



**VINAYAKA MISSIONS UNIVERSITY**  
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**PAIYANOOR – 603 104, KANCHEEPURAM Dist.**



**DEPARTMENT OF ELECTRICAL AND ELECTRONICS  
ENGINEERING**

**ISO / WI NO: 44 -Rev: 1 / Effective Date:**

**CONTROL SYSTEMS LABORATORY**

**LAB MANUAL / OBSERVATION**

**REGULATION 2017**

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## PREFACE

The Aim of this Laboratory is to encourage the students to work as a team and learn to communicate effectively. To study the effects of Lead, Lag, Lead-Lag, Series compensation on second order system transient and steady state response. To familiarize the students with servomotor and to investigate the servomotor speed and position control principles by designing and selecting specific P, I, PI gains and specific responses. For determination of transfer function of separately excited DC generator, self excited DC generator, armature controlled DC motor and field control DC motor.

This Laboratory manual in control system has been revised in order to be up to date with curriculum changes, laboratory equipment upgrading and the latest circuit simulation.

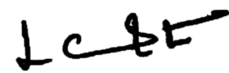
Every effort has been made to correct all the known errors, but nobody is perfect, if you find any additional errors or anything else you think is an error, Please contact the HOD/EEE at [hodeee@avit.ac.in](mailto:hodeee@avit.ac.in)

The Author thank all the staff members from the department for their valuable suggestions and contributions.

The Author  
Department of EEE

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HOD/ EEE  
Dr. L. Chitra

## LIST OF EXPERIMENTS:

- 1. Transfer function of self and separately excited DC Generator.**  
**Aim :** To determine the transfer function of self and separately excited DC generator.
- 2. Transfer function of Armature and Field controlled DC Motor.**  
**Aim :** To determine the transfer function of armature and field controlled DC motor.
- 3. Transfer function of AC Servomotor.**  
**Aim :** To derive the transfer function of the given A.C Servomotor and experimentally determine the transfer function parameters.
- 4. Frequency response of Lag, Lead & Lag – Lead networks.**  
**Aim :** To obtain the Frequency response of Lag, Lead & Lag – Lead networks.
- 5. Study of Synchros and DC Stepper Motor**  
**Aim :** To study the working of Synchros & stepper motor
- 6. Transfer function of Ward – Leonard method of speed control of DC motor.**  
**Aim :** To determine the transfer function parameters of Ward – Leonard method of speed control of DC motor.
- 7. Study of DC Position Control system and study of various transducers**  
**Aim :** To study the DC position control system and draw the error characteristics between set point and error and to study the various Transducers.
- 8. Study of P, PI and PID Controllers (First Order).**  
**Aim :** To determine the Time Response characteristics of the controllers.
- 9. Analog and simulation of type – 0 and type – 1 systems**  
**Aim:** To simulate the time response characteristics of I order and II order, type 0 and type-1 systems.
- 10. Stability analysis of Linear Systems**  
**Aim :** To analyse the stability of linear systems using Bode / Root locus / Nyquist plot.
- 11. Digital simulation of first order systems**  
**Aim :** To digitally simulate the time response characteristics of first -order system
- 12. Digital simulation of second order systems**  
**Aim :** To digitally simulate the time response characteristics of second -order system

## **TROUBLE SHOOTING HINTS**

1. Be Sure that the power is turned ON
2. Be sure the ground connections are common
3. Be sure the circuit you build is identical to your circuit diagram (Do a node by node check)
4. Be sure that the supply voltages are correct
5. Be sure that the equipment is set up correctly and you are measuring the correct parameters
6. If steps 1 through 5 are correct then you probably have used a component with the wrong value or one that doesn't work. It is also possible that the equipment does not work (although this is not probable) or the protoboard you are using may have some unwanted paths between nodes. To find your problem you must trace through the voltages in your circuit node by node and compare the signal you expect to have. Then if they are different use your engineering judgment to decide what is causing the difference or ask your lab assistant

## GUIDELINES FOR LABORATORY NOTEBOOK

The laboratory notebook is a record of all work pertaining to the experiment. This record should be sufficiently complete so that you or anyone else of similar technical background can duplicate the experiment and data by simply following your laboratory notebook. Record everything directly into the notebook during the experiment. Do not use scratch paper for recording data. Do not trust your memory to fill in the details at a later time.

Organization in your notebook is important. Descriptive headings should be used to separate and identify the various parts of the experiment. Record data in chronological order. A neat, organized and complete record of an experiment is just as important as the experimental work.

### **1. Heading:**

The experiment identification (number) should be at the top of each page. Your name and date should be at the top of the first page of each day's experimental work.

### **2.Object:**

A brief but complete statement of what you intend to find out or verify in the experiment should be at the beginning of each experiment

### **3.Diagram:**

A circuit diagram should be drawn and labeled so that the actual experiment circuitry could be easily duplicated at any time in the future. Be especially careful to record all circuit changes made during the experiment.

### **4.Equipment List:**

List those items of equipment which have a direct effect on the accuracy of the data. It may be necessary later to locate specific items of equipment for rechecks if discrepancies develop in the results.

### **5.Procedure:**

In general, lengthy explanations of procedures are unnecessary. Be brief. Short commentaries along side the corresponding data may be used. Keep in mind the fact that the experiment must be reproducible from the information given in your notebook.

### **6.Data:**

Think carefully about what data is required and prepare suitable data tables. Record instrument readings directly. Do not use calculated results in place of direct data; however, calculated results may be recorded in

the same table with the direct data. Data tables should be clearly identified and each data column labeled and headed by the proper units of measure.

### **7.Calculations:**

Not always necessary but equations and sample calculations are often given to illustrate the treatment of the experimental data in obtaining the results.

### **8.Graphs:**

Graphs are used to present large amounts of data in a concise visual form. Data to be presented in graphical form should be plotted in the laboratory so that any questionable data points can be checked while the experiment is still set up. The grid lines in the notebook can be used for most graphs. If special graph paper is required, affix the graph permanently into the notebook. Give all graphs a short descriptive title. Label and scale the axes. Use units of measure. Label each curve if more than one on a graph.

### **9.Results:**

The results should be presented in a form which makes the interpretation easy. Large amounts of numerical results are generally presented in graphical form. Tables are generally used for small amounts of results. Theoretical and experimental results should be on the same graph or arrange in the same table in a way for easy correlation of these results.

### **10.Conclusion:**

This is your interpretation of the results of the experiment as an engineer. Be brief and specific. Give reasons for important discrepancies.

## EX: NO 1 TRANSFER FUNCTION OF SELF EXCITED DC GENERATOR

AIM:

To study the transfer function of self excited dc generator.

APPARATUS REQUIRED:

1. Self excited dc generator trainer kit
2. Multimeter
3. Tachometer
4. Patch choards

PROCEDURE:

1. Make the connection as per the circuit diagram.
2. Connect 220v DC supply to the motor field.
3. Connect (100-200)V variable DC to the generator field.
4. Connect(0-200)V variable DC supply to armature.
5. Switch on the MCB keeping armature voltage control pot at its minimum position & ON/OFF switch at OFF position and also vriable field voltage pot at its maximum position.
6. Now switch ON the armature control switch and vary the armature control potentiometer till the motor rotates at it rated speed.
7. Note down  $I_f$  and  $E_g$  in tabulation.
8. Now vary the generator field supply and note down  $E_g$  for different  $I_g$  & enter in the tabulation.
9. Drow the graph of  $E_g$  &  $I_g$ .

FORMULA USED

Transfer function= $(K_g/L_f)/(s+(R_f/L_f))$



GIVEN DATA:

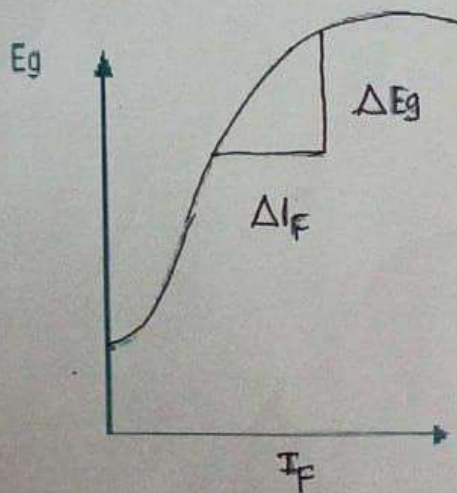
1. field inductance( $L_f$ )=21H
2. field resistance( $R_f$ )=650 ohms

TABULATION:

S.NO	If(amps)	Eg(volts)

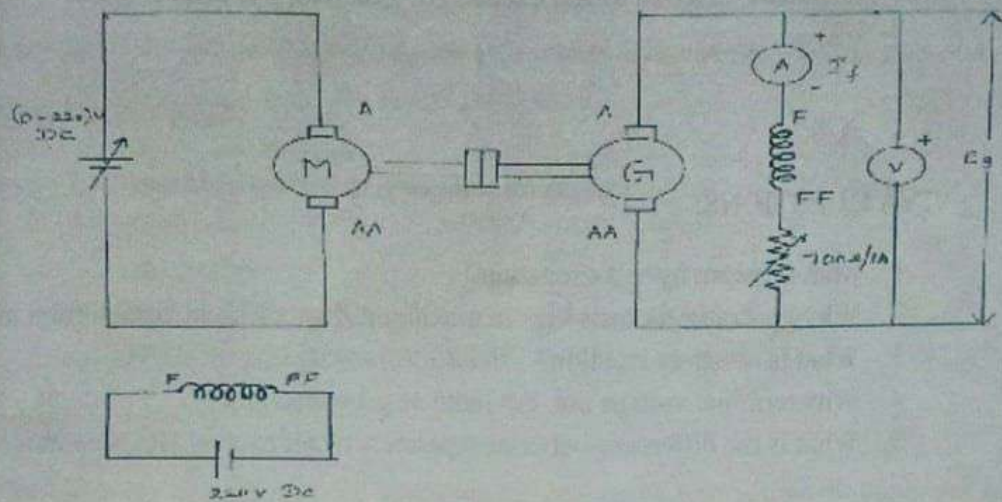
MODEL GRAPH

Generated voltage( $E_g$ ) Vs Field current( $I_f$ )



$$K_g = \frac{\Delta E_g}{\Delta I_f}$$

CIRCUIT DIAGRAM FOR TRANSFER FUNCTION OF SELF EXCITED DC GENERATOR



RESULT:

Thus the transfer function of self excited DC generator has been studied.

VIVA QUESTIONS:

1. what is meant by self excitation?
2. Why generator rheostat kept in maximum & motor field in minimum position?
3. What is armature reaction?
4. Why terminal voltage not the same as generated emf?
5. What is the difference between separately n self excited DC generator?

## TRANSFER FUNCTION OF SEPARATELY EXCITED DC GENERATOR.

AIM:

To determine the transfer function of separately excited DC generator.

APPARATUS REQUIRED:

1. Separately excited dc generator trainer kit
2. Multimeter
2. Tachometer
3. Patch chords
4. DC motor and generator(0.5)HP

THEORY:

When the field winding is supplied from external separate DC supply, then the generator is called separately excited generator. The field winding of this type of generator has large no of turns of thin wires so the length of the winding of this type of winding is more with less crosssectional area. The resistance of this winding is high in order to limit the field current.

PROCEDURE:

1. Make the connection as per the circuit diagram.
2. Connect 220v DC supply to the motor field.
3. Connect (100-200)V variable DC to the generator field.
4. Connect(0-200)V variable DC supply to armature.
5. Switch on the MCB keeping armature voltage control pot at its minimum position & ON/OFF switch at OFF position and also variable field voltage pot at its maximum position.
6. Now switch ON the armature control switch and vary the armature control potentiometer till the motor rotates at it rated speed.
7. Note down  $I_f$  and  $E_g$  in tabulation.
8. Now vary the generator field supply and note down  $E_g$  for different  $I_g$  & enter in the tabulation.
9. Draw the graph of  $E_g$  &  $I_g$ .

FORMULA USED:

Transfer function= $(K_g/L_f)/(S_f R_f/L_f)$

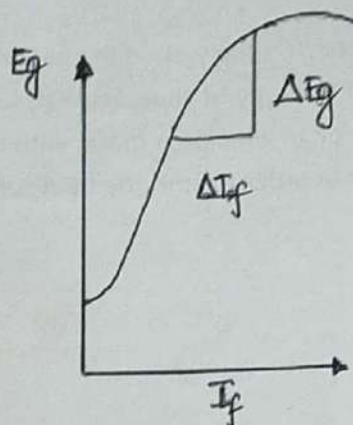
$$=(K_g/L_f)/(S+(R_f/L_f))$$

GIVEN DATA:

1. Field inductance( $L_f$ )=21H
2. field resistance ( $R_f$ )=650 ohms

MODEL GRAPH

Generated voltage( $E_g$ ) Vs Field current ( $I_f$ )



$$K_g = \frac{\Delta E_g}{\Delta I_f}$$

TABULAR COLUMN

S.No	$E_g$ (volts)	$I_f$ (Amps)

