



CONTROL SYSTEM LAB

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Syllabus

LIST OF EXPERIMENTS AND RECORD FOR PROGRESSIVE ASSESSMENT

Serial no.	Name of the Experiments	Page no.	Date of Performance	Date of Submission	Assessment Marks	Sign. Of Teacher & Remarks
1	Study of a dc motor driven position control system					
2	Study of speed torque characteristics of two phase ac servomotor and determination of its transfer function.					
3	Obtain the frequency response of a lag and lead compensator.					
4	To observe the time response of a second order process with P, PI and PID control and apply PID control to servomotor.					
5	To determine the transfer function of a system (network) using transfer function analyser.					
6	To study and validate the controllers for a temperature control system.					
7	To study the position control system using Synchroscope.					
8	Determine the transfer function of DC servomotor.					

Course Objectives:

- To determine the transfer function of DC servo motor
- To determine the characteristics of AC servomotor and find the incremental Transfer function.
- To study the different traditional control method for temperature control system.
- To find the frequency response of different compensator.
- To determine the synchronous act as an error detector.

Course Outcomes:

After completion of this lab, the student will be able to:

- The transfers function of the system and also know the closed loop and open loop system.
- To understand the different control techniques and its drawback.
- To understand how the compensator is designed for any system and its advantages.
- In temperature control system, the outcome shows the application of Zeigler-Nichols method for turning of PID controller and also knows the characteristics of first order system with delay.
- To know the characteristics of synchro transmitter and receiver pair, and also error characteristics.

EXPERIMENT-1

AIM OF THE EXPERIMENT:

To observe the time response of a second order process with P, PID and PI control and apply PID control to servomotor.

APPARATUS REQUIRED:

Serial No.	Name of the Equipment	Ratings and Range	Quantity
1	Linear System Simulator	LSS-01	1
2	DSO	0-25MHz	1
3	Patch Cords	-	As per required
4	DSO Probes	-	As per required

THEORY:

A second order control system is one where in the highest power of 's' in the denominator of its transfer function is equal to 2.

Transfer function of second order closed loop system is given by

$$C(s) / R(s) = \frac{\omega_n^2}{s^2 + 2\omega_n s + \omega_n^2}$$

Rise time (t_r): Time required for response to rise from (10 – 90) % or (0-100)% of final value.

Delay time (t_d): Time required to reach 50% of final value

Peak time (t_p): Time required to reach its first peak

Peak overshoot (M_p): Maximum (+ve) deviation of output, with respect to its desired steady state value

- **CONTROLLER :**

- 1) Proportional (P) controller:

Actuating signal for the control action in a control system is proportional to the error signal.

- 2) Integral (I) controller:

Also called as reset controller T_i & K_i are called as reset time and integral gain constant respectively.

It has high settling time but required to reduce the steady state to zero.

- 3) Derivative (D) controller :

It does not eliminate the steady state error properly but it improves the transient state characteristics of the system .

PROCEDURE:

- Patch cords are connected as per the diagram
- Switch (sw_4) was kept at first position and (sw_2) was kept in slow position.
- Proportional band settling was kept at 5% T_i at 1.5ms . T_d at 0.5 ms and the supply was given to trainer kit.
- Tracing for CRO for P,PI,PD,PID controller was taken by changing patch cords .
- Reading from CRO waveform was taken.

OBSERVATION:

For P controller				
Sl no.	Rise time	Peak time	Settling time	Peak overshoot

For PI controller				
Sln.	Rise time	Peak time	Settling time	Peak overshoot

For PD controller				
Sl no.	Rise time	Peak time	Settling time	Peak overshoot

For PID Controller				
Sl no.	Rise time	Peak time	Settling time	Peak overshoot

CONCLUSION:

Hence, the experiment was completed and waveforms from CRO were traced in a tracing paper.

EXPERIMENT -2

Aim of the Experiment:

Study of DC motor driven position control system

OBJECTIVE:

To observe

- DC SERVOMOTOR POSITION SENSOR
- DC SERVOMOTOR POSITION CONTROLLER WITH P CONTROLLER
- DC SERVOMOTOR POSITION CONTROLLER WITH PI CONTROLLER
- DC SERVOMOTOR POSITION CONTROLLER WITH SPEED FEEDBACK LOOP

Apparatus Required:

Serial No.	Name of the Apparatus	Specifications	Quantity
1	DC Position Control System	PEC-01	1
1	MOSFET	IRF540	1
2	Snubber ckt	$R=500\Omega$, $5W$, $C=0.1\mu F$	1 each
3	Op-Amp	IC TL084, TL082	1
4	Logic Gate	CD4011, 4081, 4082	1 each
5	Monoshot	4098	1
6	Transformer rating	230V \18-0-18V, 0-9V, 3A	1
7	Patch Chords	-----	As per required
8	Motor Setup	-----	As per required

THEORY:

In a system when the output quantity is controlled by varying the input quantity, the system is called control system. The output quantity is called controlled variable or response. The input quantity is called command signal or excitation.

The basic components of an automatic control system are error detector, amplifier and controller, power actuator, system and sensor (or) feedback system. The block diagram of an automatic control system is shown below.

Error Amplifier:

That compares the reference signal V_r with feedback signal. The output is a voltage proportional to the difference between the two signals.

Feed Back:

This constitutes the output sensor and associated amplifier. The feedback signal V_f is the voltage proportional to the output variable of the system.

Error Detectors :

In Position Control Systems the reference input will be an input signal proportional to desired output. The feedback signal is a signal proportional to current output of the system. The error detector compares the reference input and feedback signal and if there is a difference it produces an error signal. The error signal is used to correct the output if there is a deviation from the desired value.

CONTROLLER:

The controller process the error signal and gives an output voltage signal V_c known as the control voltage. This suggests the necessary corrective measures required in the actuating signal V_a to be applied to the system.

i. Proportional Control

For a controller with proportional control action, the relationship between the output of the controller $w(t)$ and the actual error signal $e(s)$ is

In the proportional controller action the process will be almost setting but the steady state error will be there. Whenever the actual mechanism may be and whatever the form of the operating power, the proportional controller is essentially an amplifier with an adjustable gain.

