistance (ra):

S.No	**Armature current (I)** *Amps*	**Armature voltage (V)** *Volts*	**Armature Resistance Ra=V/I** *Ohms*

TABULATION: (EMF and MMF)

S. No	Power factor	EMF method			MMF method		
		Lagging	**Leading**	**unity**	**Lagging**	**Leading**	**unity**
1.	0.2						
2.	0.4						
3.	0.6						
4.	0.8						
5.	1.0						

MODEL CALCULATION:

RESULT:

Thus the regulation of three phase alternator by EMF and MMF method and also to draw the vector diagrams is determined.

EX.NO :18	STUDY OF TRANSDUCERS AND CHARACTERIZATION
DATE	

AIM :

To study the displacement transducer using LVDT

APPARATUS REQUIRED :

S.No	Name of the Trainer Kit/ Copmponents	Quantity
1	LVDT trainer kit containing the signal conditioning unit	1
2	LVDT calibration jig	1
3	Multi meter	1
4	Patch cards	FEW

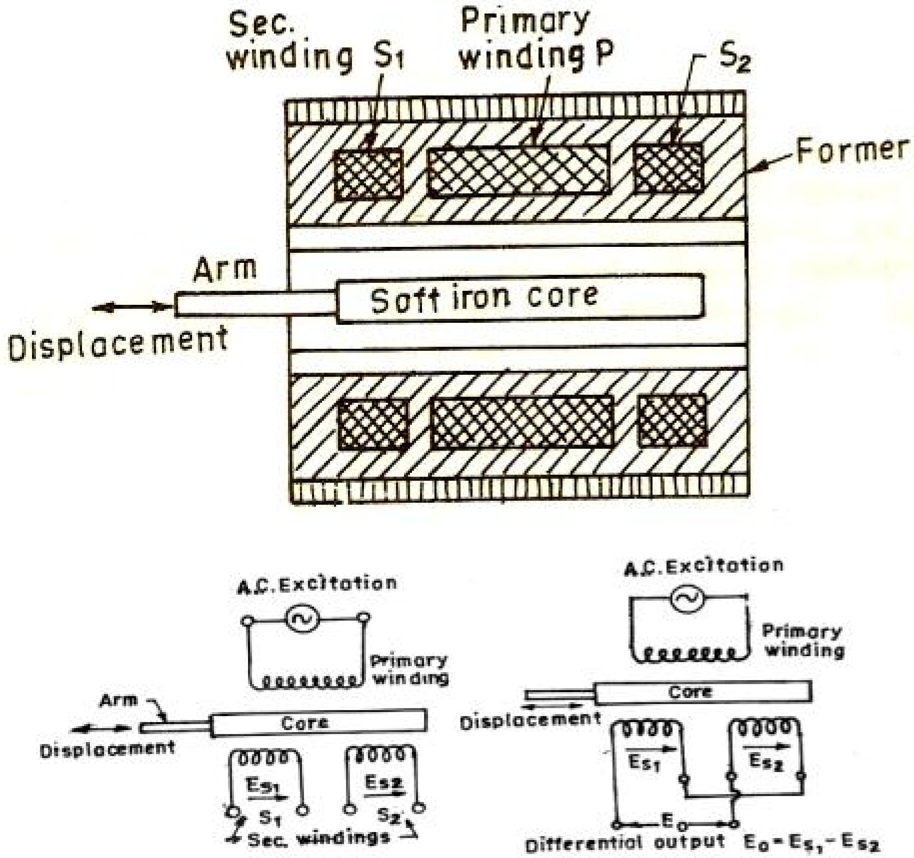
THEORY:

LVDT is the most commonly and extensively used transducer, for linear displacement measurement. The LVDT consists of three symmetrical spaced coils wound onto an insulated bobbin. A magnetic core, which moves through the bobbin without contact, provides a path for the magnetic flux linkage between the coils. The position of the magnetic core controls the mutual inductance between the primary coil and with the two outside or secondary coils. When an AC excitation is applied to the primary coil, the voltage is induced in secondary coils that are wired in a series opposing circuit. When the core is centered between two secondary coils, the voltage induced in the secondary coils are equal, but out of phase by 180°. The voltage in the two coils cancels and the output voltage will be zero.

CIRCUIT OPERATION:

The primary is supplied with an alternating voltage of amplitude between 5V to 25V with a frequency of 50 cycles per sec to 20 K cycles per sec. The two secondary coils are identical & for a centrally placed core the induced voltage in the secondary's Es1&Es2 are equal. The secondary's are connected in phase opposition. Initially the net o/p is zero. When the displacement is zero the core is centrally located. The output is linear with displacement over a wide range but undergoes a phase shift of 180°. It occurs when the core passes through the zero displacement position.

CIRCUIT DIAGRAM: (Transducers)



RESULT:

Thus the displacement transducer characteristics was studied using LVDT.