GENERATED VOLTAGE VS FIELD CURRENT

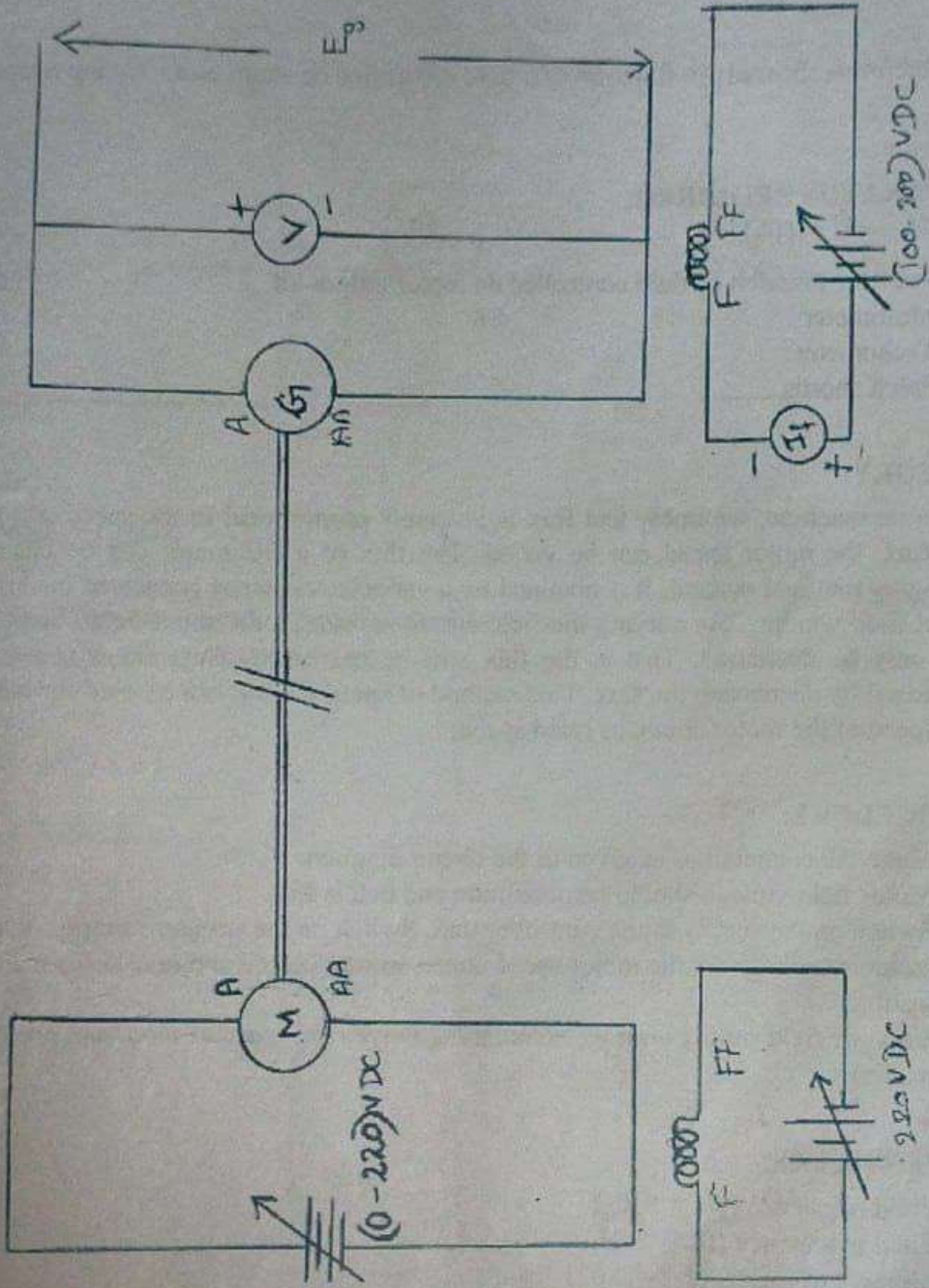
RESULT:

Thus the transfer function of self excited DC generator has been studied.

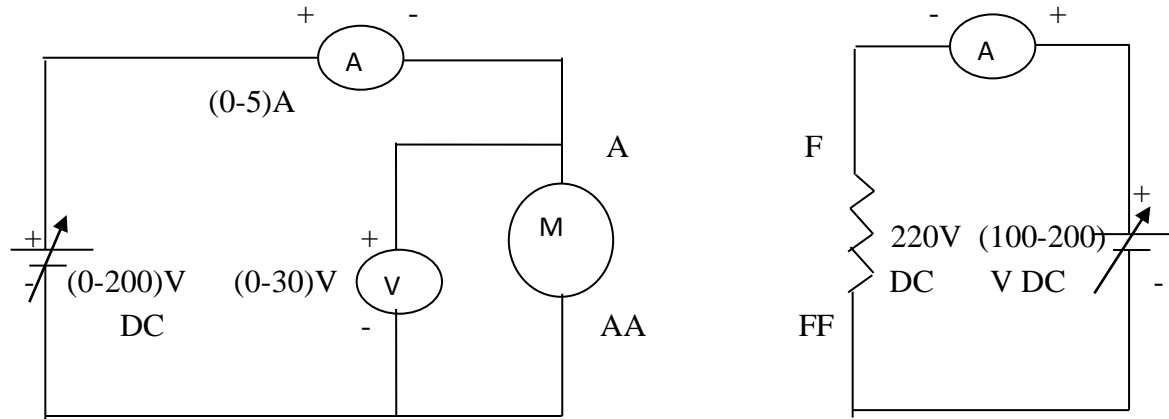
VIVA QUESTIONS:

1. What is the difference between separately n self excited DC generator?
2. where do we use DC shunt motor?
3. What is the relation between the torque & speed in dc motor?
4. What type of motor is used in train?
5. Name the types of speed control method in dc motor.

SEPARATELY EXCITED DC GENERATOR DIAGRAM



**CIRCUIT DIAGRAM:**



**FORMULA USED:**

The overall transfer function of field controlled dc motor is

$$\text{Transfer function} = \frac{K_f}{S(R_f + S L_f) (S J_m + f_m)}$$

## **EX. NO: 2 .a. TRANSFER FUNCTION OF FIELD CONTROLLED DC SHUNT MOTOR**

### **AIM**

To determine the transfer function of a field controlled dc shunt motor by the retardation test.

### **APPARATUS REQUIRED:**

1. Transfer function of field controlled dc motor trainer kit
2. Multimeter
3. Tachometer
4. Patch chords

### **THEORY:**

For a dc machine, we know that flux is inversely proportional to the speed. By varying the flux, the motor speed can be varied. The flux of a DC motor can be changed by changing the field current. It is obtained by a variable resistance connected in series with shunt field winding. By varying the field circuit resistance, the shunt field circuit current can only be decreased. That is the flux will be decreased. Thus motor speed can be increased by decreasing the flux. This method of speed control can be used for increasing the speed of the motor above its rated speed.

### **PROCEDURE:**

1. Make the connections as given in the circuit diagram.
2. Motor field voltage should be maximum and belt is free.
3. Switch on the supply to the controller unit. Switch on the armature supply. Vary the armature voltage till the motor speed comes to rated speed and note down meter readings.
4. Vary the field supply until we obtain 20% above rated speed of motor and note down the readings

### **GIVEN DATAS:**

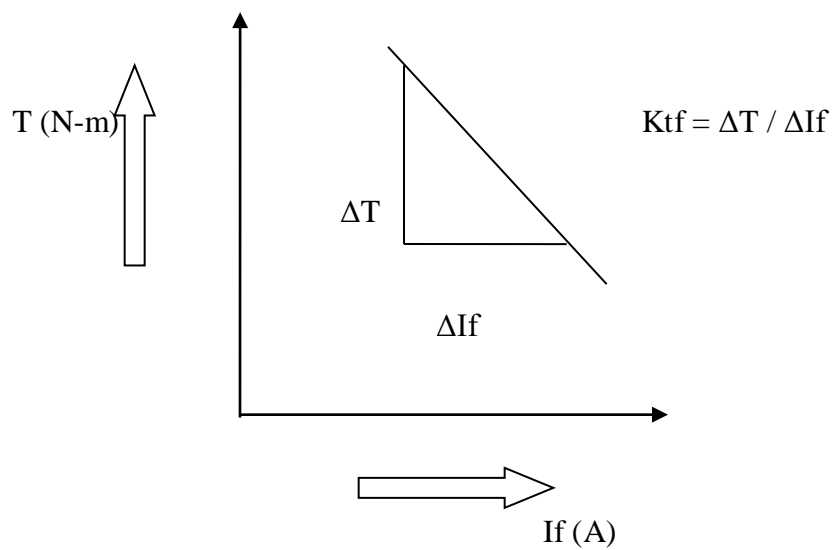
1. Field resistance ( $R_f$ ) =  $650\Omega$
2. Field inductance ( $L_f$ ) =  $21H$
3. Moment of inertia ( $J_m$ ) =  $0.021 \text{ Kgm}^{-2}$
4. Friction co-efficient ( $f_m$ ) =  $0.8$



**TABULATION:  
TO FIND T:**

Sl. No	If(amp)	Ia (amp)	N(rpm)	V(volts)	T=If Ia (N-m)

**MODEL GRAPH:**



## **RESULT**

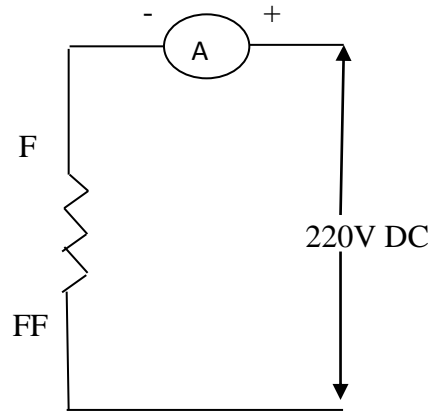
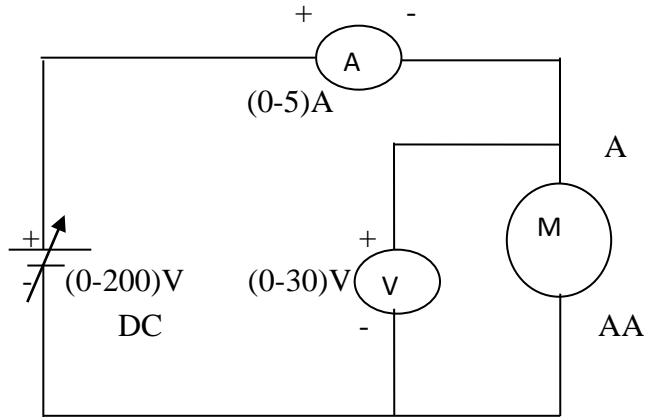
Thus the transfer function of field controlled dc shunt motor was determined by the retardation test.

## **VIVA QUESTIONS:**

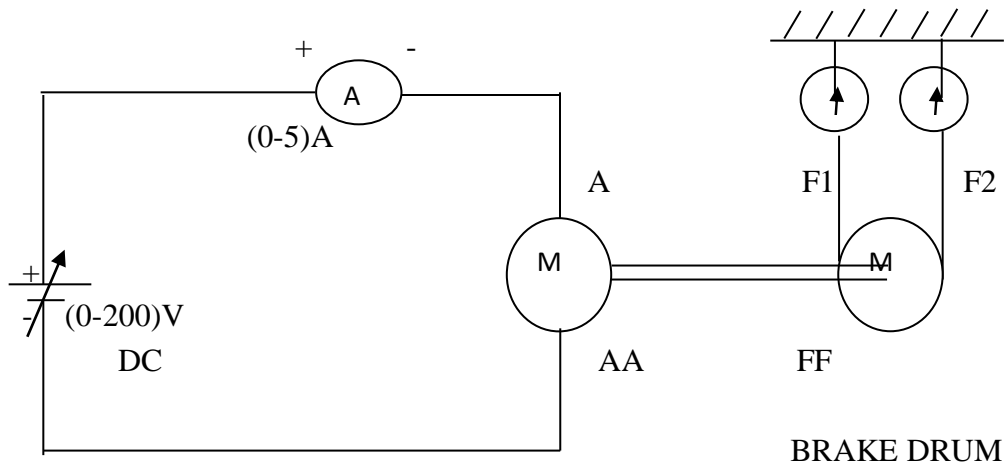
1. Define transfer function?
2. What is back EMF?
3. What are the losses present in dc shunt motor?
4. On which factors the torque of a dc motor depends?
5. Define motor constant?

**CIRCUIT DIAGRAM:**

**A) FOR NO LOAD TEST:**



**B) FOR LOAD TEST ON DC MOTOR:**



## EX. NO: 2 .b. TRANSFER FUNCTION OF ARMATURE CONTROLLED DC SHUNT MOTOR

### AIM

To determine the transfer function of a armature controlled dc shunt motor.

### APPARATUS REQUIRED:

1. Armature controlled dc shunt motor trainer kit
2. Multi meter
3. Tachometer
4. Patch chords

### THEORY

#### TRANSFER FUNCTION:

In a armature current controlled DC motor, the field current  $i_a$  is held constant, and the armature current is controlled through the armature voltage  $V_a$ . In this case, the motor torque increases linearly with the armature current.  $K$  is a constant that depends on the motor.

$$(1) V_a = R_a i_a + L_a (di_a/dt) + e_m$$

$$(2) e_m = k_e d\theta / dt$$

$$(3) T = K_t i_a$$

$$(4) T = J d^2\theta / dt + B d\theta / dt$$

Where

$V_a$  = applied voltage                       $i_a$  = armature current

$e_m$  = motor back emf                       $K_e$  = motor voltage constant

$K_t$  = motor torque constant       $T$  = torque generated by motor

$J$  = equivalent moment of inertia reflected at the motor shaft

$B$  = equivalent viscous coefficient reflected at the motor shaft

Using Laplace Transform, equations (1) to (4)

$$V_a (s) = R_a I_a (s) + L_a s I_a (s) + E_m (s)$$

$$E (s) = K_e s \theta(s)$$

$$T(s) = K_t i_a (s)$$

$$T(s) = I_m s^2 \theta(s) + B s \theta(s)$$

**TABULATION:**

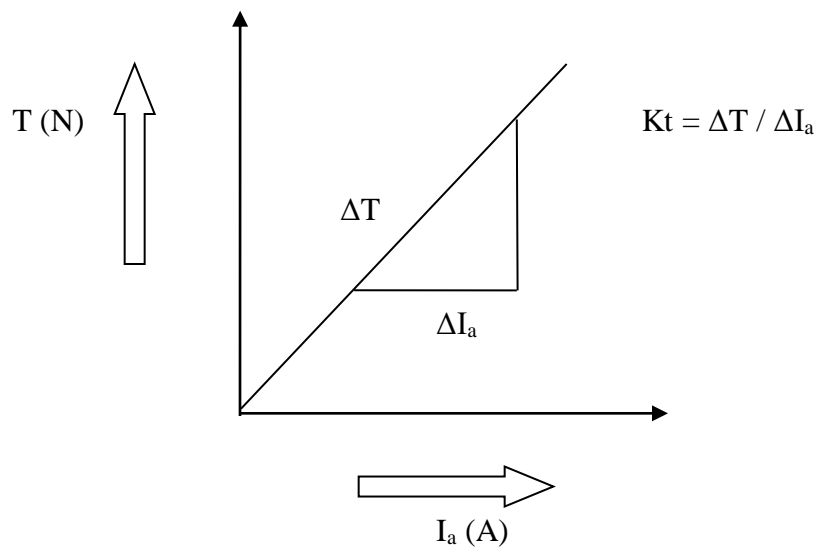
**To find w from no load test:**

Sl. No	Va(volts)	N (rpm)	Ia(amps)	$E_b = V - I_a R_a$ Ra(volts)	$W = 2 \pi N / 60$ (N-m)

**To find Torque from load test:**

Sl. No	Ia(amps)	F1	F2	N (rpm)	$T = (F1 - F2) * 6.5 * 9.8$ (N-m)

**MODEL GRAPH TO FIND MOTOR TORQUE CONSTANT Kt:**



$$V_a(s) = (R_a b)/K_t [s(\tau_a s + 1)(\tau_m s + 1)] \theta_m(s) + K_e s \theta_m(s)$$

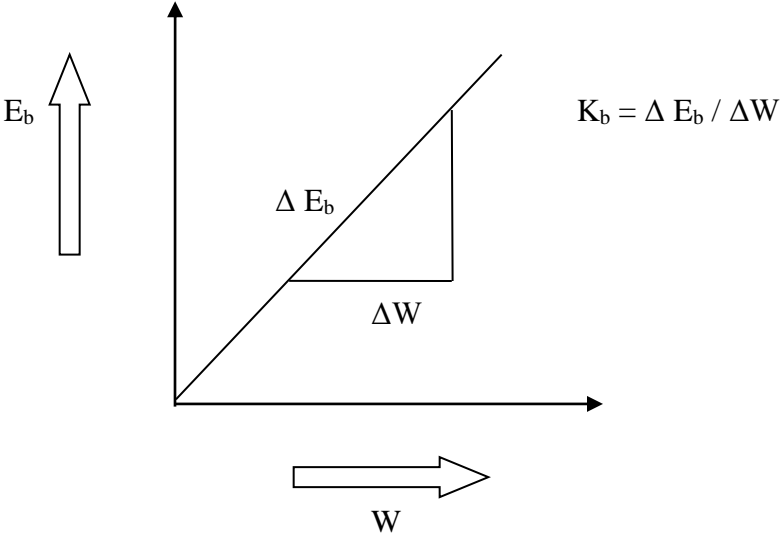
Where  $\tau_a = L_a/R_a$  and  $\tau_m = I_m/b$  are the armature and the motor time constants. The transfer function between the output speed and the applied voltage is

$$\theta_m(s)/V_a(s) = (k/Rb)/s[\tau_m \tau_a s^2 + (\tau_m + \tau_a)s + ((K_e K_t)/(R_a b) + 1)]$$

### **MODEL CALCULATION:**

Transfer function of armature controlled DC motor =  $K_t/S \{(R_a + sL_a)(SJ_m + f_m) + (K_t K_b)\}$

**MODEL GRAPH TO FIND BACK EMF CONSTANT Kb:**



## **RESULT**

Thus the transfer function of armature controlled dc shunt motor was determined by the retardation test.