With the proportional band, the controller output is proportional to the error or a change in measurement.

$$\text{Controller output} = \frac{\text{Error} \times 100}{\text{Proportional Band}}$$

With a proportional controller offset (deviation from set point (or) steady state error) is present . Increasing the controller gain will make the loop go unstable. Integral action was included in controller to eliminate this offset.

ii. Integral Control :

With Integral action, the controller output is proportional to the amount of time the error is present. Integral action eliminates offsets. The controller with integral action the value of the controller output is changed at a rate proportional to the actuating error signal $e(s)$.

$$\frac{du(t)}{dt} = K_i e(t)$$

$$u(t) = K_i \int_0^t e(t) dt$$

The transfer function of the integral controller is

$$\frac{U(s)}{E(s)} = \frac{K_i}{s}$$

If the value of $e(t)$ is doubled ,then the value of (t) varies twice as fast for zero actuating error, the value of $u(t)$ remains stationary. The integral control action sometimes called as reset control.

iii. Proportional-plus-Integral Control action:

The control action of proportional plus integral controller is defined by

$$u(t) = k_p e(t) + \frac{k_p}{T_i} \int_0^t e(t) dt$$

The transfer function of the controller is

$$\frac{u(s)}{E(s)} = k_p \left(\frac{1}{1} + \frac{1}{T_i s} \right)$$

Where K_p is the proportional gain, T_i is called integral time. Both K_p and T_i are adjustable. The integral time adjusts the integral control action, while a change in the value of K_p affects both the proportional and integral parts of control action. This inverse of the integral time is called the reset rate.

PROCEDURE:

For position sensor

- Connect one volt meter across position and ground point.
- Put the SPDT switch in NC mode in order to view the PV position of motor.
- Now manually vary the motor position step by step.
- For each step note down the voltmeter and position readings.
- Tabulate the readings and observe it.

For P controller

Connection procedure

- Connect the terminal P1 to P6 using patch cords.
- Connect the motor actual position terminal P2 to P7 using patch cords.
- Connect the terminal P8 to P10 and P12 to P17 using patch cords.
- DC output of P24 & P25 is connected to the input of permanent magnet dc motor.

Experiment procedure

- Verify the connection as per the connection diagram and connection procedure.
- Set the pulse release switch is in OFF position.
- Switch ON the power supply and switch ON the power ON/OFF switch.
- Vary the set position knob and set the motor at any position.
- Select the SPDT switch in upward direction and note the input position in digital display.
- Slightly vary the P control knob.
- Switch ON the pulse release switch S_2 . Note the maximum overshoot or maximum position achieved by the motor.
- Select the SPDT switch in downward direction and note the output position in digital display.
- Tabulate the input and output position and maximum overshoot in tabular column.

For PI Controller

Connection Procedure

- Connect the terminal P1 to P6 using patch cords.
- Connect the motor actual position P2 to p7 using patch cords.
- Connect the terminal P8 to P10 and P9 to P11 using patch cords.
- Connect the terminal P12 to P14 and P13 to P15 using patch cords.
- DC output of P24& P25 is connected to the input of permanent magnet DC motor.

Experiment procedure

- Verify the connection as per the connection diagram and connection procedure.
- Set the pulse release switch is in OFF position.
- Switch ON the power supply and switch ON the power ON/OFF position.
- Vary the set position knob and set the motor at any position.
- Select the SPDT switch in upward direction and note the input position in display.
- Slightly vary the P control knob.
- Switch ON the pulse release switch S_2 . Note the maximum overshoot or maximum position achieved by the motor.
- Select the SPDT switch in downward direction and note the output position in digital display.
- Tabulate the input and output position and maximum overshoot in tabular form.

For Speed feedback loop

Connection procedure

- Connect the P1 to P6 using patch cords.
- Connect the motor actual position terminal P2 to P7 using patch cords.
- Connect the terminal P8 to P10 and P9 to P11 using patch cords.
- Connect the terminal P12 to P14 and P13 to P15 using patch cords.
- Connect the terminal P3 to P19 and P20 to P21 using patch cords.
- DC output of P24 and P25 is connected to the input of the permanent magnet of DC motor.

Experiment procedure

- Verify the connection diagram and connection procedure .
- Set the pulse release switch is in OFF position.
- Switch ON the power supply and switch ON the power ON/OFF switch.
- Vary the set position knob and set motor at any position.
- Select the SPDT switch in upward direction and note the input position in digital display.
- Slightly vary the P control knob.
- Switch ON the pulse release switch S_2 . Note the maximum overshoot or maximum position achieved by the motor.
- Select the SPDT switch in downward direction and note the output position in digital display.
- Tabulate the input and output position and maximum overshoot in tabular form.

OBSERVATION:

For position sensor (servo pot)		
Sl No.	Motor Position	Position feedback voltage

For DC servomotor position controller with P controller				
Sl No.	Input Position degree	Output Position degree	Maximum Overshoot degree	Error in degree

For DC servomotor position controller with PI controller				
Sl No.	Input Position degree	Output Position degree	Maximum Overshoot degree	Error in degree

For DC servomotor position controller with Speed feedback loop				
Sl No.	Input Position degree	Output Position degree	Maximum Overshoot degree	Error in degree

CONCLUSION:

Thus the characteristics of DC servomotor Position Controller with position sensor, P Controller , PI Controller , Speed feedback loop were studied and verified .

EXPERIMENT- 3

Aim of the experiment:

Study of speed torque characteristics of two phase ac servomotor and determination of its transfer function.

Objective:

To observe

- To find the value of motor constant K_1
- To find the value of motor constant K_2 .

Apparatus Required:

Sl.No	Name of the Apparatus	Quantity
1	Transfer function of AC servo motor(VPET-302) Trainer kit	1
2	Two phase AC servo motor with load setup and loads	1
3	PC power cord	2
4	SP6 Patch cords	4
5	9 Pin cable	1

Theory:

AC Servomotor is basically a two phase induction motor except certain special design function. A two phase AC servomotor differs in two ways from a normal induction motor.

The servomotor rotor side is built in high resistance so the X/R ratio is small which results in linear mechanical characteristics even if getting higher efficiency. Another difference AC servomotor is that the excitation voltage applied to two stator winding should have a phase difference of 90 degrees.

AC Servomotor specification:

- Reference voltage (V_r)=230V AC
- Control winding voltage (V_i)=230V AC
- Rated power= 50 watts
- Speed=2000rps

Procedure:

TO FIND THE VALUE OF K_1 :

CONNECTION PROCEDURE:

- Initially keep all the switches in OFF position.
- Connect the banana connector P_{out} to P_{in} and N_{out} to N_{in} .
- The banana connector P_{in} terminal is also connected with motor control winding P terminal and the banana connector N_{in} terminal is also connected with motor control winding N terminal.

- Keep the variable AC source in minimum position.