## **VIVA QUESTIONS:**

1. Give the equation of back emf?
2. What is the difference between armature control & field control?
3. What is servo mechanism?
4. List the various method of controlling the speed of dc motor?
5. Define torque constant and back emf constant?





## **EX:NO 3 AC SERVO MOTOR POSITION CONTROL**

### **AIM**

To study the operation of A.C servomotor position control with PI controller using PEC-02

### **APPARATUS REQUIRED**

- 1.PEC-02
- 2.Motor setup
- 3.Patch chords

### **PRECAUTIONS**

- 1.Check whether power ON/OFF switch is in OFF condition
2. Check whether 230V AC ON/OFF switch is in OFF condition
3. Check whether main winding voltage 230V AC is in OFF condition

### **CONNECTION PROCEDURE**

- 1.Connect set position (SP) to error detector input
- 2.Connect position feedback (PV) to error detector (PV) input
- 3.Connect 12-0-12 V output of centre tapped transformer to input 12-0-12 V of power circuit.
- 4.Connect output of power circuit to motor control winding(12 V)

## TABULATION

Sl.No	Set position	Output position

## **EXPERIMENTAL PROCEDURE**

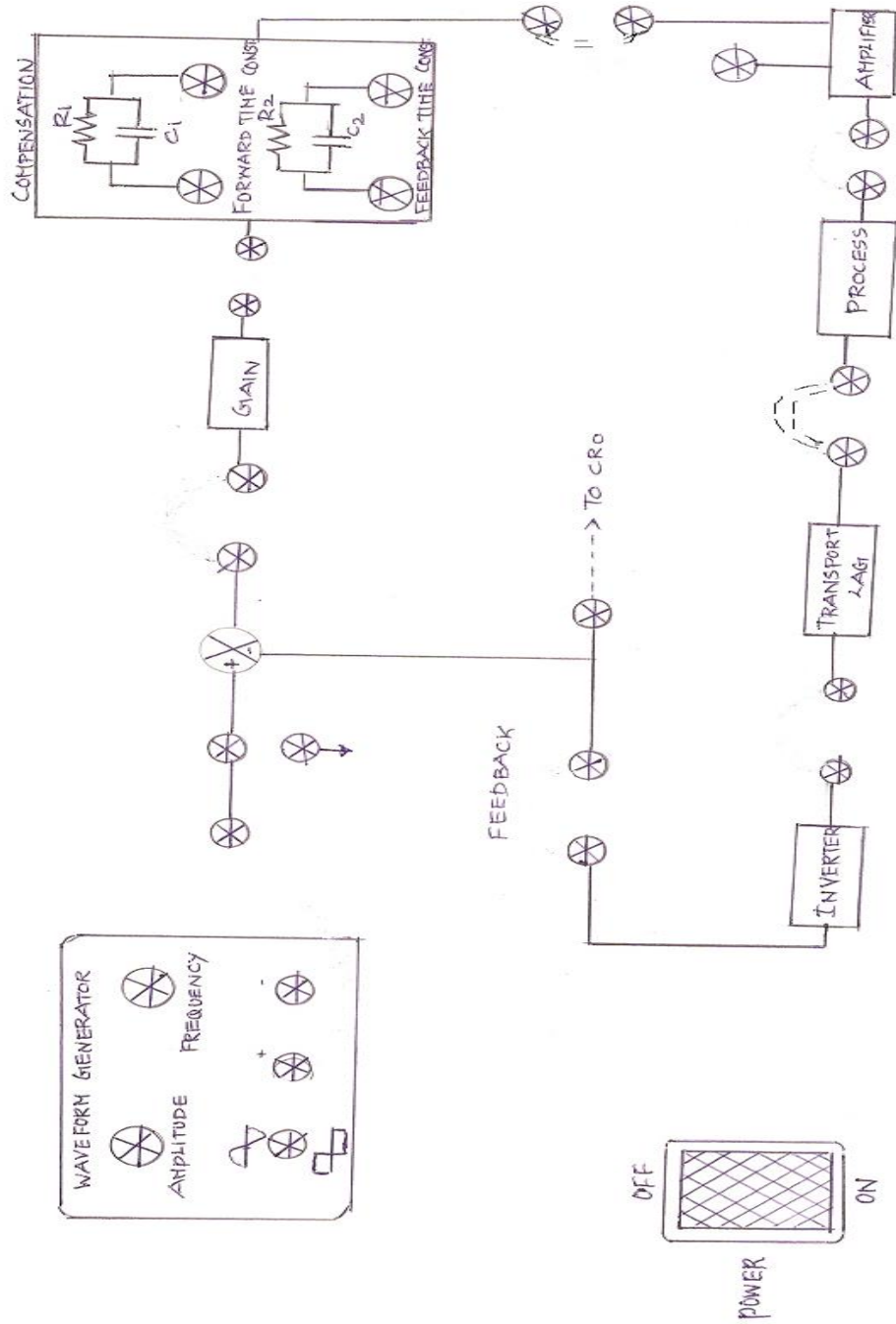
1. Switch on the trainer power ON/OFF
2. Switch on the constant 230 V AC main winding voltage
3. Switch on the transformer primary 230 V AC ON/OFF switch
4. Set the motor position using set position knob and take the reading for set position & output position.
5. Repeat the procedure step by step upto 340 degree
6. for each step note down the set position & output position and tabulate it.
7. From the reading we can know that set position = output position

## **RESULT**

Thus the A.C servo motor position control experiment was conducted & their readings are tabulated

## **VIVA QUESTIONS:**

1. Define AC servo motor?
2. What are the different types of rotor used in AC servo motor?
3. What are the special features of DC servo motor?
4. Compare AC and DC servo motor?
5. What are the characteristics of servo motors?



## **EX:NO 4 FREQUENCY RESPONSE OF LAG ,LEAD,LAG-LEAD NETWORKS**

### **AIM**

To determine the frequency response of the lag,lead,lag-lead networks

### **APPARATUS REQUIRED**

- 1.Lead lag trainer kit (VLNN-01)
- 2.Patch chords
- 3.CRO and connecting wires

### **FORMULA TO BE USED**

$$\phi = \sin^{-1} (X1/X2) = \sin^{-1} (Y1/Y2)$$

### **THEORY**

Compensator networks are implemented as electrical circuits in the feed forward path of a control system. Compensators may be employed to improve system

performance and can permit an increased forward gain (K) to reduce steady-state error & improve damping and thus reduce overshoot and improve settling time.

Phase lead compensators and improved damping, specifically.

Phase lead compensators are placed in cascade, in the forward path, and are used to manipulate the phase margin. Phase lead compensators shift Bode phase plots of  $KGH(j\omega)$  (open loop transfer function) upward in a desired frequency range. This increases phase margin, which improves damping, as described below. Fundamentally a phase lead network is beneficial because often other (electromechanical) components introduce phase lag, due to inertia and inductance. The phase lead network counters these plant dynamics.

Transfer function of a phase-lead compensator  $G_c(s) = \alpha (s+z)/(s+p)$ , where  $|z| < |p|$

The multiplier  $\alpha = |p| / |z|$ . As a result, the compensator amplifies at frequencies near and above the location of the zero, and increases the phase of the system near the pole and zero locations

Transfer function of a phase-lag compensator  $G_c(s) = \alpha (s+z)/(s+p)$ , where  $|p| < |z|$

The multiplier  $\alpha = |p| / |z|$  As a result, the compensator decreases the gain of the system at frequencies above the location of the pole, and decreases the phase of the system near the pole and zero locations.

**TABULATION:**

**Lag Compensator**

**Input Voltage  $V_{in} =$**

S.No	Frequency (HZ)	$Y_1$ (V)	$Y_2$ (V)	Output Voltage(V)	Gain= $20\log(V_o/V_i)$ (db)	Phase Angle $\Phi = \sin^{-1}(Y_1/Y_2)$

**Lead Compensator**

**Input Voltage  $V_{in} =$**

S.No	Frequency (HZ)	$Y_1$ (V)	$Y_2$ (V)	Output Voltage(V)	Gain= $20\log(V_o/V_i)$ (db)	Phase Angle $\Phi = \sin^{-1}(Y_1/Y_2)$

main use of a phase-lag compensator is to decrease the steady-state error. The cost is often to increase the system's rise and settling times.

Compensation is a very important requirement for amplifier design. When feedback is applied to an amplifier, the possibility for instability is inherently introduced. Compensation means for controlling the location of poles, by inserting a dominant pole, and thus guaranteeing the stability of the amplifier.

Instability refers to the chance that the output changes sign so that the output actually adds to the input, instead of subtracting. This will cause the output to grow without bound and saturate the amplifier.

The problem occurs when the phase delay decreases too slowly relative to the gain. The phase reaches a value of  $-180$  degrees before the gain drops to 0 dB or less. If there is positive gain and  $-180$  degrees of phase, the output will add to the input and since there is positive gain, the output will continue to increase without bound.

To fix this problem, the circuit has a dominant pole added to guarantee that the gain will be 0 dB or less before the phase reaches  $-180$  degrees. In practice, to insure stability, the gain should reach 0 dB before  $-120$  degrees, leaving a conservative 60 degree margin. This distance an amplifier's phase is from  $-180$  degrees at 0 dB gain is called the phase margin

## **PRECAUTIONS**

1. Check for loose connections
2. Input to channel 1 of the CRO should be sine wave

## **PROCEDURE: LAG & LEAD**

1. Give the connections as per the circuit diagram
2. Switch on the power to the unit.
3. Give the sine wave as input.
4. measure the amplitude and frequency of the input signal.
5. calculate the value of  $R_1 C_1$ ,  $R_2 C_2$ .
6. Connect the components at the points provided.

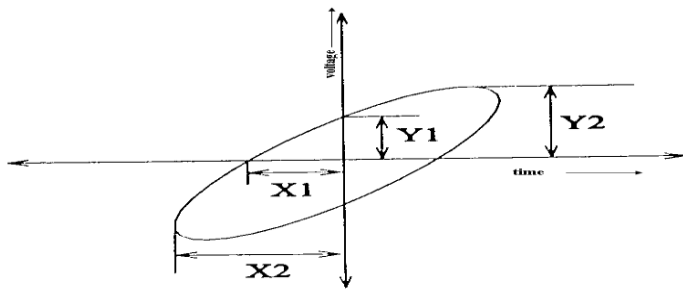


**Lead Lag Compensator**

**Input Voltage  $V_{in}$ =**

S.No	Frequency (HZ)	$Y_1$ (V)	$Y_2$ (V)	Output Voltage(V)	Gain= $20\log(V_o/V_i)$ (db)	Phase Angle $\Phi=\sin^{-1}(Y_1/Y_2)$

**MODEL GRAPH**



**LISSAJOUS PATTERN**

7.Observe the lissajous pattern through CRO by keeping the CRO in XY mode and calculate the phase shift.

8.Tabulate the values for various frequencies

### **PROCEDURE: LAG – LEAD NETWORK**

1.Give the connections as per the circuit diagram

2.Switch on the power to the unit.

3.Connect the individual blocks using patch chords by passing the compensation network & gain

4.Give the sine wave input as the set value to the error detector .

5..measure the amplitude and frequency of the input signal.

6. measure the amplitude and phase shift of the output signal with respect to the sine wave using CRO

7..calculate the value of  $R_1 C_1$  , $R_2 C_2$ .

8.Connect the components at the points provided.

9.Include the compensation block in the forward path before the process using patch chords

10..Observe the lissajous pattern through CRO by keeping the CRO in XY mode and calculate the phase shift of the output signal with the input signal.& verify the compensation .

11.After compensation observe the lissajous pattern on the CRO

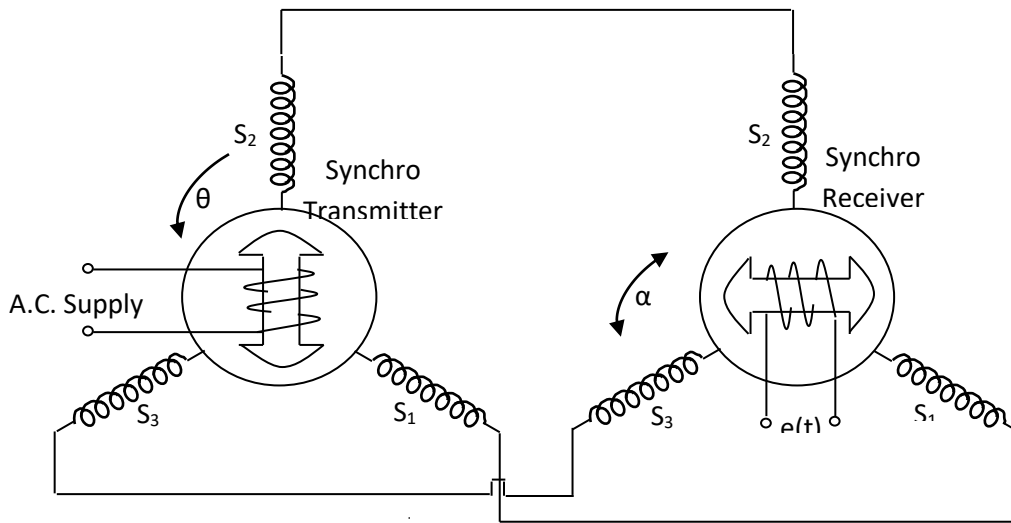
## **RESULT**

Thus the frequency response of the lag,lead,lag -lead network is plotted.