EXPERIMENTAL PROCEDURE

- Apply 3 ϕ AC supply to the 3 ϕ input banana connector S at the back side of the module.
- Switch ON the power switch.
- Switch ON the control winding and main switches S_1 and S_2 respectively.
- Now slowly vary the variable AC source to the control winding till motor reaches 300rpm.
- Apply load one by one till motor stops.
- Note down the load values and control voltage.
- Now again vary the AC source and apply voltage to control winding till the motor reaches 300rpm.
- Again apply loads till the motor stops.
- Repeat the above steps and note down the values and tabulate it.
- Calculate the torque of the motor.
- Draw a graph between control voltage Vs torque.
- From the graph find out the motor constant K_1 .

To find the value of K2:**CONNECTION PROCEDURE:**

- Initially keep all the switches in OFF position.
- Connect the banana connector P_{out} to P_{in} and N_{out} to N_{in} .
- Connect the 9 Pin D connector from AC servomotor to VPET 302 trainer kit for measuring the speed.
- Keep the variable AC source in minimum position.

EXPERIMENTAL PROCEDURE:

- Switch ON the power supply
- Switch ON the main winding power supply S_2 .
- After giving the power supply to the main winding, switch ON the control winding power supply switch S_1 .
- Vary the control voltage to set a rated voltage of the control winding (180V)
- Apply the load in step by step upto the motor run at a zero rpm and note down the speed of the motor and applied load.
- After taking the readings, fully remove the load from the motor and bring the variable AC source in minimum position.
- Switch OFF the control winding switch S_1 .
- Finally Switch OFF the main winding switch S_2 and power supply switch.
- Tabulate the speed and load values and calculate torque.
- Draw a graph of Torque Vs Speed and find the motor constant K_2 .

Tabulation:

To find K_1

Control Voltage(volts)	Load (grams)	Torque(N.m.)

Torque= $9.81 \cdot r \cdot s$

To find K_2

Load (Grams)	Speed in R.P.M	Torque

Torque = $9.81 \cdot r \cdot s$

Conclusion:

Hence the above experiment is performed and all the values are noted down.

EXPERIMENT- 4

Aim of the experiment:

To study and validate the controllers for a temperature control system.

OBJECTIVE:

To study the performance of various types of controllers used to control the temperature of an oven.

EQUIPMENT REQUIRED:

Sl No.	Name of the equipment	Ratings/ Range	Quantity
1	Temperature Controller System		01
2	Patch Cords		As per required
3	Temperature Controller Oven		01

THEORY:

There are three modes of heat transfer viz. conduction, convection and radiation. Heat transfer through radiation maybe neglected in the present case since the temperatures involved are quite small. For conductive and convective heat transfer

$$\theta = \alpha \Delta T,$$

Where, θ = rate of heat flow in Joule/ sec.

ΔT = temperature difference in degree C

α = Constant

t = time in seconds

Under assumptions of linearity, the thermal resistance is defined as, $R = \text{Temperature} - \text{difference} / \text{rate of heat flow} = \Delta T / \theta = 1/\alpha$. This is analogous to electrical resistance defined by $I = V/R$. In a similar manner thermal capacitance of the mass is defined by

$$\theta = Cd(\Delta T)/dt$$

Which is analogous to the V-I relationship of a capacitor, namely $I = C Dv/dt$. In the case of heat ,

$C = \text{Rate of heat flow} / \text{Rate of temperature change}$

This equation of an oven may now be written by combining the above two equations , implying that a part of heat input is used in increasing the temperature of the oven and the rest goes out as loss. Thus

$$\theta = \frac{CdT}{dt} + \left(\frac{1}{R}\right) \theta T,$$

With the initial condition $T(t=0) = T_{\text{amb}}$. Now , taking Laplace transform with zero initial condition

$$T(s)/\theta(s) = R/(1+Scr)$$

An analogous electrical network and block diagram may be drawn as defined by the equation
 $I = C dv/dt + V/R$

Controller:

Basic control actions commonly used in temperature control systems are

- ON – OFF or relay
- Proportional
- Proportional – Integral
- Proportional -Integral-Derivative

(a) ON-OFF or Relay type controllers:

Also referred to as two position controllers, consist of a simple and inexpensive switch/ relay and are, therefore, used very commonly in both industrial and domestic control systems. Typical applications include air – conditioner and refrigerators, ovens, heaters with thermostat. Solenoid operated two position valves are commonly used in hydraulic and pneumatic systems.

(b) Proportional controller:

is simply an amplifier of gain K_p which amplifies the error signal and passes it to the actuator. The noise, drift and bias currents of this amplifier set the lower limit of the input signal which may be handled reliably and therefore decide the minimum possible value of the error between the input signal and output. Also the saturation characteristics of this amplifier set the linear and non-linear regions of its operation. Such controllers give non-zero steady state error to step input for a type-0 systems indicated earlier. The proportional (P) block in the system consists of a variable gain amplifier having a maximum value, K_{pmax} of 20.

(c) Proportional – Integral (PI) controller :

Mathematical equation of such a controller is given by

$$m(t) = K_p e(t) + K_1 \int_0^t e(t) dt = K_p e(t) + 1/T_1 \int_0^t e(t) dt$$

It may be easily seen that this controller introduces a pole at the origin, i.e. increases the system type number by unity. The steady state error of the system is therefore reduced or eliminated. Qualitatively, any small error signal $e(t)$, present in the system, would get continuously integrated and generate actuator signal $m(t)$ forcing the plant output to exactly correspond to the reference input so that the error is zero. In practical systems, the error may not be exactly zero due to imperfections in an electronic integrator caused by bias current needed, noise and drift present and leakage of the integrator capacitor.

The integral block in the present system has a transfer function

$$G_r(s) = 1/(28s) = K_1/s$$

The integral gain is therefore adjustable in the range 0 to 0.036(approx). Due to the tolerance of large capacitance's, the value of K_1 is approximate.

(d)Proportional-Integral-Derivative (PID) Controller:

Mathematical equations governing the operation of this controller is as

$$M(t) = K_p e(t) + K_1 \int_0^t e(t) dt + K_D de(t)/dt$$

$$= K_p e(t) + 1/T_1 \int_0^t e(t) dt + T_D de(t)/dt$$

So that in the Laplace transform domain,

$$M(s)/E(s) = (K_p + T_D s + 1/T_I s)$$

The derivative (D) block in this system has a transfer function

$$G_D = 19.97s \text{ (approx)}$$

The derivative gain is therefore adjustable in the range 0 to 20 approximately. Again, the approximation is justified due to higher tolerance in the values of large electrolytic capacitances.

PID controller is one of the most widely used controller because of its simplicity. By adjusting its coefficient K_p , K_D (or T_D) and K_I (or T_I) the controller can be used with a variety of systems.