## **VIVA QUESTIONS:**

1. what is Compensation?
2. what is Compensators?
3. Name some types of compensators.
4. What is lead-lag networks?
5. Why Use Lag Compensators?

## SYNCHRO TRANSMITTER AND RECEIVER DIAGRAM:



## **EX: NO 5 STUDY OF SYNCHROS**

### **AIM:**

To determine performance characteristics of synchros

### **APPARATUS REQUIRED:**

Synchro control transformer and synchro differential transmitter kit

patch cords

Multimeter

### **THEORY**

The term synchro is a generic name for a family of inductive devices which works on the principle of a rotating transformer. The trade names for synchros are Selsyn, Autosyn, Telesyn. Basically they are electro-mechanical devices (or) electro magnetic devices or electro magnetic transducers which produces an output voltage depending upon angular position of the rotor.

A synchros system is formed by interconnection of the devices called the synchros transmitter and the synchro control transformer. They are called as synchro pair. The synchro pair measures and compares two angular displacements and its output voltage is approximately linear with angular difference of the axis of both the shafts. They can be used in the following two ways.

- (i) To control the angular position of load from a remote place/long distance.
- (ii) For automatic correction of changes due to disturbance in the angular position of the load.

**TABULATION:**

SI.No	Synchro Transmitter Angular position in degree	Synchro Receiver Angular position in degree

**TABULATION:**

SI.No	Position of Rotor in degree	Stator terminal voltage (V)		
		$V_{S3. S1}$	$V_{S1. S2}$	$V_{S2. S3}$

**PROCEDURE:**

1. Make the connections as per circuit diagram.
2. Give supply to rotor of synchro transmitter.
3. Note the angle  $\theta$  which is an angle between rotor and stator coil axes.
4. The transmitter output connected to control transformer which in turn produces angle of  $\alpha$  in rotor which should be noted.
5. Change the angular position of transmitter and take the corresponding changes in angular position of receiver and stator terminal voltage.

**FORMULA:**

Terminal voltages for stator of Synchro transmitter

$$V_{S1, S2} = V_{S1N} - V_{S2N} = \sqrt{3} K V_r \sin(\theta + 240^\circ) \sin \omega_c t$$

$$V_{S2, S3} = V_{S2N} - V_{S3N} = \sqrt{3} K V_r \sin(\theta + 120^\circ) \sin \omega_c t$$

$$V_{S3, S1} = V_{S3N} - V_{S1N} = \sqrt{3} K V_r \sin(\theta) \sin \omega_c t$$

Where  $V_{S1N}$ ,  $V_{S2N}$ ,  $V_{S3N}$  are voltages induced in stator coils  $S_1$ ,  $S_2$  and  $S_3$  respectively

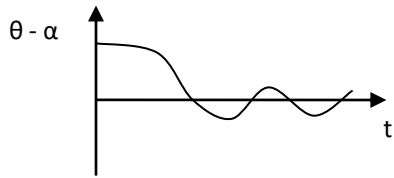
Voltage at rotor terminals of control transformer,

$$E(t) = K' V_r \sin(\theta - \alpha) \sin \omega_c t$$

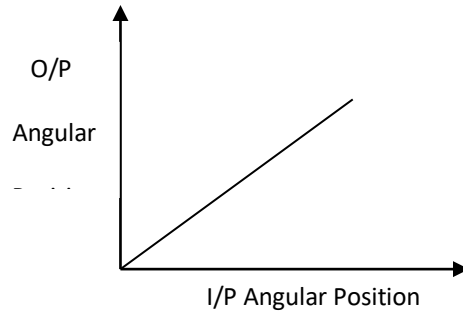
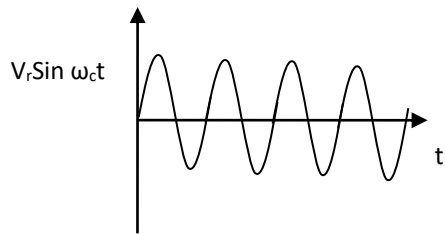
Where  $\theta$  is the angle between rotor coil and stator coils

**MODEL GRAPH:**

SYNCHRO ERROR DETECTOR:



WAVE FORM:





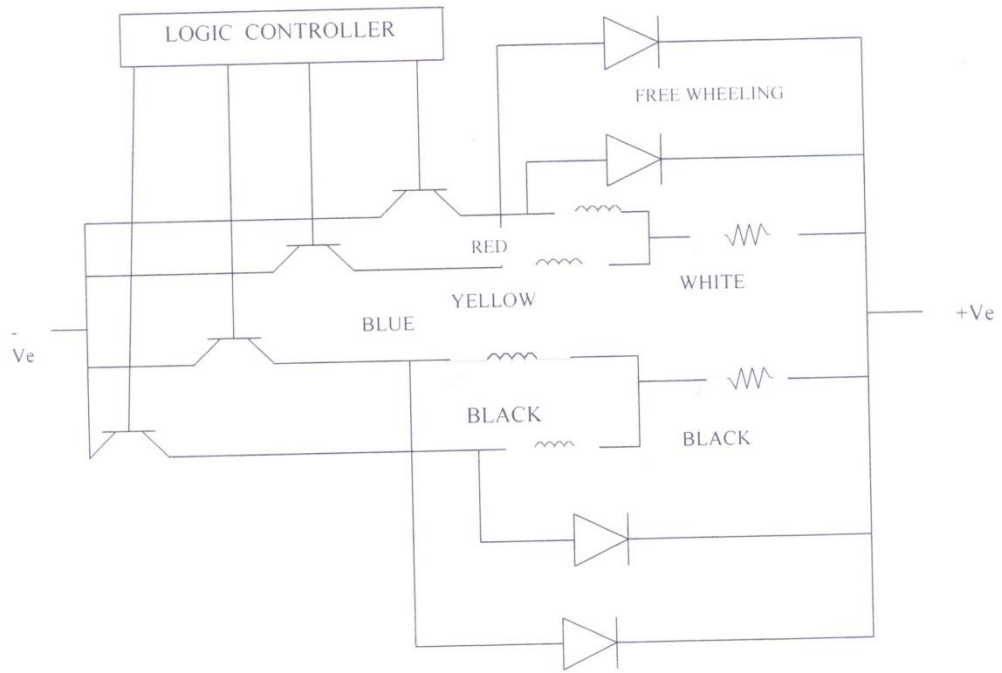
**RESULT:**

Thus the performance characteristic of Synchro was determined and the graph was drawn as follows: i) Transmitter(stator) angular position Vs Receiver (rotor) angular position ii) Rotor angular position Vs Stator terminal voltage.

**VIVA QUESTIONS:**

1. What is a Synchro?
2. What are the commercial names of a Synchro?
3. What is Synchro pair? What for is it used?
4. What are the differences between a Synchro transmitter and a Synchro control transformer?
5. What is electrical zero position of a Synchro transmitter?
6. What is electrical zero position of a Synchro control transformer?
7. What is aligned position of a Synchro pair?
8. What are the applications of Synchro?

**CIRCUIT DIAGRAM :**



# STUDY OF DC MOTOR

## THEORY:

The stepping motor is an electron-magnetic device which connects digital pulses into discrete mechanical rotational movements. In rotary step motor, the output shaft or motor rotates in equal increments in response to a train of input pulses.

## CHARACTERISTICS:

### CONSTRUCTION:

Stepper motor is basically a motor which has two phases, eight salient poles, toothed iron rotor and a permanent magnet. This rotor is known as hybrid rotor. The rotor is suspended in the stator by means of seated ball bearings. All parts of the motor are precision machined for better performance and accuracy of steps.

Step angle:

$1.8^\circ$  +or  $-0.1^\circ$  non-cumulative

Holding Torque:

2.8kg.cm

### DYNAMIC TORQUE:

Dynamic torque is mainly controlled by the electronics. Controlled by the electronics control circuits. Torque will drop down as the speed increases.

### RESIDUAL TORQUE OR DETENT TORQUE:

Because of the presence of permanent magnet in the rotor.

### WORKING TEMPERATURE AND INSULATION CLASS:

Temperature of stepping motors may rise  $50^\circ$  C above ambient. It is observed that body temperature generally stabilizes at about  $85^\circ$  C to  $90^\circ$  C.

The insulation used is of class B type which can withstand hotspot temperature  $130^\circ$  C for better heat motors. Dry titled with heat sinks are recommended. This reduces the temperature by about  $10^\circ$  C to  $15^\circ$  C.

**SWITCHING TRANSISTORS:**

$V = 4X$  Motor voltage

$R_s = 3X R_m$  (motor resistance phase)

Suitable for slow RPM

**SWITCHING LOGIC SEQUENCE:**

**Full step**

A1	A2	B1	B2
Red	Black	Blue	Green
0	1	0	1
0	1	1	0
1	0	1	0
1	0	0	1
Q1	Q2	Q3	Q4

**Half step**

A1	A2	B1	B2
Red	Black	Blue	Green
0	1	0	1
0	0	0	1
1	0	0	1
1	0	0	0
1	0	1	0
0	0	1	0
0	1	1	0
0	1	0	0

### **WORKING OF STEPPING MOTOR:**

The stepping action is caused by sequential switching of supply to the two phase of motor as shown in the switching logic sequence table. The specified torque of any stepping motors is the torque at stands still (holding torque) . This torque is directly proportional to the current to rated level within the time given for one step.

This is mainly due to L/R time constant of winding. The drop in current level causes drop in torque as the speed increases. In order to improve torque as the speed increases . In order to improve torque at high speed it is necessary to maintain current at the rated level.

### **NEVER EXCEED RATED CURRENT:**

Stepper motors differ from conventional DC servo motors in the following respects.

1. There is no central winding in stepping motors both windings are identical.
2. The stepping rate (speed of rotation) is governed by frequency of switching and not by supply voltage
3. A single pulse input will move the shaft of motor by one steps can be precisely controlled by controlling number of pulses.
4. When there is no pulse input, the rotor will remain locked in the position in which the last step was taken since at any time two winding are always energized which lock the rotor electromagnetically.
5. Stepping motors can be programmed in there parameters a) direction, b) speed, c) Number of steps.
6. Stepping motor is brushless so no wear and tear.
7. Load and no load condition makes no difference in running currents of the motor.

### **GENERAL INFORMATION:**

1. Resonance when a stepping motor is operated at its natural frequency an increase in noise and vibration occurs. This phenomenon is called as resonance. The frequencies at which this resonance occurs depends widely on the characteristics of load and it also varies from motor to motor. The change in inertial load will change the resonance may be reduced or avoided.

### SWITCHING TRANSISTORS:

$V = 4X$  Motor voltage

$R_s = 3X R_m$  (motor resistance phase)

Suitable for slow RPM

### SWITCHING LOGIC SEQUENCE:

#### Full step

A1	A2	B1	B2
Red	Black	Blue	Green
0	1	0	1
0	1	1	0
1	0	1	0
1	0	0	1
Q1	Q2	Q3	Q4

#### Half step

A1	A2	B1	B2
Red	Black	Blue	Green
0	1	0	1
0	0	0	1
1	0	0	1
1	0	0	0
1	0	1	0
0	0	1	0
0	1	1	0
0	1	0	0

2. Ramp acceleration (soft start) and deceleration (soft stop) are essential factors of controller. Acceleration is required to run the motor at high step rates and deceleration is to stop motor accurately at specified position.

3. Half step mode advantage smoother motion, resolution factor increase by the factor 2, reduces resonance problems.

Disadvantages: loss of torque (above 40%) In half step mode who not offer guarantee for accuracy but error automatically gets corrected on next half step.

4. Mounting - mounting motor must be mounted with reference to and net with reference to mounting holes.

5. Synchronization - "N" no. of synchronous step motors can be operated simultaneously at time with single controller and "N" no. of drives.

#### **APPLICATION:**

Numerically controlled tools and maintaining profile utilizing grinding, drilling, milling and boring machines, latches spark erosion machines sheets metal process, induction motor etc:

6) PLASTIC & PACKAGING:

Mask registration to length

7) GRAPHICS:

Photo printing and developing, photo type setting, printing presses, film projector and camera etc:

8) PROCESS CONTROL AND INSTRUMENTATION:

Textile web control, valve controls, materials, handling systems, assembly lines carburator adjusting, In process ganging, servo mechanism electronic gear bails etc:

9) MECHANICAL INSTRUMENTS:

Infusion pumps, X-ray and radio active machinery, blood analyses etc:

10) OFFICE AUTOMATION EQUIPMENT:

Printer, plotters, hard and floppy disc, teleprinters and type writer, copying machines and accounting machines.





**SPECIFICATION:**

Permanent Magnet, Bifilar wound. Steps per Revolution: 200

Two phase. No of leads -6

Step Angle:  $1.8^\circ \pm 0.1^\circ$  non cumulative.

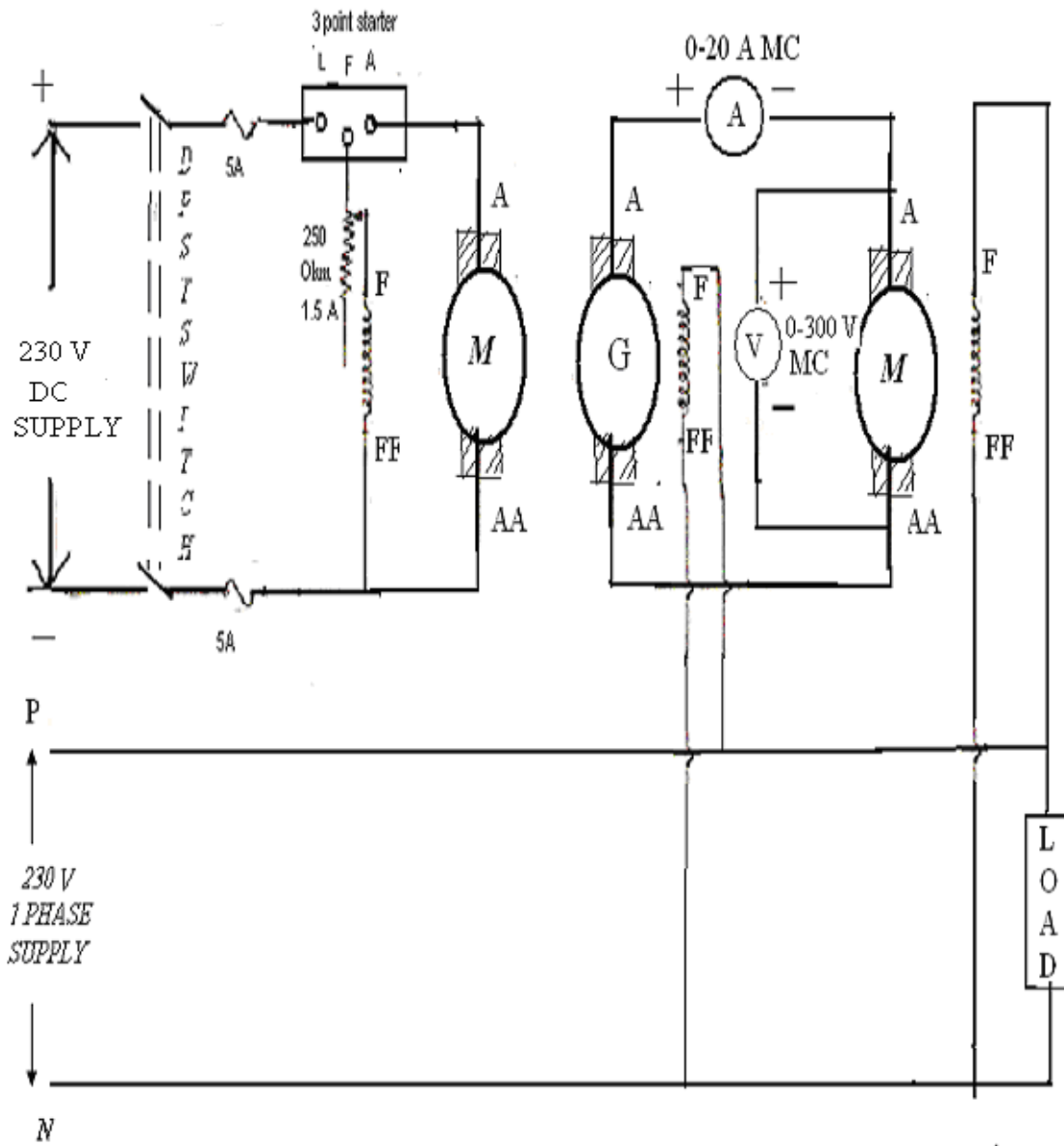
$3\text{Kg.cm.} = 0.1\text{N.m} = 13.9\text{Oz}$

Voltage -5v

**RESULT:**

Thus the characteristics and working principle of the DC brushless stepper motors has been studied.

TO FIND  $K_a$



## EX:NO 6 WARD LEONARD METHOD OF SPEED CONTROL OF D.C MOTOR

### AIM

To find the transfer function of speed control of dc motor by ward leonard system.

### APPARATUS REQUIRED

S.NO	NAME OF APPARATUS	RANGE	TYPE	QUANTITY
1	Voltmeter	(0-10)V,(0-300)V,(0-100)V,(0-100)V,	MC	Each1
2	Ammeter	(0-100)mA, (0-1)A	MI	1
3	Rheostat	250 $\Omega$ ,1.5A;1200 $\Omega$ ,0.8A;50 $\Omega$ 4A	-	Each1
4	1 $\Phi$ variatic	(230/0-270)V	-	1
5	tachometer	-	-	1

### THEORY

In a Ward Leonard system, a prime mover drives a direct current (DC) generator at a constant speed. The armature of the DC generator is connected directly to the armature of a DC motor. The DC motor drives the load equipment at an adjustable speed. The motor speed is adjusted by adjusting the output voltage of the generator using a rheostat to adjust the excitation current in the field winding. The motor field current is usually not adjusted, but the motor field is sometimes reduced to increase the speed above the base speed. The prime mover is usually an alternating current (AC) motor, but a DC motor or an engine might be used instead. To provide the DC field excitation power supply, Ward Leonard systems usually include an exciter generator that is driven by the prime mover.

A Ward Leonard drive is a high-power amplifier in the multi-kilowatt range, built from rotating electrical machinery. A Ward Leonard drive unit consists of a motor and

TO FIND  $K_a$

Sl.No	$V_{am}$	$I_{am}$	N	$W_m = 2IIN/60$	$P_L$	$W = P_L/W_m$

TO FIND  $R_{fg}$

S.No	$V_f (V)$	$I_f (A)$	$R_f (\Omega)$

generator with shafts coupled together. The motor, which turns at a constant speed, may be AC or DC powered. The generator is a DC generator, with field windings and armature windings. The input to the amplifier is applied to the field windings, and the output comes from the armature windings. The amplifier output is usually connected to a second motor, which moves the load, such as an elevator. With this arrangement, small changes in current applied to the input, and thus the generator field, result in large changes in the output, allowing smooth speed control.

The speed of motor is controlled by varying the voltage fed from the generator,  $V_{gf}$ , which varies the output voltage of the generator. The varied output voltage will change the voltage of the motor, since they are connected directly through the armature. Consequently changing the  $V_{gf}$  will control the speed of the motor. The picture of the right shows the Ward Leonard control system, with the  $V_{gf}$  feeding the generator and  $V_{mf}$  feeding the motor.

## **PROCEDURE**

### **MEASUREMENT OF ARMATURE RESISTANCE OF GENERATOR**

**( $R_{ag}$ )**

1. Ensure all switch in off position before that field voltage making correction
2. Ensure that field voltage control plot in minimum position
3. make connections as per circuit diagram
4. Switch on the control power supply to the transient module
5. Switch on the MCB
6. Switch on control supply to transient supply to ac regulation using MCB.
7. Calculate the armature inductance of generator, motor impedance of ammeter= $V/I$

$$Z_{ag} = \sqrt{R_{ag}^2 + X_{ag}^2}$$

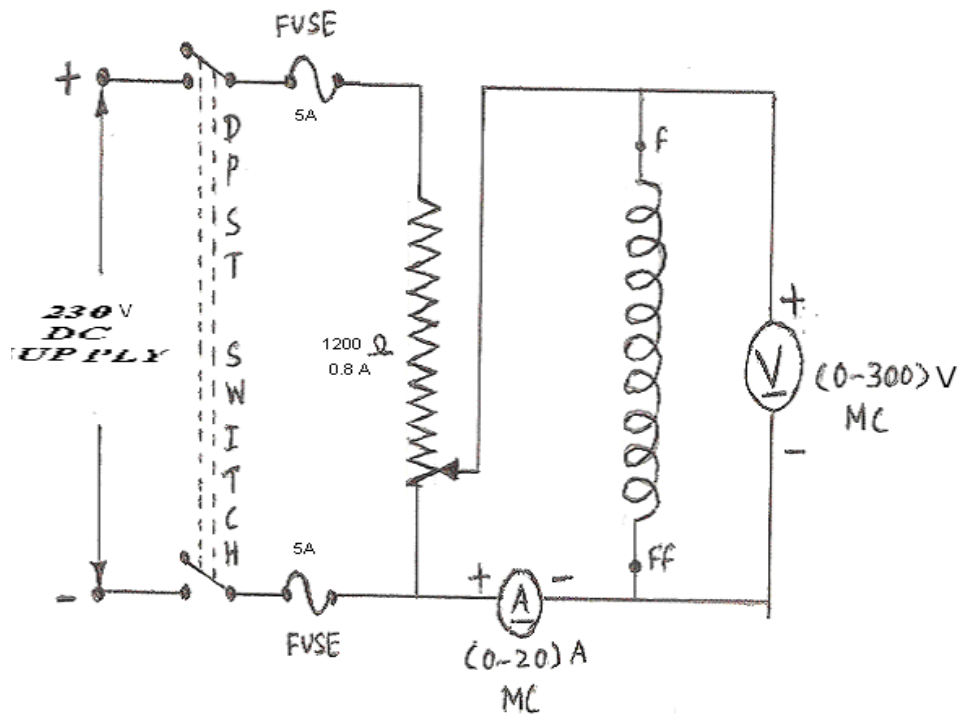
$R_{ag}$  = Armature resistance of generator

$L_{ag}$  = inductance of generator motor

F = supply frequency

$$X_{ag} = \sqrt{Z_{ag}^2 - R_{ag}^2}$$

TO FIND  $R_{fg}$



TO FIND  $R_{fm}$

S.No	$V_f$ (V)	$I_f$ (A)	$R_f$ ( $\Omega$ )

F=Supply frequency

$$L_{ag} = X_{ag} / 2\pi f$$

### **MEASUREMENT OF FIELD RESISTANCE OF GENERATOR( $R_{fg}$ ):**

1. Make the connections as per the circuit diagram.
2. Switch on power supply to trainer and on MCB.
3. Apply different voltage to field winding before varying the field control plot and note down ammeter and voltmeter reading.

### **MEASUREMENT OF FIELD INDUCTANCE OF GENERATOR( $L_{fg}$ ):**

1. Make the connections as per the circuit diagram.
2. Release gating signals to ac voltage control plot before varying a.c control plot and note down the ac ammeter and voltmeter reading.
3. Field inductance of generator  $L_{fg}$

$$Z_{fg} = \sqrt{R_{fg}^2 + X_{fg}^2}$$

$$X_{fg} = \sqrt{Z_{fg}^2 - R_{fg}^2}$$

$$L_{fg} = X_{fg} / 2\pi f$$

Impedance of armature =  $V/I$

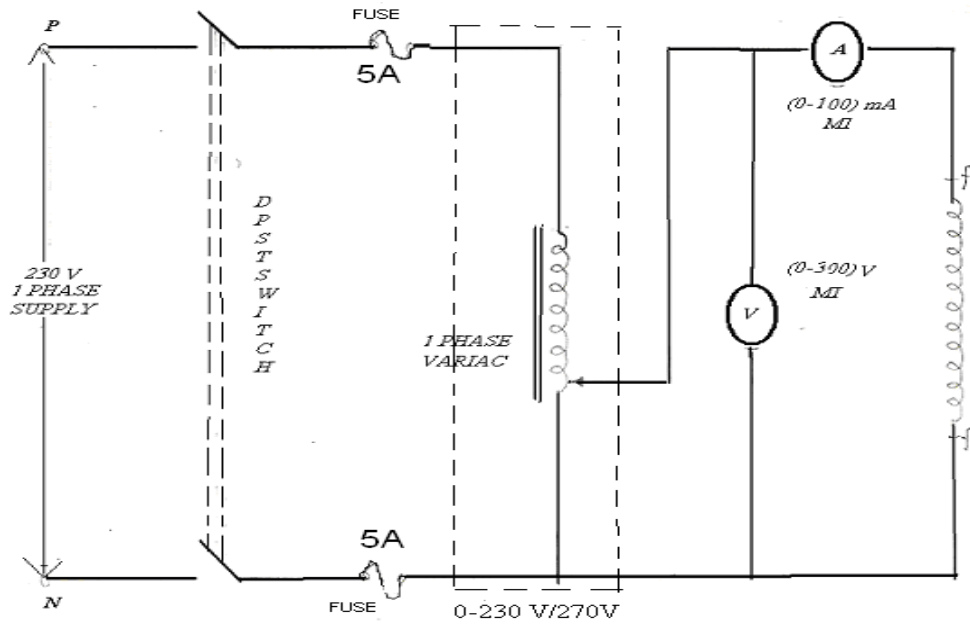
### **MEASUREMENT OF GENERATES EMF CONSTANT $K_g$ :**

1. connections are given as per the circuit diagram.
2. By increasing the generated field current control plot, note down the generated e.m.f. for each field control.
3. calculate  $K_g = \Delta E_f / \Delta I_f$

### **MEASUREMENT OF MOTOR PARAMETER**

1. Make the connections as per the circuit diagram.
2. Switch on then control power supply to the trainer module.

TO FIND  $Z_{fm}$



TO FIND  $Z_{fm}$

SL.No	$V_{fm}$ (V)	$I_{fm}$ (A)	$Z_{fm}(\Omega)$



3. Now apply different voltage to armature varying the control plot and note down the ammeter and voltmeter readings.

4. Calculate the value of armature resistance.

### **MEASUREMENT OF ARMATURE INDUCTANCE $L_{am}$**

1. Make connections as per circuit diagram.

2. Switch on control power supply to trainer and supply to an a.c regulator

3. Release gating signals to ac regulator.

4. Calculate armature inductance generation motor.

Impedance of armature =  $V/I$

$$Z_{am} = \sqrt{R_{am}^2 + X_{am}^2}$$

$L_{am}$  = Armature inductance

$R_{am}$  = Armature resistance

F = supply frequency

$$X_{am} = \sqrt{Z_{am}^2 - R_{am}^2}$$

$$L_{am} = X_{am} / 2\pi f$$

### **PROCEDURE**

1. A dc generator coupled to a 3 $\Phi$  inductor motor is used for speed control of dc motor.

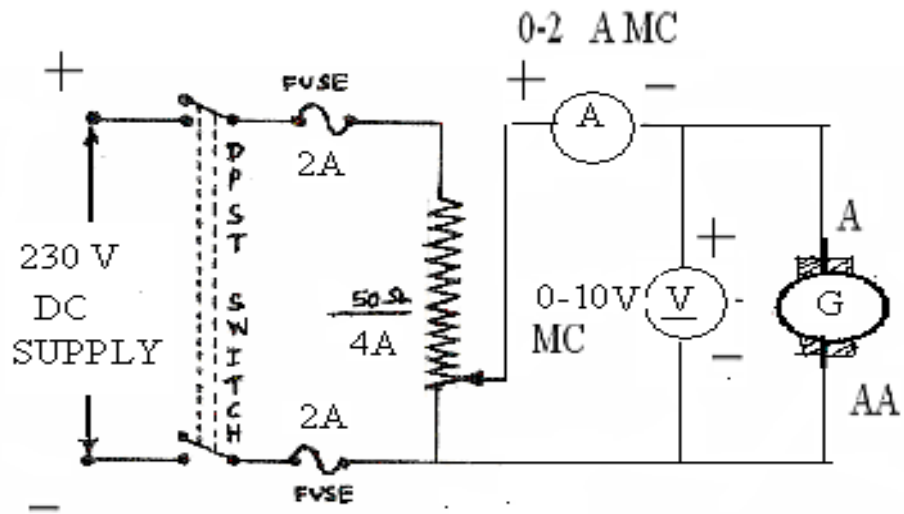
2. The field of generation is connected to variable field voltage