PROCEDURE:

Identification of oven parameters:

- Keep switch S_1 to 'WAIT', S_2 to 'SET' and open 'FEEDBACK' terminals.
- Connect P output to the driver input and switching ON the unit.
- Set P potentiometer to 0.5 which gives $K_p = 10$. Adjust reference potentiometer to read 50.0 on the DVM. This provides an input of 0.5 V to the controller, i.e. 5V to the driver.
- Put switch S_2 to the 'MEASURE' position and note down the room temperature.
- Put switch S_1 to the 'RUN' position and note temperature readings every 10 sec., till the temperature becomes almost constant. Use the timer on the panel to monitor time.
- Plot temperature – time curve on a graph paper. Referring to fig., calculate T and T and hence write the transfer function of the oven including its driver as

$$G(s) = K \exp(-ST_2)/(1+ST_1) \text{ with } T \text{ in } ^\circ\text{C}$$

ON-OFF Controller:

- Keep switch S to 'WAIT' position and allow the oven to cool to room temperature. Short 'FEEDBACK' terminals.
- Keep switch S_2 to the 'SET' position and adjust reference potentiometer to the desired output temperature, say 60.0 $^\circ\text{C}$, by seeing on the digital display.
- Connect R output to the driver input. Outputs of P, D and I must be disconnected from driver input. Select 'HI' or 'LO' value of hysteresis.
- Switch S_2 to 'MEASURE' and S_1 to 'RUN' position. Read and record oven temperature every 10 sec. for about 20 minutes.
- Plot a graph between temperature and time and observe the oscillations in the steady state. Note down the magnitude of oscillations.
- Repeat above steps with the 'HI' setting for hysteresis and observe the rise time, steady-state error and percentage overshoot.

Proportional Controller:

- Ziegler and Nichols suggest the value of K_p for P- Controller as

$$K_p = (1/K) \times T_1/T_2$$
- Starting with a cool oven, keep switch S_1 to 'WAIT' position and connect P output to the driver input. Keep R, D and I outputs disconnected. Short 'FEEDBACK' terminals.
- Potentiometer setting needs some explanations here. The formula for K_p above is for an unity feedback system and has the dimension of Volts/ $^\circ\text{C}$. In the present unit a

temperature sensor having sensitivity of $10\text{m V}/^{\circ}\text{C}$ ($0.01\text{V}/^{\circ}\text{C}$) is used between oven output and controller input. Thus, the K_p calculated above will need to be divided by 0.01 to obtain the P-controller potentiometer setting. K_D and K_I have dimensions of sec and sec^{-1} respectively hence do not require any further consideration. These values may be set directly on the respective potentiometers.

- Select and set the desired temperature to say 60.0°C .
- Keep switch S_1 to 'RUN' position and record temperature readings as before.
- Plot the observations on a linear graph paper and observe the rise time, steady-state error and percentage overshoot.

Proportional – Integral Controllers:

- Ziegler and Nicholas suggested the value of K_p and K_I for P-I controller as $K_p = (0.9/K) \times T_1/T_2$; $T_1 = 1/K_I = 3.3T_2$, giving $K_I = 1/3.3T_2$
- Starting with a cool oven, keep switch S_1 to 'WAIT'. Connect P and I outputs to driver input and disconnect R and D outputs. Short feedback terminals.
- Set P and I potentiometers to the above values of K_p and K_I respectively keeping in mind that the maximum value of K_p is 20 and that of K_I is 0.036.
- Select and set the desired temperature to say 60.0°C
- Keep switch S_1 to 'RUN' position and record temperature readings as before.
- Plot the response on a graph paper and observe the steady state error and percentage overshoot.

Proportional-Integral-Derivative Controller:

- Ziegler and Nichols suggest the values of K_p , K_D and K_I for this controller as $K_p = (1.2/K) \times T_1/T_2$; $T_1 = 1/K_I = 2T_2$, giving $K_I = 1/2T_2$
 $K_D = T_D = 0.5T_2$
- Starting with a cool oven, keep switch S_1 to 'WAIT' position and connect P, D and I outputs to driver input. keep R output disconnected. Short feedback terminals.
- Set P, I and D potentiometers according to the above calculated values of K_p , K_I and K_D keeping in mind that maximum values for these are 20, 0.036 and 23.5 respectively.
- Select and set the desired temperature, say 60.0°C .
- Switch S_1 to 'RUN', and record temperature – time readings.
- Plot the response on a linear graph paper and observe the rise time, steady state error and percentage overshoot.
- Compare the results of the various controller options.
- Set P potentiometer to above calculated value of K_p , keeping that in mind that the maximum gain is 20. The measurement and interpretation of K_p and P-control. Keep switch S_2 to the 'SET' position and adjust reference potentiometer to the desired output temperature, say 60.0°C , by seeing on the digital display.
- Connect R output to the driver input. Outputs of P, D and I must be disconnected from driver input. Select 'HI' or 'LO' value of hysteresis.
- Switch S_2 to 'MEASURE' and S_1 to 'RUN' position. Read and record oven temperature every 10 sec., for about 20 minutes.

- Plot a graph between temperature and time and observe the oscillations in the steady state. Note down the magnitude of oscillations.
- Repeat above steps with the 'HI' setting for hysteresis and observe the rise time, steady state error and percentage overshoot

RESULTS:

(a) Open – loop measurement : The constant K for oven plus driver controller is given by

$$K = \text{Final temperature Oven} - \text{Ambient temp.} / \text{Input (volts)}$$

(b) Calculation for K_p , K_I , K_D :

(i) P Control : $K_p = (1/K) \times T_1/T_2$

(ii) P-I Control : $K_p = (0.9/K) \times T_1/T_2$

(iii) P-I-D Control : $K_p = (1.2 / K) \times (T_1 / T_2)$

CONCLUSION :

Hence the above experiment is conducted in according to the steps described above and all the data values are noted down and tabulation is done.

EXPERIMENT – 5

Aim of the Experiment:

To determine the transfer function of a system (network) using transfer function analyser.

Objective:

To study the time response of a various controller using linear system simulator and to correlate the studies with theoretical results.

Apparatus Required:

- Linear System simulator
- Patch Cords (red , black,)

Theory:

The transfer function is defined as the ratio of Laplace transform of output to Laplace transform of input. The transfer function of a given state model is given by: A state space representation is a mathematical model of a physical system as a set of input, output and state variables related by first-order differential equations. The state space representation (also known as the "time-domain approach") provides a convenient and compact way to model and analyze systems with multiple inputs and outputs. Unlike the frequency domain approach, the use of the state space representation is not limited to systems with linear components and zero initial conditions.

"State space" refers to the space whose axes are the state variables. The state of the system can be represented as a vector within that space. The input state equation is given by

$$\dot{X}(t) = A x(t) + B u(t)$$

The output equation is written as;

$$y(t) = C x(t) + D u(t)$$

MATLAB PROGRAM:

```
A=input('enter the matrix A')
B=input('enter the matrix B')
C=input('enter the matrix C')
D=input('enter the matrix D')
Sys=ss2tf(A,B,C,D)
```

PROCEDURE:

- Type the program in the MATLAB editor that is in M-file.
- Save and run the program.
- Give the required inputs in the command window of MATLAB in matrix format.
- The command ss2tf(A,B,C,D) converts the given transfer function into a state model.
- Note down the output obtained in MATLAB.
- The Transfer Function is also obtained theoretically.
- Both the state models are compared

THEORETICAL CALCULATIONS:

A=
B=
C=
D=

Results:

EXPERIMENT – 6

Aim of the Experiment:

To study the position control system of synchroscope .

Objective:

- To observe the characteristics of a synchro transmitter
- To observe characteristics of transmitter-receiver pair and use these as torque
- Synchro acts as error detector.

Equipments Required:

1. Synchro device
2. Synchro transmitter and receiver
3. Electric demodulator
4. Connecting wires

Theory:

A synchro device, which consists of transmitter, receiver or control transformer, consists essentially of a stator and a rotor. The stator consists of three windings with their axes 120 degrees for three phase supply. The phase of the signal in these windings taken out S1, S2 and S3 are of course the same. In its simplest form, the rotor consists of a laminated core carrying a single winding, the ends of which R1 and R2 are brought out to slip rings.

It is of two types:

- I. Control type synchro
- II. Torque Transmission type synchro

Torque Transmission Type Synchro:

This type of synchro has small output torque and hence they are used for running the very light load like a pointer. The control type synchro is used for driving the large loads.

Control type synchro system:

The control synchro is used for error detection in positional control system. It consists of two units.

- Transmitter
- Receiver

Procedure:

Transmitter:

Connect the transmitter rotor terminals R1 and R2 to excitation supply V on the panel.

Stator terminals S₁, S₂, S₃ are left unconnected .

Vary rotor angle from 0 degrees to 360 degrees in steps of 30 degrees and measure the three voltage, V_{S1S2}, V_{S2S3}, and V_{S1S3} with help of voltmeter on the panel.

Error detector operation:

- I. Connect the transmitter rotor terminals R1 AND R2 to excitation supply V on the panel. Interconnect the respective stator terminals of the transmitter and receiver ie; S1 to S1, S2 to S2, and S3 to S3.
- II. Connect receiver rotor terminals to voltmeter on panel. Also connect the CRO to get the error voltage.

- III. Varying the transmitter rotor angle 0 degree to 360 degrees in steps of 30 degrees and record error voltage.

Torque synchro pair operation:

- I. Connect both transmitter and receiver rotors to the excitation supply V_s on the panel. Interconnect the respective stator terminals of the transmitter and receiver, i.e, S1 to S2, S2 to S3, and S3 to S1. Do not lock the receiver.
- II. Vary the transmitter rotor angle from 0° to 360° in steps of 30° and note the receiver rotor angle. The receiver should follow the transmitter rotor.

Tabulation:

- Characteristics of transmitter:

Sl no.	Rotor shaft angle Θ	V_{s1s2}	V_{s2s3}	V_{s3s1}
1				
2				
3				
4				
5				
6				
7				

- Torque synchro pair:

Sl no.	Input shaft angle Θ_i	Output shaft angle Θ_o
1		
2		
3		
4		
5		

- Error detector:

Sl no.	Input shaft angle Θ_i	Error voltage V_c (rms)	Demodulator output V_d (DC)

Conclusion:

Hence the above experiment is conducted in according to the steps described above and all the data values are noted down and tabulation is done.

EXPERIMENT – 7

AIM OF THE EXPERIMENT – Obtain the frequency response of a lag and lead compensator.

OBJECTIVE:

- ❖ To study frequency response of Lag network.
- ❖ To study frequency response of Lag network.
- ❖ To study frequency response of Lag-lead network.

APPARATUS REQUIRED:

SL NO.	EQUIPMENT NAME	QUANTITY

THEORY:

The Lead Lag Network consists of a type0, order2 process for studying the Lag - Lead compensation effect.



The process may be lag, lead or lag lead. These are given individually to perform frequency domain analysis of the process.

LAG PROCESS

A Process having the characteristics of a lag network is called a lag Process if a sinusoidal signal is applied to a lag network. Then its steady state output will have a phase lag with respect to its input.

Lag Process results in large improvement in steady state performance but results in slower response due to reduced bandwidth. The attenuation due to the lag compensator will shift the gain crossover frequency to a lower frequency point where the phase margin is acceptable. Thus, the lag Process will reduce the bandwidth of the system and will result in slower transient response

Lag Process is essentially a low pass filter and so high frequency noise signals are attenuated. If the pole introduced by the Process is not cancelled by a zero in the system, then lag compensator increases the order of the system by one.

S-PLANE REPRESENTATION OF LAG PROCESS

The lag Process has a pole $S = -1/\beta T$ and a zero $S = -1/T$. The pole-zero plot of lag Process is shown in fig. With respect to $\beta > 1$, the zero is located to the left of the pole on the negative real axis. The general form of lag Process transfer function is given by equation

The transfer function of the lag Process ,

$$G_c = \frac{S + Z_c}{S + P_c} = \frac{(S + 1/T)}{(S + 1/\beta T)}$$

Where, $T > 0$ and $\beta > 1$

The zero of lag compensator, $Z_c = 1/T$

The pole of lag compensator, $P_c = 1/\beta T = Z_c * 1/\beta$

From equation (1), $T = 1/Z_c$

From equation (2), $\beta = Z_c / P_c$

LEAD PROCESS

A Process having the characteristics of a lead network is called a lead Process. If a sinusoidal signal is applied to the lead network, then in steady state output will have a phase lead with respect to its input.

The lead compensation increases the bandwidth, which improves the speed of response and also reduces the amount of overshoot. Lead compensation appreciably improves the transient response, whereas there is a small change in steady state accuracy. Generally, lead compensation is provided to make an unstable system as a stable system.

A lead Process is basically a high pass filter and so it amplifies high frequency noise signals. If a pole is introduced by the Process and it is not cancelled by a zero in the system, then lead compensation increases the order of the system by one.