3. Connect the rotor field to fixed dc in front panel.

4. Switch in control power supply.

5. Tabulate voltage and speed values of various values of voltages.

TO FIND  $R_{ag}$

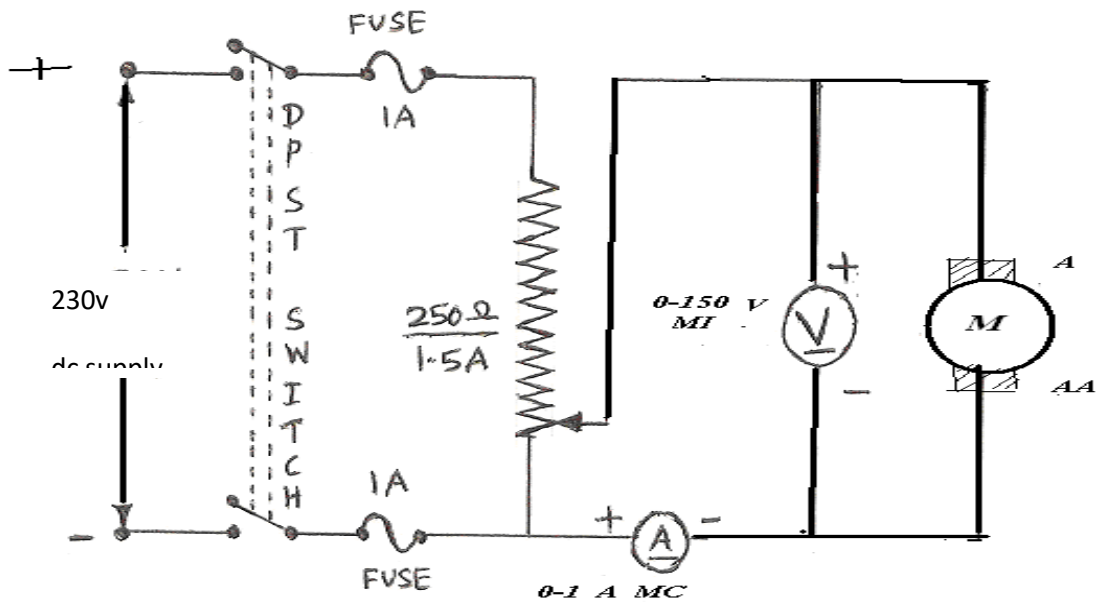


TO FIND  $R_{ag}$

S.No	$V_{ag}$ (V)	$I_{ag}$ (A)	$R_{ag}$ ( $\Omega$ )



TO FIND  $R_{am}$

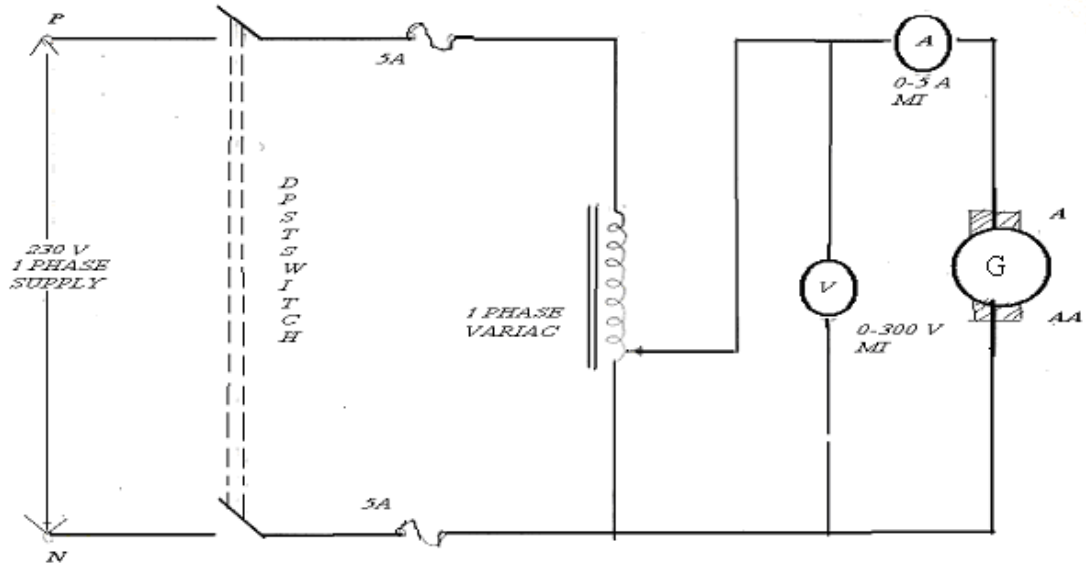


TO FIND  $R_{am}$

S.No	$V_a$ (V)	$I_a$ (A)	$R_{am}$ ( $\Omega$ )



**TO FIND  $Z_{ag}$**

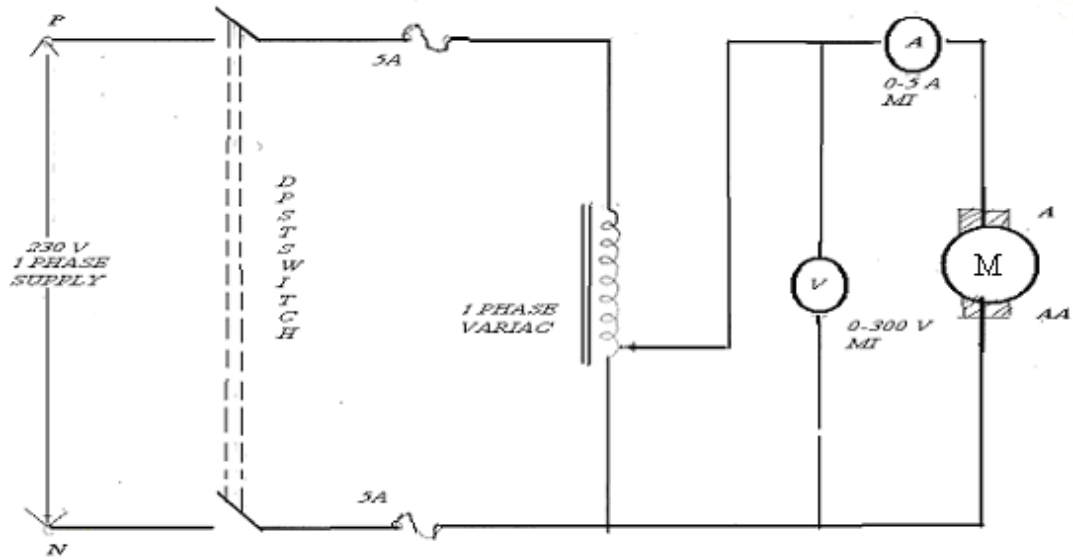


**TO FIND  $L_{ag}$**

	$V_{ag}$ (V)	$I_{ag}$ (A)	$Z_{ag}$ ( $\Omega$ )	$X_{ag}$ ( $\Omega$ )	$L_{ag}$ (henry)



**TO FIND  $Z_{am}$**



**TO FIND  $Z_{am}$**

SL.No	$V_{am}$ (V)	$I_{am}$ (A)	$Z_{am}$ ( $\Omega$ )

**TO FIND  $K_a$**

Sl.No	$I_f$	$E_g$



## WARDLEONARD

Sl.No	$V_{fg}(V)$	N (rpm)	$W=2\pi N/60$ (rad/sec)

## RESULT

Thus the transfer function of speed control dc shunt motor was determined by ward Leonard method.

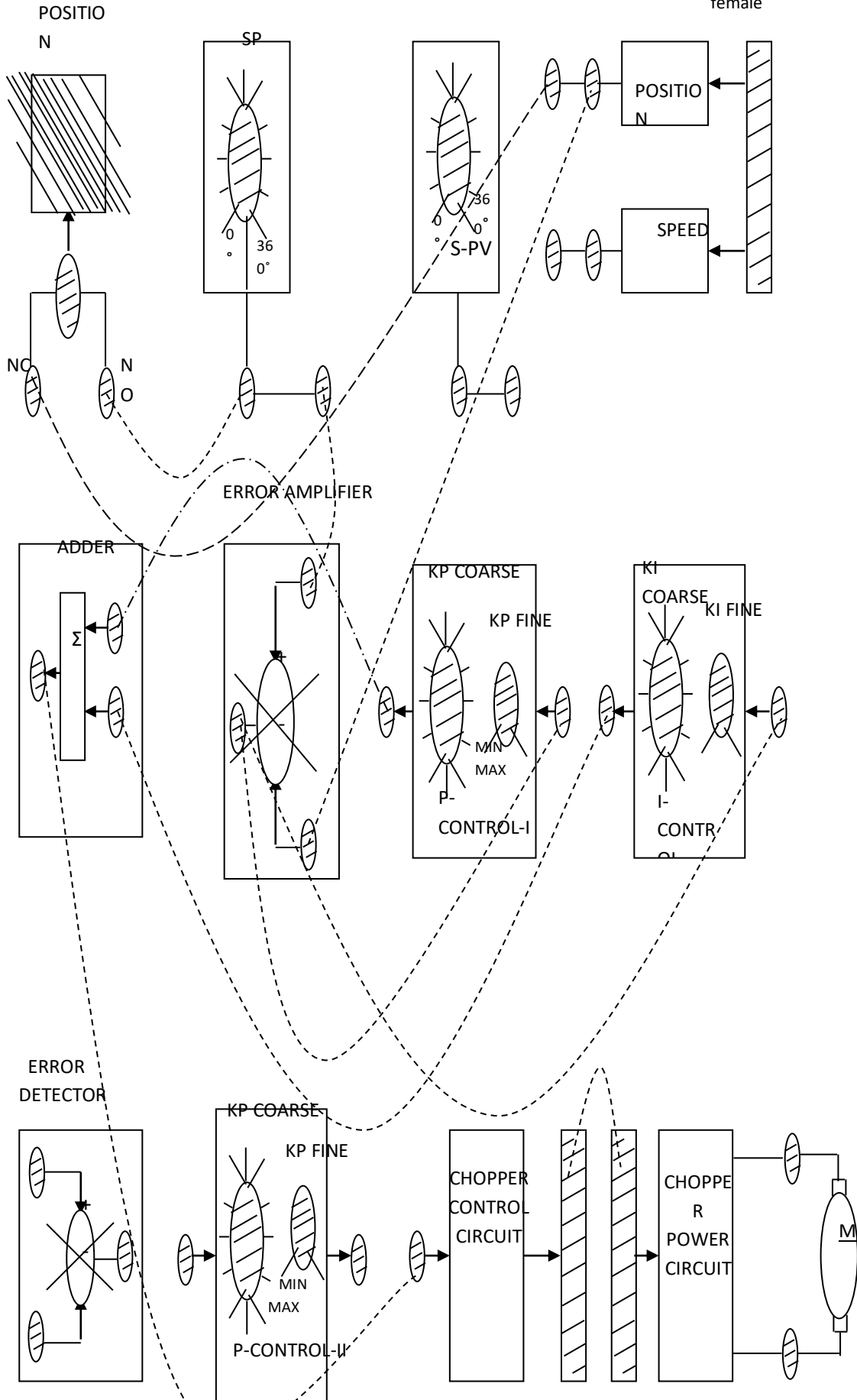
## VIVA QUESTIONS:

1. What are the advantages and disadvantages of ward Leonard method?
2. Explain the various methods of speed control of DC motor?
3. Define drives?
4. State whether transfer function technique is applicable to non linear system?
5. What is a primemover?

# DC SERVO MOTOR POSITION CONTROLLER

PEC 01

9-pin 'D' female



## EX:NO 7 (a) DC SERVO MOTOR POSITION CONTROLLER

### AIM:

To study the servomotor position controller with PI controller.

### APPARATUS REQUIRED:

PEC-01 Kit - 1No

Patch cards - As required

Motor setup - 1No

### THEORY:

Servomechanism or servo is an automatic device which uses error-sensing feedback to correct the performance of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position or other parameters. For example an automotive power window control is not a servomechanism, as there is no automatic feedback which controls position -- the operator does this by observation. By contrast the car's cruise control uses closed loop feedback, which classifies it as a servomechanism.

A common type of servo provides position control. Servos are commonly electrical or partially electronic in nature, using an electric motor as the primary means of creating mechanical force. Other types of servos use hydraulics, pneumatics, or magnetic principles. Usually, servos operate on the principle of negative feedback, where the control input is compared to the actual position of the mechanical system as measured by some sort of transducer at the output. Any difference between the actual and wanted values (an "error signal") is amplified and used to drive the system in the direction necessary to reduce or eliminate the error. An entire science known as control theory has been developed on this type of system.

Servomechanisms were first used in military fire-control and marine navigation equipment. Today servomechanisms are used in automatic machine tools, satellite-tracking antennas, automatic navigation systems on boats and planes, and antiaircraft-gun

**TABULATION:**

SI.NO	Input position <sup>0</sup>	Output position <sup>0</sup>	Maximum overshoot <sup>0</sup>	Error in <sup>0</sup>

control systems. Other examples are fly-by-wire systems in aircraft which use servos to actuate the aircraft's control surfaces, and radio-controlled models which use RC servos for the same purpose. Many auto focus cameras also use a servomechanism to accurately move the lens, and thus adjust the focus.

### **PROCEDURE:**

- 1.Connections are made as per the diagram.
- 2.Check whether the pulse release switch is in OFF position.  
If it is in ON position kept it in OFF position.
- 3.Switch on the unit.
- 4.Set the motor at any position by varying the set position (SP) knob.
- 5.Notice the input position in digital display by toggling the SPDT switch on mode.
- 6.Now release the pulse release switch S2 at the same time, notice the maximum overshoot or maximum position achieved by the motor.
- 7.Notice the output position in the digital display.
- 8.Tabulate the input and output position and maximum overshoot in the tabular column shown below.