S-PLANE REPRESENTATION OF LEAD PROCESS

The lead Process has a zero at $S = -1/T$ and a pole at $S = -1/\alpha T$. With respect to, $\alpha < 1$, the zero is closer to the origin than the pole. The general form of lead Process transfer function is given by equation,

$$G(s) = \frac{s + z_c}{s + p_c} = \frac{s + \frac{1}{T}}{s + \frac{1}{\alpha T}}$$

Where $1 > 0$ and $\alpha < 1$

The zero of lead Process, $z_c = \frac{1}{T}$, The pole of lead Process $P_c = \frac{1}{\alpha T}$

From these expression, $T = \frac{1}{z_c}$, $\alpha = \frac{z_c}{p_c}$

LAG-LEAD PROCESS

A Process having the characteristics of lag-lead network is called lag-lead Process. In a lag-lead network when a sinusoidal signal is applied, both phase lag and phase lead occurs in the output, but in different frequency regions. Phase lag occurs in the low frequency region and phase lead occurs in the high frequency region (i.e) the phase angle varies from lag to lead as the frequency is increased from zero to infinity.

A lead Process basically increases bandwidth and speeds up the response and decreases the maximum overshoot in the step response, Lag compensation increases the low frequency gain and thus improves the steady state accuracy of the system, but reduces the speed of responses due to reduced bandwidth.

If improvements in both transient and steady state response are desired, then both a lead Process and lag Process may be used simultaneously, rather than introducing both a lead and lag Process as separate elements. However it is economical to use a single lag lead Process.

A lag-lead process combines the advantages of lag and lead process. A lag-lead Process possess two poles and two zeros and so such a process increases the order of the system by two, unless cancellation of poles and zeros occurs in the compensated system.

S-PLANE REPRESENTATION OF LAG-LEAD PROCESS

The s-plane representation of lag-lead Process is shown in fig. The lag section has one real pole and one real zero with the pole to the right of zero. The lead section also has one real pole and one real zero but the zero is to the right of the pole.

$$\text{Transfer function of lag-lead Process } G(s) = \frac{s + \frac{1}{T_1}}{s + \frac{1}{\beta T_1}} * \frac{s + \frac{1}{T_2}}{s + \frac{1}{\alpha T_2}}$$

Where $\beta > 1$ and $0 < \alpha < 1$

LEAD-LAG COMPENSATION NETWORK

The Lead Lag compensator present in the unit has two pair of connecting points named as Forward time constant (LEAD), and Feedback time constant (LAG). There are provisions to connect and external values of forward (R,C) and feedback (R,C) time constant values. If the forward time constant in the Lead- Lag compensator is greater than feedback compensator, the compensator is said to be lead compensator or if the feedback time constant is greater than the forward time constant. The compensator is said to be a Lag compensator. The theoretical oriented calculation is follow.

PROCEDURE:

To study the frequency response of the lag process:

1. Connections are made as per the connection diagram shown in figure-2.

2. Switch ON the unit.

3. Give the sine wave as input.

4. Note down the amplitude and frequency of the input signal.
5. Observe the Lissajous pattern through CRO, by keeping the CRO in X-Y mode and calculate the phase shift (ϕ) of the output signal with the input.
6. Conduct the experiment for various frequencies.
7. Plot the bode plot and conclude the behaviour of lead process
8. The gain is measured from the formula,

$$A_v = 20 \log_{10} \left| \frac{v}{v} \right| \text{dB}$$

9. The phase angle (ϕ) is measured from Lissajous pattern is shown in figure.

$$\sin \phi = \frac{x_1}{x_2} = \frac{y_1}{y_2}$$

$$\phi = \sin^{-1} \frac{x_1}{x_2} = \sin^{-1} \frac{y_1}{y_2}$$

To study the frequency response of the lead process

PROCEDURE

1. Connections are made as per the connection diagram shown in figure-3.
2. Switch ON the unit.
3. Give the sine wave as input.
4. Measure the amplitude and frequency of the input signal and tabulate it
5. Observe the Lissajous pattern through CRO, by keeping the CRO in X-Y mode and calculate the phase shift (ϕ) of the output signal with the input.
6. Conduct the experiment for various frequencies of lead process
7. Plot the bode plot and conclude the behaviour
8. The gain is measured from the formula,

$$A_v = 20 \log_{10} \left| \frac{v}{v} \right| \text{dB}$$

9. The phase angle (ϕ) is measured from Lissajous pattern is shown in figure.

$$\sin \phi = \frac{x_1}{x_2} = \frac{y_1}{y_2}$$

$$\phi = \sin^{-1} \frac{x_1}{x_2} = \sin^{-1} \frac{y_1}{y_2}$$

To study the frequency domain characteristics of the lead lag process.

1. Connections are made as per the connection diagram shown in figure -4.
2. Switch ON the unit
3. Give a sinusoidal input as the set value to the error detector.
4. Measure the amplitude and frequency of the input signal.
5. Observe the Lissajous pattern through CRO, by keeping the CRO in X-Y mode and calculate the phase shift (ϕ) of the output signal with input.
6. Conduct the experiment for various frequencies.
7. Plot the bode plot and conclude the behaviour of lead lag process.
8. The gain is measured from the formula,

$$A_v = 20 \log_{10} \left| \frac{v}{v} \right| \text{dB}$$

9. The phase angle (ϕ) is measured from Lissajous pattern is shown in figure.

$$\sin \phi = \frac{x_1}{x_2} = \frac{y_1}{y_2}$$

$$\phi = \sin^{-1} \frac{x_1}{x_2} = \sin^{-1} \frac{y_1}{y_2}$$

TABULATION:

To study the frequency response of the lag process

SL NO.	Frequency (Hz)	Phase Shift (ϕ)

To study the frequency response of the lead process

SL NO.	Frequency (Hz)	Phase Shift (ϕ)

SL NO.	FREQUENCY IN HZ	X1	X2	ϕ IN DEG	Vout	Gain (A_v) in dB

To study the frequency domain characteristics of the lead lag process

CONCLUSION:

Thus the frequency domain characteristics of the lead lag process were studied.

EXPERIMENT-8

AIM OF THE EXPERIMENT – To find the Transfer function of DC servo motor.