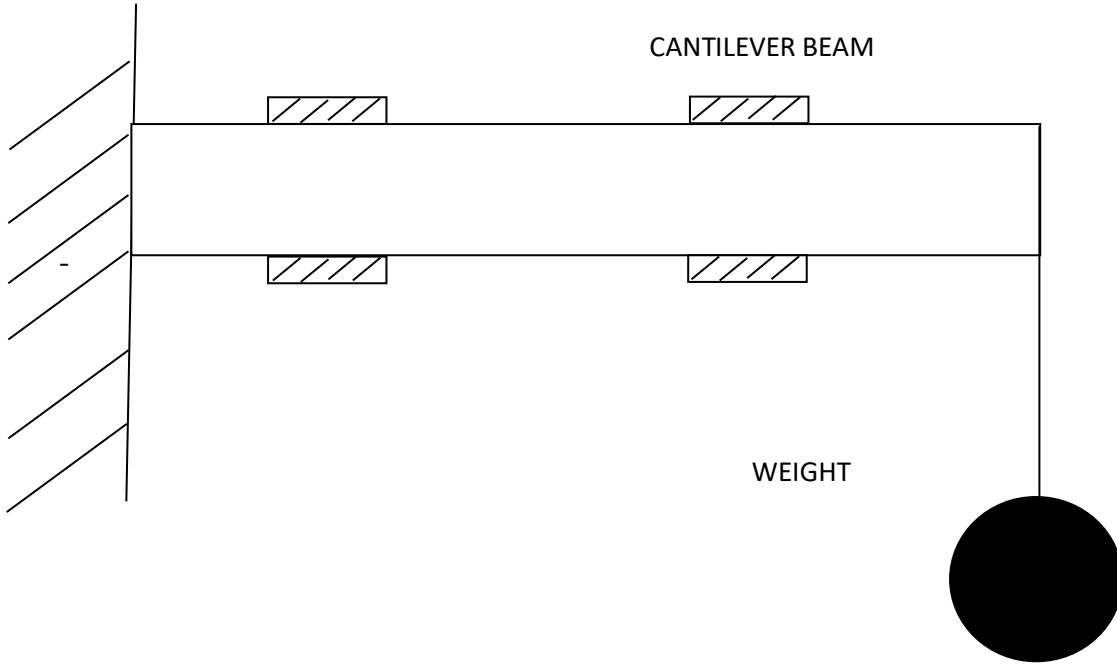
### **RESULT:**

Thus the DC servo motor position controller with PI controller was studied

### **VIVA QUESTIONS:**

- 1.Define servomechanism.
- 2.What is the need for a controller?
- 3.What is difference between ac servo motor & two phase induction motor?
- 4.write the differential equation governing the AC servo motor?
5. what are the advantages of permanent magnet DC servo motors?

STRAIN GAUGE



## **EX NO : 7 (b) STUDY OF TRANSDUCERS**

### **AIM**

To obtain sensitivity of the given strain gauge module.

### **APPARATUS REQUIRED**

1. Strain gauge
2. Weights
3. Multimeter

### **THEORY**

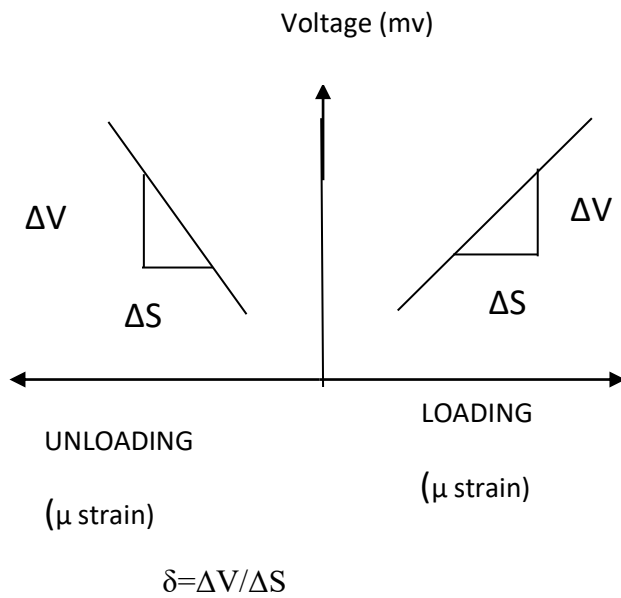
A Strain gage is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can be measured. The strain gage is one of the most important tools of the electrical measurement technique applied to the measurement of mechanical quantities. As their name indicates, they are used for the measurement of strain. As a technical term "strain" consists of tensile and compressive strain, distinguished by a positive or negative sign. Thus, strain gages can be used to pick up expansion as well as contraction.

The strain of a body is always caused by an external influence or an internal effect. Strain might be caused by forces, pressures, moments, heat, structural changes of the material and the like. If certain conditions are fulfilled, the amount or the value of the influencing quantity can be derived from the measured strain value. In experimental stress analysis this feature is widely used. Experimental stress analysis uses the strain values measured on the surface of a specimen or structural part to state the stress in the material and also to predict its safety and endurance. Special transducers can be designed for the measurement of forces or other derived quantities, e.g., moments, pressures, accelerations, and displacements, vibrations and others. The transducer generally contains a pressure sensitive diaphragm with strain gages bonded to it.

## TABULATION

Sl.No	MICRO STRAIN	O/P VOLTAGE LOADING (MV)	O/P VOLTAGE UNLOADING(MV)	LOAD

## MODEL GRAPH





## **MEASURING CIRCUITS**

In order to measure strain with a bonded resistance strain gage, it must be connected to an electric circuit that is capable of measuring the minute changes in resistance corresponding to strain. Strain gage transducers usually employ four strain gage elements electrically connected to form a Wheatstone bridge circuit. A Wheatstone bridge is a divided bridge circuit used for the measurement of static or dynamic electrical resistance. The output voltage of the Wheatstone bridge is expressed in millivolts output per volt input. The Wheatstone circuit is also well suited for temperature compensation. The number of active strain gages that should be connected to the bridge depends on the application. For example, it may be useful to connect gages that are on opposite sides of a beam, one in compression and the other in tension. In this arrangement, one can effectively double the bridge output for the same strain. In installations where all of the arms are connected to strain gages, temperature compensation is automatic, as resistance change due to temperature variations will be the same for all arms of the bridge.

## **PROCEDURE**

1. Fix the weight pan to the beam
2. Adjust the sensitivity control to read some value.
3. Add weights one by one and note down the readings
4. Repeat the same procedure by unloading the weights
5. Plot the graph between voltage and strain

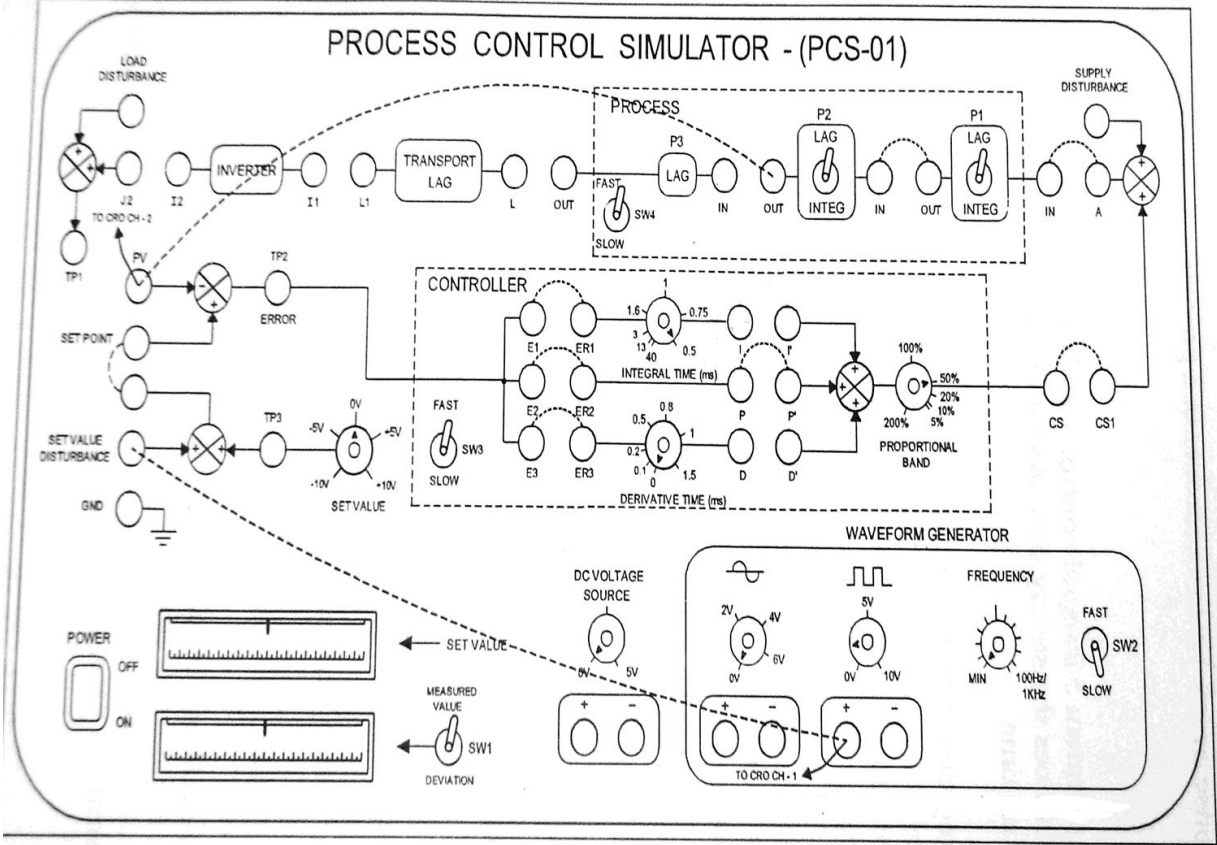
## **RESULT**

Thus the sensitivity of the given strain gauge was found and the graph was drawn.

## **VIVA QUESTIONS**

1. Define sensitivity ?
2. what is LVDT ?
3. what are the types of transducers?
4. where do you use transducers?
5. on which principle piezo- electric transducer works?

# PROCESS CONTROL SIMULATOR - (PCS-01)



## **EX:NO 8 STUDY OF P, PI AND PID CONTROLLER**

### **AIM**

To design P, PI and PID controllers for first order systems and draw its time response characteristic

### **APPARATUS REQUIRED**

Process Control Simulator (PCS-01) KIT – 1No

CRO - 1No

Patch Cords - As Required

### **THEORY**

A controller is used to achieve a better control action in feedback control systems by modifying the error signal. They also change the transient response and steady state error of the system.

#### **P Controller**

The proportional controller produces an actuating output, which is proportional to the error signal. Some advantages in using a proportional controller are (i) relative stability of the system is improved (ii) Noise signal rejection is better (iii) Accuracy of steady state tracking is improved.

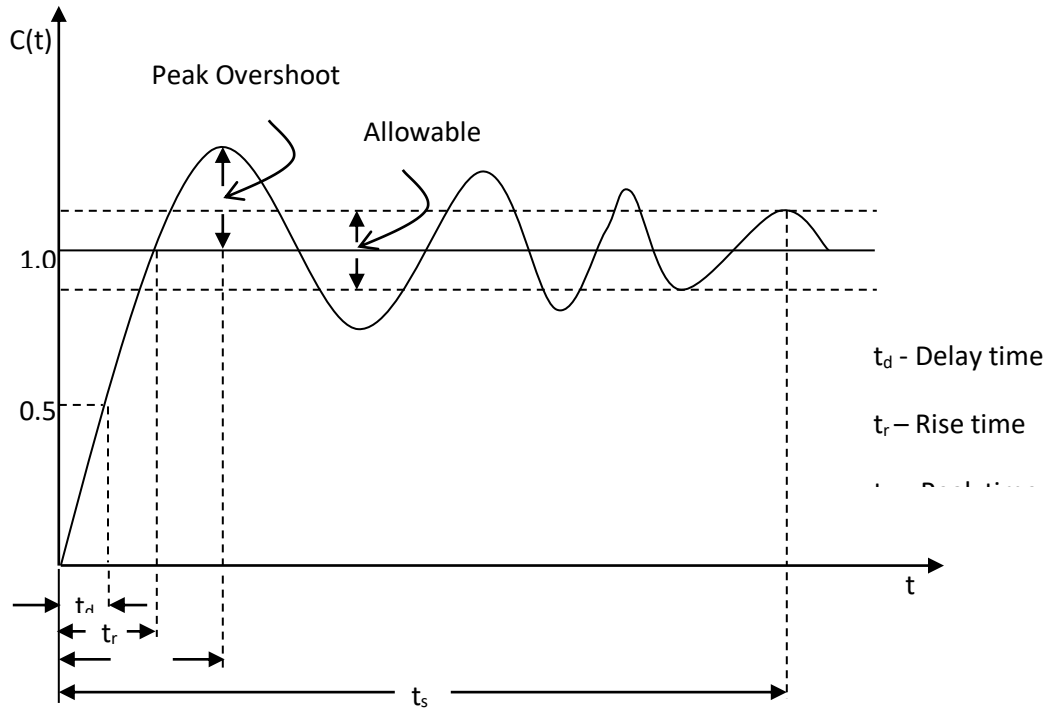
Apart from these, we see that as the loop gain increases, the sensitivity of the system to parameter variation decreases. The drawback of the controller is that, it produces a constant steady state error.

#### **PI Controller**

The proportional plus integral controller produces an actuating output which has two terms, one term proportional to the error signal and the other term proportional to the integral of the error signal.

## MODEL GRAPH:

### Time Response Specification



A PI controller introduces a zero in the system thereby increasing the order and type of the system by one. The increase in the type of the system ensures a decrease in the steady state error of the system.

The drawback of PI controller is that, it needs special provisions to remove integral windup.

### **PID Controller**

The proportional plus integral plus rate controller produces an output which has three terms-one proportional to the error, another one proportional to the integral of error-and the third one proportional to the derivatives of the error.

It is also called as anticipatory controller, as it can anticipate what the error will be in future, with the knowledge of the current error. Some drawbacks with this type of controller are (i) Even for a small amount of error, the derivative term leads to larger derivatives, thus initiating large control actions which are not needed. (ii) It produces no action for any constant error signal, as the derivative of a constant term is zero.

### **PROCEDURE:**

#### **P CONTROLLER**

- 1.Patch the Front Panel of PCS-01 as shown in Figure
  - 2.Set the process Fast/Slow switch (SW4) in fast position and controller fast/Slow switch(SW3) in slow position
  - 3.Keep the set value pot to zero.
  - 4.Apply a square wave signal of  $2V_{p-p}$  at around 50HZ.
  - 5.Alternatively display in the oscilloscope the set value disturbance point and measured value from the point PV.
  - 6.Repeat all the above test with the percentage proportional band 50% and 40%
- As each step is applied system responds.

**TABULATION:**

**P- CONTROLLER**

Sl. No.	Proportional Band (PB) (%)	Peak Overshoot ( $M_p$ ) (V)	Rise Time ( $t_r$ ) (ms)	Peak Time ( $t_p$ ) (ms)	Settling Time ( $t_s$ ) (ms)

**P-I CONTROLLER**

Sl. No	Proportional Band (PB) (%)	Integral Time( $t_i$ ) (ms)	Peak Overshoot ( $M_p$ ) (V)	Rise Time ( $t_r$ ) (ms)	Peak Time ( $t_p$ ) (ms)	Settling Time ( $t_s$ ) (ms)

**PID CONTROLLER**

Sl. No	Proportional Band (PB) (%)	Integral Time( $t_i$ ) (ms)	Peak Overshoot ( $M_p$ ) (V)	Rise Time ( $t_r$ ) (ms)	Peak Time ( $t_p$ ) (ms)	Settling Time ( $t_s$ ) (ms)

## **PI CONTROLLER**

1. Give Connections as shown in figure.
2. Set the process Fast/Slow switch (SW4) in fast position and controller fast/Slow switch(SW3) in slow position
3. Keep the set value pot to zero.
4. Apply a square wave of  $2V_{p-p}$  at around 50HZ.  
Adjust the Proportional band control until the system settles with 2 to 3 overshoots.
5. Now connect the integral section as shown in figure.
6. Slowly reduce the integral action time until deviation falls to zero.
7. Monitor both the set value disturbance socket and PV socket .The typical output waveform is as shown in fig.

## **PID CONTROLLER**

1. Patch the Front Panel as shown in figure.
2. Set the process Fast/Slow switch (SW4) in fast position and controller fast/Slow switch(SW3) in slow position
3. Apply a Square wave of  $2V_{p-p}$  at around 50HZ.
4. Now patch I and I' and adjust the integral time until steady state deviation is Zero.
5. Now note down the number of overshoots before the system settles.
6. Now connect D and D' and slowly increase the derivative time and note down the effect of this, in system response.



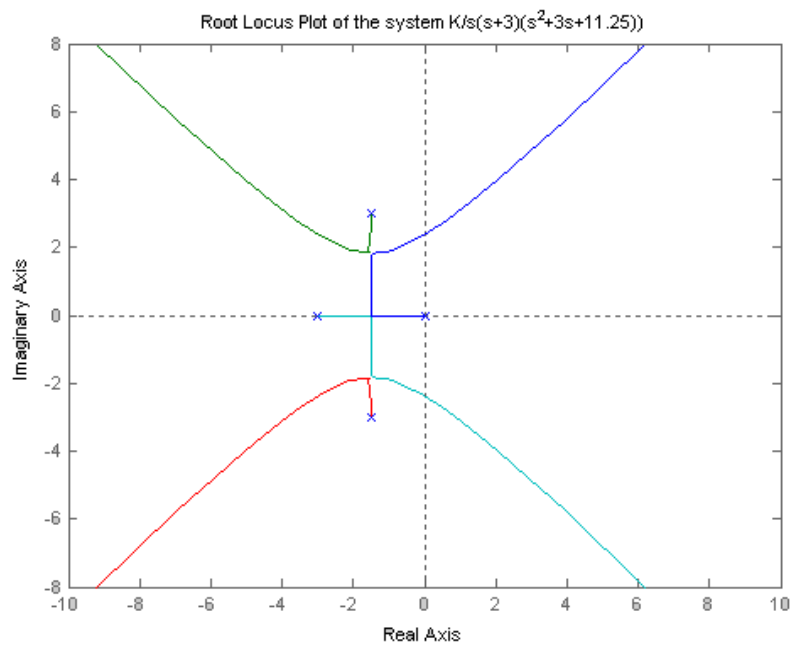
**RESULT:**

Thus the first order P, PI and PID controllers time response characteristics were drawn.

**VIVA QUESTIONS:**

1. What is steady state error?
2. What are static error constants?
3. What is the disadvantage in proportional controller?
4. What is the effect of PD controller on system performance?
5. Why derivative controller is not used in control system?
6. What is the effect of PI controller on the system performance?
7. What are the standard test signals employed for time domain studies?
8. What are the time domain specifications?

## GRAPH



## EX: NO 10 STABILITY ANALYSIS OF LINEAR SYSTEMS (ROOT LOCUS PLOT)

### AIM OF THE EXPERIMENT:

To obtain the Root locus plot for the given system whose transfer function is given as  
 $G(S) = Ks(s+3)(s^2+3s+11.25)$

### APPARATUS REQUIRED

Mat lab Software

### THEORY

#### ROOT LOCUS PLOT :

The characteristic of the transient response of a closed-loop system is related to the location of the closed loop poles. If the system has a variable loop gain, then the location of the closed-loop poles depend on the value of the loop gain chosen. A simple technique known as “Root Locus Technique” used for studying linear control systems in the investigation of the trajectories of the roots of the characteristic equation. This technique provides a graphical method of plotting the locus of the roots in the s-plane as a given system parameter is varied over the complete range of values(may be from zero to infinity). The roots corresponding to a particular value of the system parameter can then be located on the locus or the value of the parameter for a desired root location can be determined from the locus. The root locus is a powerful technique as it brings into focus the complete dynamic response of the system . The root locus also provides a measure of sensitivity of roots to the variation in the parameter being considered. This technique is applicable to both single as well as multiple-loop systems.

### PROCEDURE:

1. Write a Program to (or using SIMULINK) obtain the Root locus plot for the given system.
2. Access the stability of given system using the plots obtained.

### PROGRAM

```
%ROOT LOCUS OF THE SYSTEM%
num=[0 0 0 0 1]
den=[1 6 20.25 33.75 0]
sys=tf(num,den)
rlocus(sys)
v=[-10,10,-8,8];
axis(v)
xlabel('Real Axis')
ylabel('Imaginary Axis')
title('Root Locus of the sytem ')
title('Root Locus Plot of the system K/s(s+3)(s^2+3s+11.25)')
```

### MANUAL CALCULATIONS

1. Number of poles =4, zeros = 0, number of root locus branches =4. Starting points  $s=0, -3$  &  $1.5+j3$ .
2. Pole – zero plot is as follows  
Section between 0 and -3 is part of root locus. One breakway point is between  $s=0$  and  $s=-3$ .
3. Angle of asymptotes are 45,135,225 and 315 degrees
4. Centroid = -1.5
5. Three Breakway points are -1.5,-1.5 + j 1.8371
6. Intersection with imaginary axis  $s= + j2.37$ .
7. Angle of departure -90, +90.
8. Root locus is plotted.
9. Stability for  $0 < K < 82.26$  system is stable.  
 $K=82.26$  system is marginally stable.  
 $K > 82.26$  system is unstable

### OUTPUT

num = 0 0 0 0 1

den = 1.0000 6.0000 20.2500 33.7500 0

Transfer function:

1

-----

$s^4 + 6 s^3 + 20.25 s^2 + 33.75 s$

### RESULT:

Thus the stability analysis of linear system using locus plot are determined.

## **EX.NO :11 DIGITAL SIMULATION OF FIRST ORDER SYSTEMS**

### **AIM:**

To digitally simulate the time response characteristics of a linear system without non-linearities and to verify it manually.

### **APPARATUS REQUIRED:**

A PC with MATLAB package

### **THEORY:**

The time response characteristics of control systems are specified in terms of time domain specifications. Systems with energy storage elements cannot respond instantaneously and will exhibit transient responses, whenever they are subjected to inputs or disturbances.

The desired performance characteristics of a system of any order may be specified in terms of transient response to a unit step input signal. The transient response characteristics of a control system to a unit step input is specified in terms of the following time domain specifications

- Delay time  $t_d$
- Rise time  $t_r$
- Peak time  $t_p$
- Maximum peak overshoot  $M_p$
- Settling time  $t_s$

### **STUDY OF BASIC MATLAB COMMANDS:**

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. It 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 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

It 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 non-interactive language such as C or Fortran. It also 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**.

Some practical examples of first order systems are RL and RC circuits.

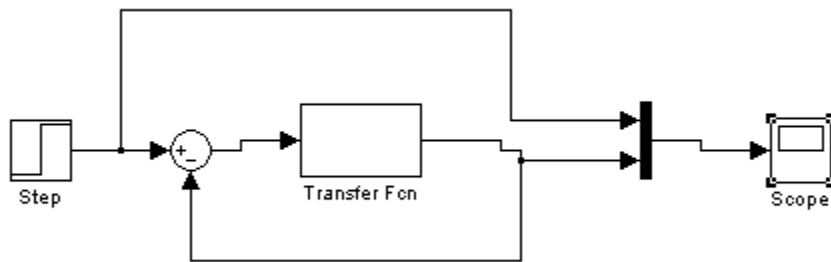
#### **PROCEDURE:**

1. Derive the transfer function of a RL series circuit.
2. Assume  $R = 1 \text{ Ohms}$   $L = 0.1 \text{ H}$ . Find the step response theoretically and plot it on a graph sheet.
3. To build a SIMULINK model to obtain step response / sine response of a first order system, the following procedure is followed:
  1. In MATLAB software open a new model in SIMULINK library browser.
  2. From the continuous block in the library drag the transfer function block.

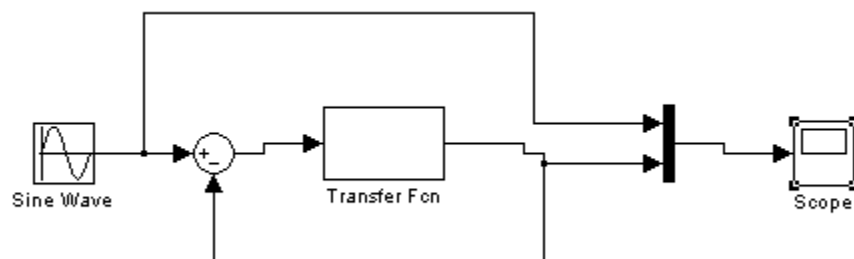
3. From the source block in the library drag the step input/ sine input.
4. From the sink block in the library drag the scope.
5. From the math operations block in the library drag the summing point.
6. Connect all to form a system and give unity feedback to the system.
7. For changing the parameters of the blocks connected double click the respective block.
8. Start simulation and observe the results in scope. (Use a mux from the signal routing block to view more than one graph in the scope)
9. Compare the simulated and theoretical results.

### **BLOCK DIAGRAM:**

*Step response of a first order system:*



*Sine response of a first order system:*



## 2. MATLAB (m-file) program to obtain the step response and impulse response

% MATLAB program to find the step response

```
num=[      ];
```

```
den=[      ];
```

```
sys = tf (num,den);
```

```
step (sys);
```

```
grid
```

OUTPUT: (Paste the graph obtained from PC)

% MATLAB program to find the impulse response

```
num=[      ];
```

```
den=[      ];
```

```
sys = tf (num,den);
```

```
impulse (sys);
```

```
grid
```

OUTPUT: (Paste the graph obtained from PC)

CALCULATIONS:

Unit step response of the given RL series circuit:

Unit Impulse response of the given RLC series circuit:

**RESULT:**

The time response characteristics of a first order system is simulated digitally and verified manually



## EX.NO:12 DIGITAL SIMULATION OF SECOND ORDER SYSTEMS

*AIM:*

To digitally simulate the time response characteristics of a second order system and verify manually.

### APPARATUS REQUIRED

A PC with **MATLAB** Software

### THEORY

The time characteristics of control systems are specified in terms of time domain specifications. Systems with energy storage elements cannot respond instantaneously and will exhibit transient responses, whenever they are subjected to inputs or disturbances. The desired performance characteristics of a system of any order may be specified in terms of transient response to a unit step input signal. The transient response characteristics of a control system to a unit step input is specified in terms of the following time domain specifications:

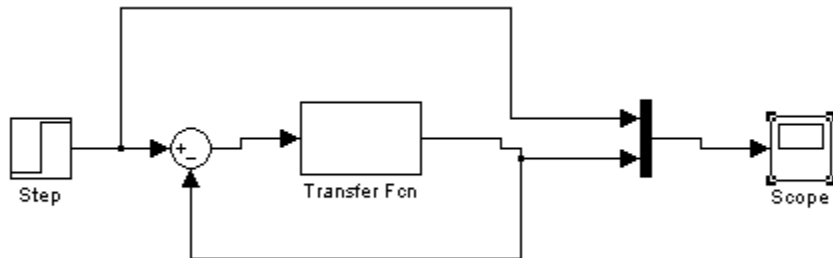
- Delay time  $t_d$
- Rise time  $t_r$
- Peak time  $t_p$
- Maximum overshoot  $M_p$
- Settling time  $t_s$

### PROCEDURE:

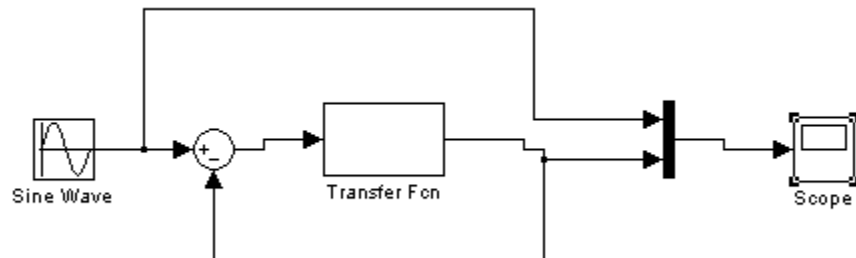
1. Derive the transfer function of a RLC series circuit.
2. Assume  $R = 1$  Ohms,  $L = 0.1$  H and  $C = 1$  micro Farad. Find the step response theoretically and plot it on a graph sheet.
3. To build a SIMULINK model to obtain step response / sine response of a second order system, the following procedure is followed:
  1. In MATLAB software open a new model in SIMULINK library browser.
  2. From the continuous block in the library drag the transfer function block.
  3. From the source block in the library drag the step input/ sine input.
  4. From the sink block in the library drag the scope.
  5. From the math operations block in the library drag the summing point.
  6. Connect all to form a system and give unity feedback to the system.
  7. For changing the parameters of the blocks connected double click the respective block.
  8. Start simulation and observe the results in scope. (Use a mux from the signal routing block to view more than one graph in the scope)
  9. From the step response obtained note down the rise time, peak time, peak overshoot and settling time.
  10. Compare the simulated and theoretical results.

**BLOCK DIAGRAM:**

*Step response of a second order system:*



*Sine response of a second order system:*



## **2. MATLAB program to obtain the step response and impulse response of second order system.**

```
% MATLAB program to find the step response
num=[      ];
den=[      ];
sys = tf (num,den);
step (sys);
```

**OUTPUT: (Paste the graph obtained from PC)**

```
% MATLAB program to find the impulse response
num=[      ];
den=[      ];
sys = tf (num,den);
impulse (sys);
```

**OUTPUT: (Paste the graph obtained from PC)**

**CALCULATIONS:**

**Unit step response of the given RLC series circuit:**

**Unit impulse response of the given RLC series circuit:**

**RESULT:**

The time response characteristics of the given second order system is simulated digitally and verified manually.