OBJECTIVE:

1. Determination of armature of resistance and Inductance of DC servomotor
2. Determination of Field of resistance and Inductance of DC servomotor
3. To find the back emf constant of DC servomotor
4. To find the field torque constant of DC servomotor
5. To find the Armature torque constant of DC servomotor
6. To find the moment of inertia of DC servo motor

APPARATUS REQUIRED:

Sl no.	Name of the apparatus	quantity
1	VPET – 300(A)	01
2	DC Servo Motor	01
3	Patch chords	As per required
4	9 Pin D connector	01

THEORY:**DC SERVO MOTOR****BASIC OPERATING PRINCIPLE:**

The DC motor is basically a torque transducer that converts electric energy into mechanical energy. The torque developed on the motor shaft is directly proportional to the field flux and the armature current.

$$T_m = K_m \phi_f i_a \quad - (i)$$

K_m = Proportionality constant

T_m = Motor torque

ϕ_f = Field flux

i_a = Armature current

In addition to the torque when conductor moves in magnetic field, voltage is generated across its terminals which opposes the current flow and hence called as Back e.m.f denoted as

$$E_b = K_m \phi_f \omega_m \quad - (ii)$$

This back e.m.f is directly proportional to the shaft velocity ω_m

Equations (1) and (ii) form the basic equation of d.c. servo motor operation.

Basic Classification

Basically d.c. servo motors are classified as:

(1) Variable magnetic flux motors.

(ii) Constant magnetic flux motors.

In variable magnetic flux motors magnetic field is produced by the field windings which are connected to the external supply. These are also called as separately excited or field controlled. The constant magnetic flux motors are also known as permanent magnet d.c. motors. The motors have relatively linear torque-speed characteristics.

Derivation of transfer functions for

- (i) Field controlled d.c. servo motor
- (ii) Armature controlled d.c. servo-motors.

Field Controlled DC Servo motor

Assumptions

- (1) Constant armature current is fed into the motor.
- (2) $\phi_f \propto I_f$ Flux produced is proportional to field current.

$$\phi_f = k_f I_f$$

- (3) Torque is proportional to product of flux and armature current.

$$T_m \propto \phi I_a$$

$$T_m = K' \phi I_a = K' k_f I_f I_a$$

$$T_m = K_m k_f I_f$$

Where $K_m = k' I_a = \text{constant}$

Apply Kirchoff's law to field circuit.

$$L_f \frac{dI_f}{dt} + R_f I_f = e_f$$

Now shaft torque T is used for driving load against the inertia and frictional torque.

$$T_m = J_m \frac{d^2 \theta_m}{dt^2} + B_m \frac{d\theta_m}{dt}$$

$$\text{Inertia force} = J_m \frac{d^2 \theta_m}{dt^2} \text{ similar to } m \frac{d^2 x}{dt^2}$$

$$\text{Frictional force} = B_m \frac{d\theta_m}{dt} \text{ similar to } B \frac{dx}{dt}$$

Finding Laplace Transforms of equations (1), (2) and (3) we get,

$$T_m(s) = K_m k_f I_f(s)$$

$$E_f(s) = (sL_f + R_f) I_f(s)$$

$$T_m(s) = J_m s^2 \theta_m(s) + B_m s \theta_m(s)$$

$$T_m(s) = K_m k_f E_f(s) / (sL_f + R_f)$$

Eliminate $I_f(s)$ from equations (4) and (5) Input = $E_f(s)$

Output = Rotational displacement $\theta_m(s)$

$$(s^2 J_m + s B_m) \theta_m(s) = K_m k_f E_f(s) / (sL_f + R_f)$$

$$\text{Transfer function} = \theta_m(s) / E_f(s) = K_m k_f / (s^2 J_m + s B_m) (sL_f + R_f)$$

$$= K_m k_f / (s R_f B_m) (1 + s \tau_m) (1 + s \tau_f)$$

$$\tau_m = J_m / B_m = \text{motor time constant}$$

$$\tau_f = L_f / R_f = \text{Field time constant}$$

$$TF = k_f / R_f [1 + s \tau_f] \cdot K_m / B_m [1 + s \tau_m] \cdot 1/s$$

- iii) Armature Controlled D.C. Servo Motor

Assumptions:

- (1) Flux is directly proportional to current through field winding.

$$\phi_m = K_f I_f = \text{constant}$$

- (ii) Torque produced is proportional to product of flux and armature current.

$$T = K' \phi I_a$$

$$T = K'_m K_f I_f I_a$$

(iii) Back e.m.f is directly proportional to shaft velocity as flux is constant.

$$\text{as } \omega_m = \frac{d\theta(t)}{dt}$$

$$E_b = K_b \omega_m(s) = k_b s \theta_m(s)$$

Apply Kirchoff's law to armature circuit:

$$E_a(s) = E_b(s) + I_a(s)[R_a + sL_a]$$

$$I_a(s) = [E_a(s) - E_b(s)] / [R_a + sL_a]$$

$$I_a(s) = [E_a(s) - k_b s \theta_m(s)] / [R_a + sL_a]$$

$$\text{Now } T_m = K_m k_f I_f I_a$$

$$T_m = K_m k_f I_f \{ [E_a(s) - k_b s \theta_m(s)] / [R_a + sL_a] \}$$

$$\text{Also } T_m = \{ J_m s^2 + sB_m \} \theta_m(s)$$

Equating equations of T_m ,

$$K_m k_f I_f E_a(s) / [R_a + sL_a] = K_m k_f I_f k_b s \theta_m(s) / [R_a + sL_a] + \{ J_m s^2 + sB_m \} \theta_m(s)$$

$$K_m k_f \frac{I_f}{R_a + sL_a} E_a(s) = \left[\frac{K_m k_f I_f k_b s}{R_a + sL_a} + J_m s^2 + sB_m \right] \theta_m(s)$$

$$\theta_m(s) / E_a(s) = k_m / s R_a B_m (1 + s\tau_m) (1 + s\tau_a)$$

$$= 1 + \frac{K_m}{s R_a B_m (1 + s\tau_m) (1 + s\tau_a)} \cdot s k_b$$

$$= G(s) / [1 + G(s) H(s)]$$

$$\text{Where } \tau_m = J_m / B_m \text{ and}$$

$$\tau_a = L_a / R_a$$

$$K_m = K_m K_f$$

$$G(s) = K_m / s R_a B_m (1 + s\tau_m) (1 + s\tau_a)$$

$$H(s) = s K_b$$

Therefore transfer function can be represented in its block diagram as in Fig. 6

AIM:-

To find the armature of resistance of DC servomotor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment POT in minimum position.
4. Connect VPET-300(A) module Armature output A and AA to motor Armature terminal A and AA respectively.
5. Switch ON the power switch and SPST Switch 'SI'
6. Shaft should not rotate, when applying the DC input voltage
7. Now down the Armature current for various Armature, voltage in the table-1. Armature current should not exceed rated current value (2.5A).
8. Calculate the Resistance value $R_a = V_a / I_a$
9. The average resistance value gives the armature resistance.

AIM:-

To find the armature inductance of DC servomotor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment POT in minimum position.
4. Connect VPET-300(A) module variac output P and N to motor Armature terminal A and AA respectively.
5. Switch ON the power.
6. Shaft should not rotate, when applying the AC input voltage
7. Now note down the AC current for various AC voltage in the table-2.
8. Calculate the Inductance value $L_a = V_a / I_a$
- 9 The average Inductance value gives the armature Inductance.

AIM:-

To find the field resistance of DC servomotor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARLAC) in minimum position.

3. Initially keep Armature and field voltage adjustment POT in minimum position.
4. Connect VPET-300(A) module Field output F and FF to motor Field terminal F and FF respectively.
5. Switch ON the power and SPST Switch 'S2'
6. Shaft should not rotate, when applying the DC input voltage.
7. Now note down the Field current for various Field voltage in the table-3.
8. Calculate the Resistance value

$$R_f = V_f / I_f$$

9. The average resistance value gives the field resistance.

AIM:-

To find the field inductance of DC servomotor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment POT in minimum position.
4. Connect VPET-300(A) variac output P and N to motor Field terminal F and FF respectively.
5. Switch ON the power.
6. Shaft should not rotate, when applying the AC input voltage.
7. Now note down the AC current for various AC voltage in the table-4.
8. Calculate the Inductance value $L_f = V_f / I_f$
9. The average Inductance value gives the Field Inductance.

To find the back emf constant of DC servomotor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment POT in minimum position.
4. Connect VPET-300(A) module, armature output A and AA to motor Armature terminal A and AA respectively.
5. Connect VPIT-300(A) module, field output F and FF to motor Field terminal F and FF respectively.
6. Switch on the power and SPST Switch 'S1' and 'S2'.

7. Set the field Voltage at rated value (48V).
8. Adjust the Armature voltage by using Armature POT. Now note down the Armature current and speed for various Armature Voltage (up to Motor rated Speed) in the table-5.
9. Plot the graph E_b versus ω , model graph is as shown in Fig.7 and calculate the back emf constant k_b from graph as shown below.

To find the field torque constant of DC servomotor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment POT in minimum position.
4. Connect VPET-300(A) module Armature output A and AA to motor Armature terminal A and AA respectively.
5. Connect VPET-300(A) module field output F and FF to motor Field terminal F and FF respectively.
6. Switch ON the power supply and SPST switches 'S1' and 'S2'
7. Adjust the Field voltage at 50% of rated value.
8. Apply 50% of armature voltage.
9. Apply the load by tightening belt.
10. Now, note down the field current and spring balance readings in the table-6.
11. Increase the field current and repeat the step 9 & 10 up to rated field current.
12. Plot the graph Torque vs Field current.

To find the Armature torque constant of DC servomotor using VPET – 300(A) module .

PROCEDURE

1. Initially keep all switches in OFF Position.
2. Initially keep voltage adjustment POT (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment POT in minimum position
4. Connect VPET-300(A) module armature output A and AA to motor Armature terminal A and AA respectively.
5. Connect VPET-300(A) field output F and FF to motor Field terminals F and FF respectively.
6. Switch ON the power and SPST switches 'S1' and 'S2'.
7. Adjust the Field voltage to rated value.
8. Apply the Armature voltage till the Motor run at rated speed.

9. Apply load by tightening.
10. Now, note down the armature voltage, current and spring balance reading in the table-7.
- II. Plot the graph Torque V_s Armature current (I_a) model graph is shown figure-9.
12. Calculate the Torque constant from graph as shown below.

To find the moment of inertia of DC servo motor using VPET-300(A) module.

Procedure:-

1. Initially keep all switches in OFF Position. 2. Initially keep voltage adjustment (VARIAC) in minimum position.
3. Initially keep Armature and field voltage adjustment pot in minimum position.
4. Connect VPET-300(A) module field output F and FF to motor Field terminal F and FF respectively.
5. Motor Armature terminals are connected to common point of DPDT switch.
6. Connect one end of PDT Switch one end to armature output terminal of VPET-300(A) Module..
7. Connect the other end of DPDT switch to Ammeter through Resistor R.
8. Initially DPDT switch is connected to Armature side.
9. Switch ON the power and SPST switches 'S1' and 'S2'.
10. Adjust the motor speed, slightly beyond the rated speed (i.e) above (1500rpm) and the DPDT switch (supply) is open (cut off from the armature) while keeping the field excited. 11. Measure the time taken for the motor speed fall to 900 rpm by using digital stop watch.
12. Reduce the Armature voltage to zero and Connect DPDT switch to Armature side. 13. Increase the Armature voltage, slightly motor speed will be increased and beyond (1650rpm) the rated speed, DPDT switch cuts the armature supply, and it is connected to a non-inductive Resistance R as shown in figure-10.
14. Measure the time taken for the motor speed fall to (same) 900 rpm, by using a digital stop watch and at the same time note the voltage and current value in the table-8.
15. Note the various Armature Voltage and current values of Motor, (This reading is taken till the motor speed falls to 900rpm).

TABLE:-1

SL.NO	Armature voltage V_a (v)	Armature current I_a (A)	$R_a = V_a / I_a$	Average R_a

TABLE:-2

Armature Voltage V_a	Armature Current I_a	$Z_a = V_a/I_a$	$X_a = X_1 = \sqrt{Z_a^2 - R_a^2}$	$L_a = X_a/2\pi f$ (H)	Average L_a (H)

TABLE:-3

SL No.	Field Voltage V_f (V)	Field Current I_f (A)	$R = V_f/I_f$ (Ω)	Average R_f (Ω)

TABLE:-4

Field Voltage V_f	Field Current I_f (mA)	$Z_f = V_f/I_f$	$X_f = \sqrt{Z_f^2 - R_f^2}$	$L = X_f / 2\pi f$ (H)	Average L_f (H)

TABLE:-5

Armature Voltage V_a	Armature Current I_a	$E_b = V_b - I_a R_a$	Speed N	$\omega R_{nd} / \text{sec}$

TABLE:-6

SL No.	Field Voltage (V)	Field Current (A)	S1 kg	S2 kg	S1 – S2	$T = r (S_1 \sim S_2) \times 9.81 \text{N-m.}$

TABLE:-7

SL No.	Armature voltage (V)	Armature Current (A)	S1 kg	S2 kg	$S_1 \sim S_2 \text{ kg}$	$T = (S_1 \sim S_2) \times 9.81 \text{ N-m}$

TABLE:-8

Without Electrical load t_1	With Load				
	t_2	V_{ga}	I_{ga}	Average V_{ga}	Average I_{ga}

Conclusion: