GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Industrial Automation

POWER SEMICONDUCTOR DRIVES

LABORATORY MANUAL /RECORD

CERTIFICATE

This is to certify that this is bonafide record of practical work done in the engineering lab……………………………….. in B.Tech…………………………year, during the academic year ……………..

Student name: ___________________________

Roll no: _________________________________

Class: __________________________________

Branch: _________________________________

Signature of staff **signature of external examiner**

Index

Sl.No	Experiment Name	Date	Signature	Remarks
1	Firing angle control of thyristor based DC drive connected to DC motor using LabVIEW			
2	Closed loop speed control of DC motor using PI,PID, PD controllers using LabVIEW			
3	Step,ramp,parabolic response of second order DC motor system using LabVIEW			
4	Indirect speed control of DC motor using armature voltage control with PI,PID controllers using LabVIEW			
5	V/F control of AC drive connected to AC motor using LabVIEW			
6	Closed loop speed control of AC motor with step, ramp,parabolic inputs and PI,PID controllers using LabVIEW			
7	Closed loop speed control of AC motor- DC generator set with load using PI,PID controllers using LabVIEW			
8	Speed control of SRM in forward motoring and reverse motoring mode			
9	Speed control of PMBLDC motor in forward motoring and reverse motoring and Forward breaking mode			
10	Speed control of PMSM in forward motoring mode			

1. FIRING ANGLE CONTROL OF THYRISTOR BASED DC DRIVE CONNECTED TO DC MOTOR

AIM: To obtain speed response of firing angle control of thyristor based DC drive connected to DC motor.

Apparatus:

i. NI LabView Software, DAQ
ii. Thyristorised DC drive
iii. DC motor
iv. Proximity Sensor

Specifications:

DC Drive	***DC motor, DC generator***
Thyristorized Bridge Rectifier: 0-220V DC	*Armature voltage:* 220V DC
Diode Bridge Rectifier : 220V DC	*Current:* 2Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

Many industrial applications such as steel-rolling mills, paper mills and traction systems etc, make use of controlled DC power. DC power is obtained earlier from motor-generator sets or by thyristor rectifiers. The advent of thyristors has changed the art of ac to dc conversion. Presently phase controlled ac to dc converters employing thyristors are extensively used for changing constant ac input voltage to controlled dc output voltage. Here a thyristor is turned off as ac supply voltage reverse biased it, provided anode current has to fallen to a level below the holding current. The turning off or commutation, of a thyristor by supply voltage is called natural commutation or line commutation. Phase controlled concept is implemented by generating and triggering thyristor by firing pulse at desired firing angle. Firing angle of thyristor is measured from the instant it would start conducting if it were replaced by a diode. Firing angle may be defined as the angle measured from the instant SCR gets forward biased to the instant it is triggered. A single phase semi controlled converter is used in this experiment to vary voltage applied to DC motor. Semi converter has an advantages of freewheeling action is present inside converter itself, which improves p.f of circuit.

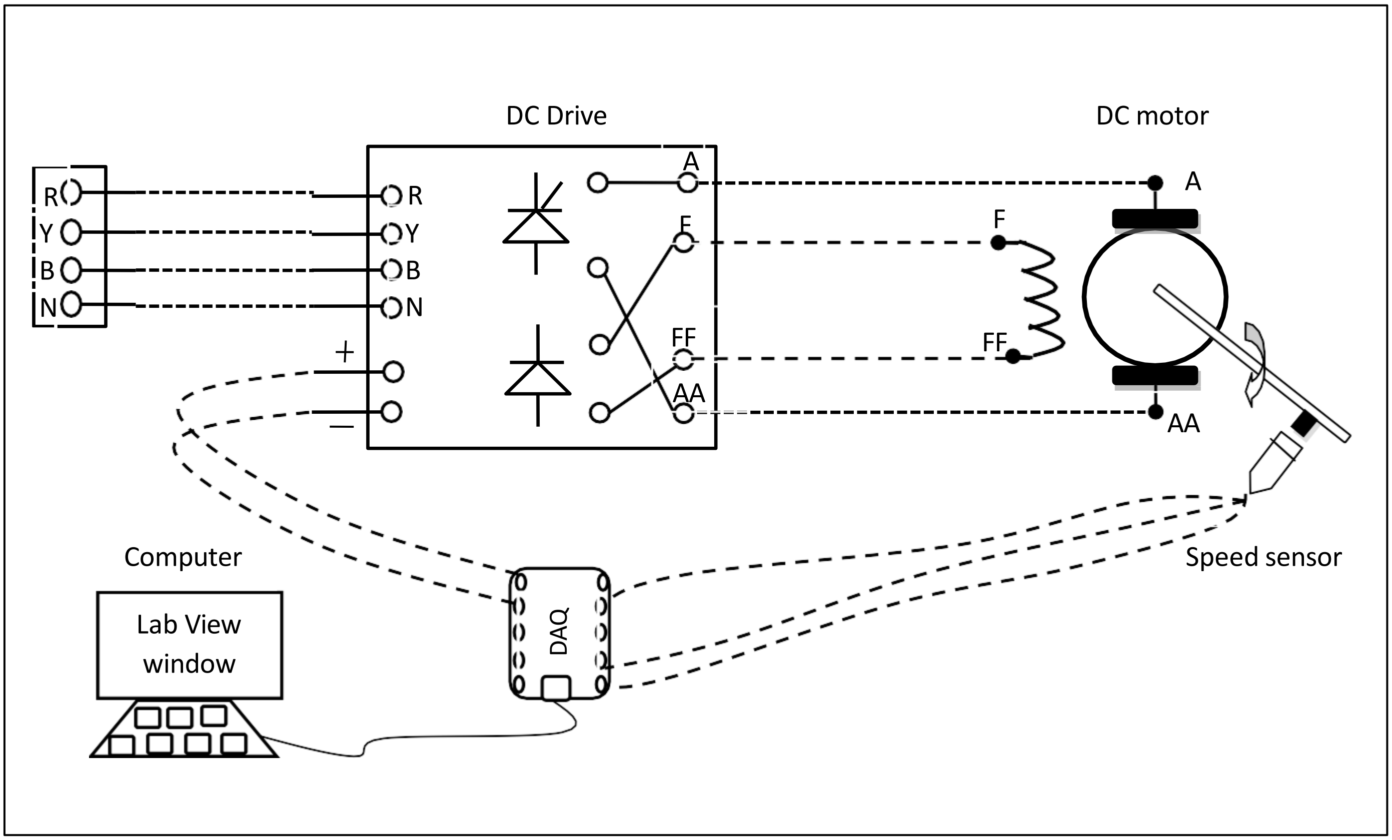


Fig.1.1 Circuit diagram for firing angle control of thyristorised DC drive

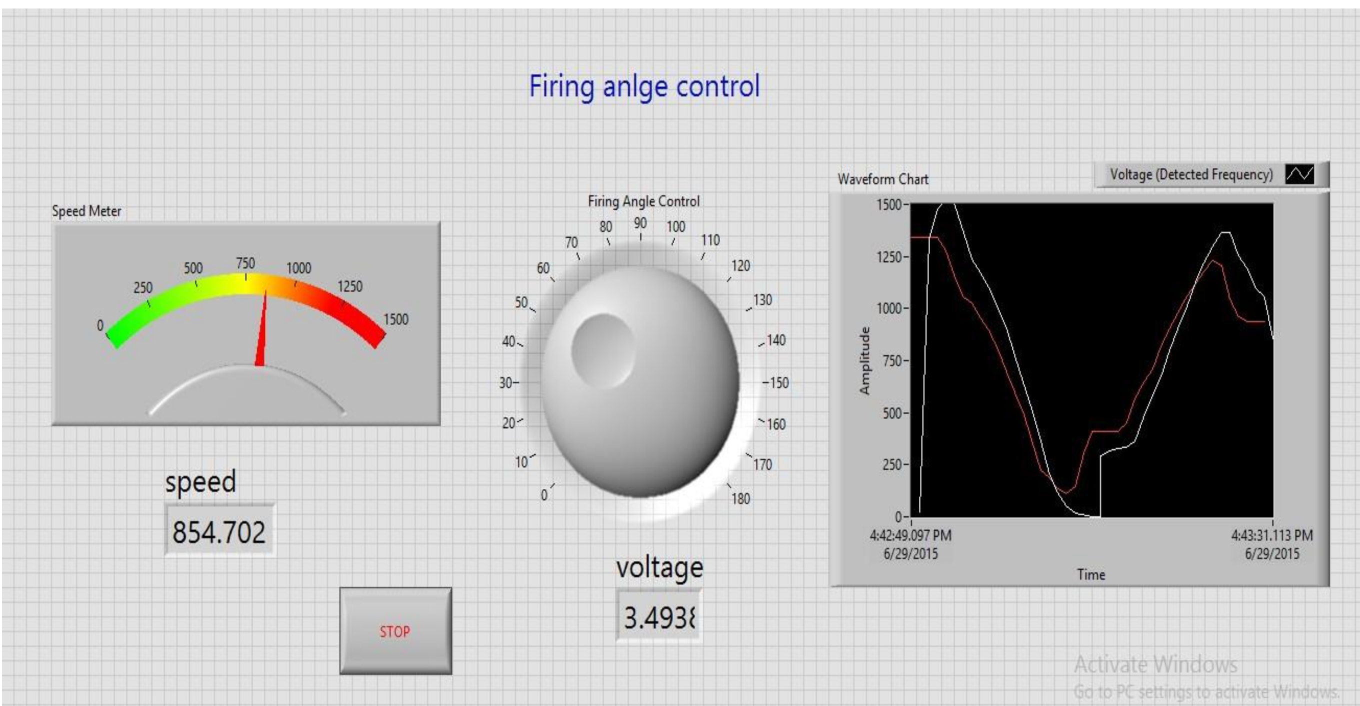
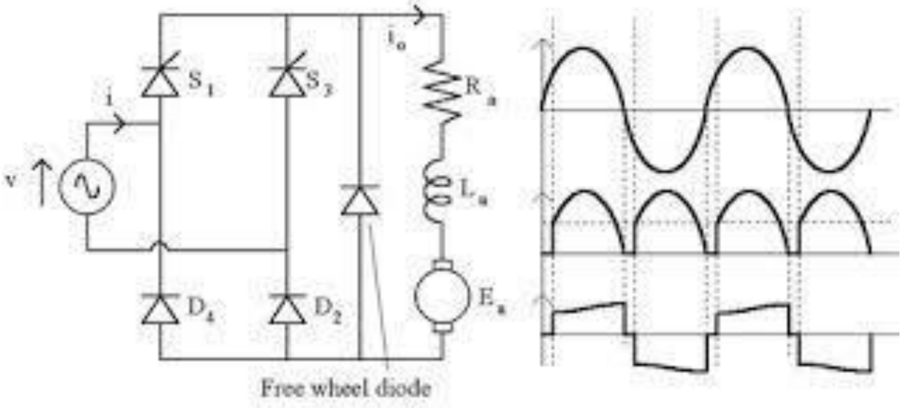


fig.1.2 LabView front panel diagram of firing angle control



The average output voltage of semi converter is given by $V_0 = \frac{V_m}{\Pi}(1+\cos\alpha)$

as the firing angle to thyristors varies from 0^0-180^0, average output voltage from semi converter 0 to V_m/Π

than speed control of dc motor can be done by firing angle control from relation

$$w_m = \frac{(V_m/\Pi)(1+\cos\alpha)}{K_m} - \frac{r_a}{K_m^2}.T_e$$

Procedure:

1. Connect circuit as per circuit diagram
   i. Connect supply to DC drive
   ii. Connect output of DC drive to armature and field supplies of DC motor
   iii.Connect speed sensor & DC drive variable point to DAQ assistant
2. Develop LabView diagram in block diagram consists of firing angle control nub and speed feedback.
3. Run the LabView diagram and vary firing angle nub around 1 mint.
4. Ensure that motor speed follows the set speed or reference speed.
5. Take the data to excel file, draw the set speed and actual speed on a single plot
6. Observe the response of speed control loop using plot

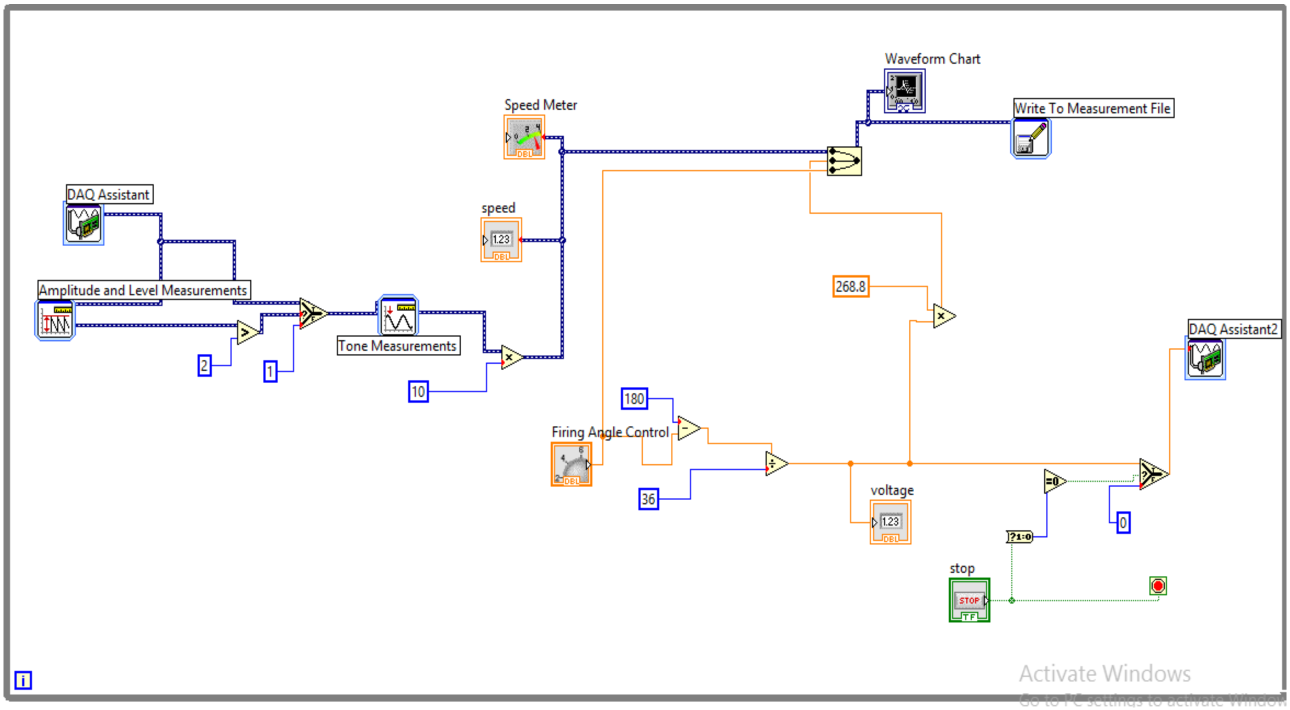


Fig.1.3 LabView block diagram of firing angle control

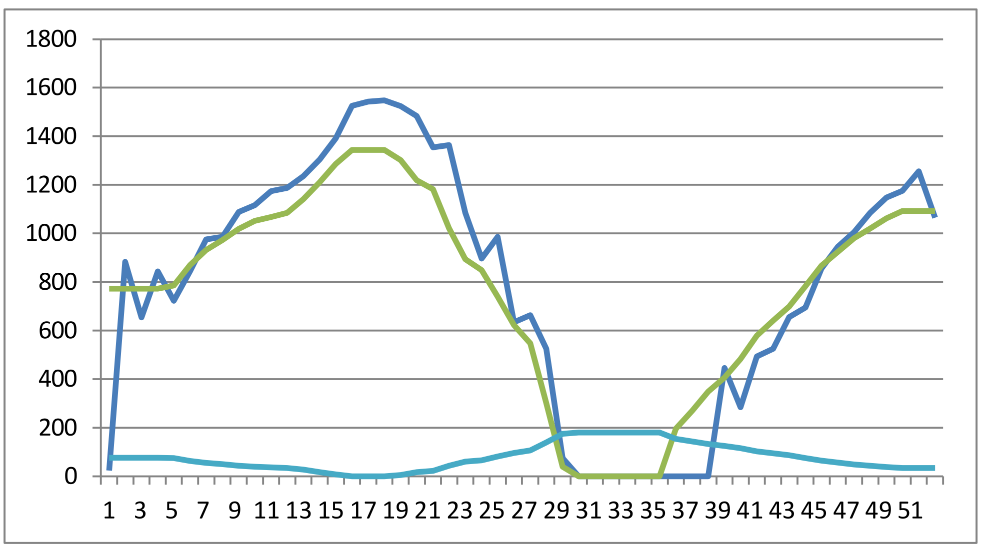


Fig.1.4 speed response plot of firing angle control of DC motor & firing angle.

RESULT: Firing angle control of thyristorised DC drive connected to DC motor is done and speed response of drawn.

2. CLOSED LOOP SPEED CONTROL OF DC MOTOR USING PI, PD AND PID CONTROLLERS

AIM: To design and tune proper PI, PD & PID controllers for speed control of DC motor drive

Apparatus:

i. NI LabView Software, DAQ
ii. Control design and simulation tool kit
iii. Thyristorised DC drive
iv. DC motor
v. Proximity Sensor

Specifications:

DC Drive	***DC motor***
Thyristorized Bridge Rectifier: 0-220V DC	*Armature voltage:* 220V DC
Diode Bridge Rectifier : 220V DC	*Current:* 2Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

Motion control is required in large number of industrial and domestic applications like transportation systems, rolling mills, fans, pumps & robots etc. systems employed for motion control are called drives. Drives employing electric motors are called electrical drives.

Block diagram of electric drive is shown in figure 2.1

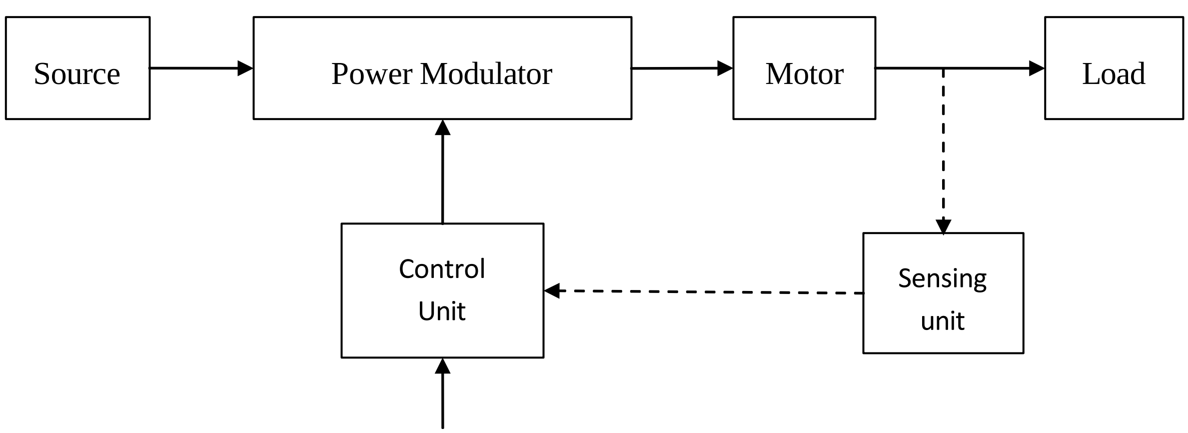


Fig.2.1 Block diagram of electric drive

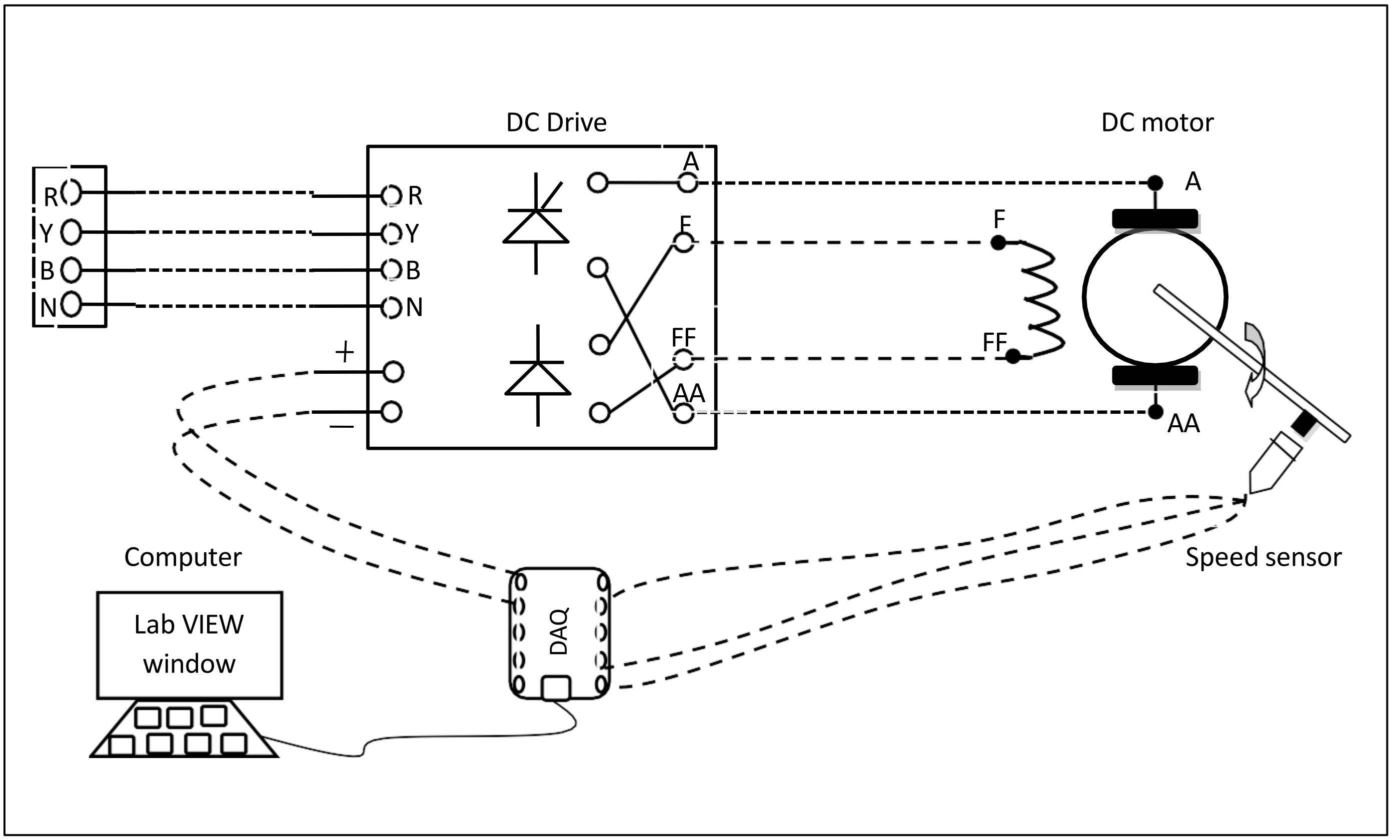


Fig.2.1 Circuit diagram for closed loop speed control of DC motor

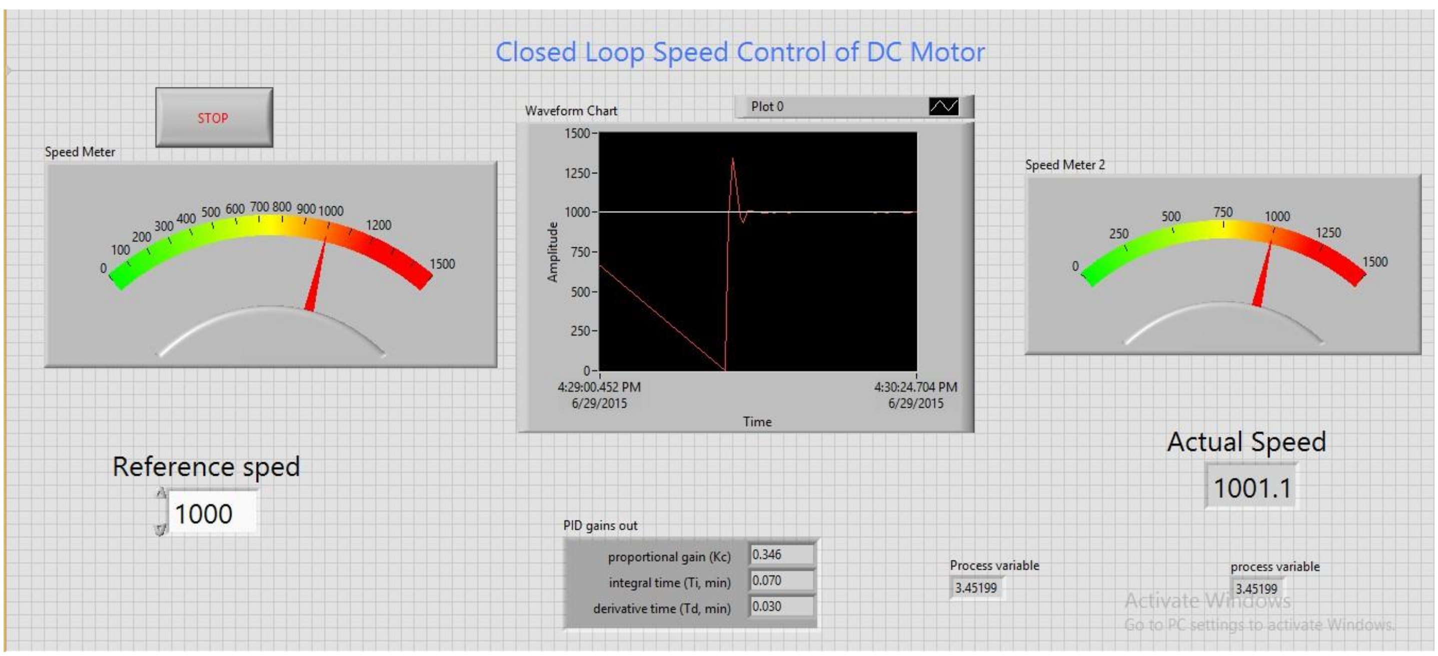


Fig.2.2 LabView front panel diagram of closed loop speed control of DC motor

Load is usually machinery designed to accomplish a given task. Usually load requirements can be specified in terms of speed control and torque demands. A motor having speed-torque characteristics and capabilities compatible with load demands. Power modulator modulates flow of power from the source to the motor in such a manner that motor is imparted speed-torque characteristics required by load. Controls for power modulator built in control unit which usually operates at much lower voltage and power levels.

Closed loop speed control of DC motor is shown in fig2.2 it consists of same elements present in block diagram 2.1, control unit is a computer in which control concept is implemented using LabView where auto tuning of PID control is done to get the motor speed to reference speed or set speed. Thyristor drive gives the required DC voltage to drive motor at desired speed according to output voltage variable from PID controller. PID controller adjusts the output voltage variable till the motor speed reaches desired speed.

Procedure:

1. Connect circuit as per circuit diagram
    - i. Connect supply to DC drive
    - ii. Connect output of DC drive to armature and field supplies of DC motor
    - iii. Connect speed sensor & DC drive variable point to DAQ assistant
2. Develop LabView diagram in back panel consists of reference speed, PID controller design and speed feedback.
3. Set the reference speed to some value say 1000 RPM
4. Tune the PID controller using auto-tune block till we get desired P, I , D values.
5. Ensure that motor speed follows the set speed or reference speed.
6. Take the data to excel file from LabView, draw the set speed and actual speed on a single plot
7. Observe the response of speed control loop using plot
8. Vary the P, I, D gains around the tune values and see the response.
9. Design the PI, PD controllers and repeat the step 3 to 8.

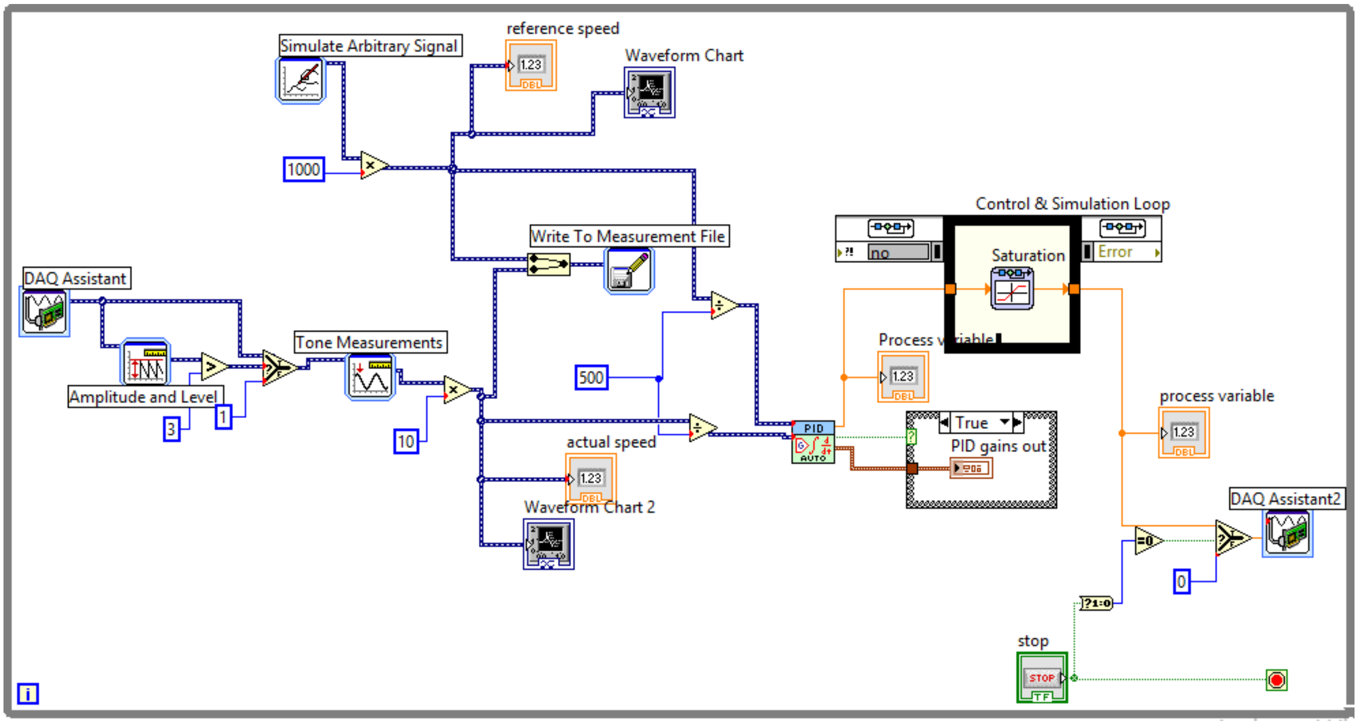


Fig.2.3 LabView Back panel diagram of closed loop speed control of DC motor

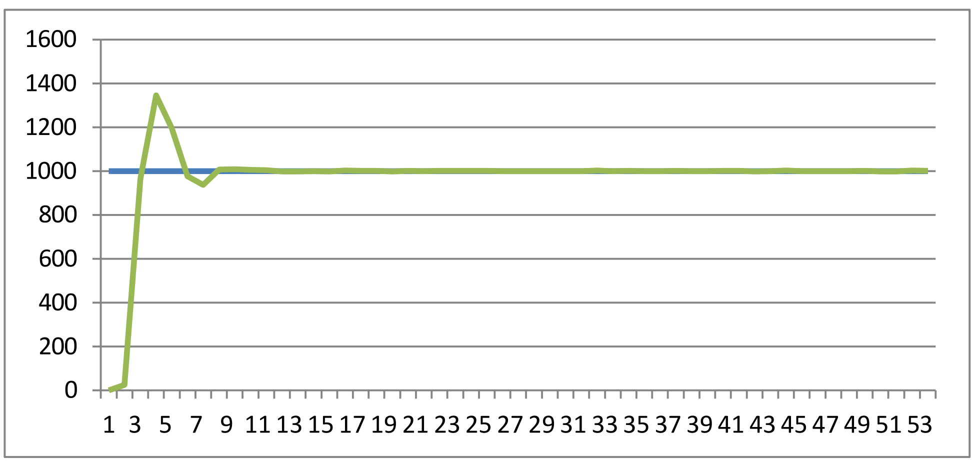


Fig.2.4 Model graph of closed loop speed control of DC motor

Table:

Reference Speed	PI gains	PD gains

Table 1: Different set speeds & P, I, D gains

Result: closed loop speed control of DC motor is done and speed response is plotted.

3. STEP,RAMP AND PARABOLIC SPEED RESPONSE OF SECOND ORDER DC MOTOR SYSTEM ON LABVIEW

AIM: To find step, ramp and parabolic speed response of second order DC motor system on LabView.

Apparatus:

i. NI LabView Software, DAQ
ii. Thyristorised DC drive
iii. DC motor
iv. Proximity Sensor

Specifications:

DC Drive	***DC motor, DC generator***
Thyristorized Bridge Rectifier: 0-220V DC	*Armature voltage:* 220V DC
Diode Bridge Rectifier : 220V DC	*Current:* 2Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

Most of the control systems use time as its independent variable, so it is important to analyse the response given by the system for the applied excitation which is function of time. The evaluation of system is based on the analysis of such response. The complete base of stability analysis, system accuracy and complete evaluation is always based on the time response analysis.

In many practical cases, the desired performance characteristics of control systems can be given in terms of transient response specifications and step, ramp, and parabolic inputs are commonly used as input for this purpose, since such an input is easy to generate. Mathematically, if the response of a linear system to a step input is known, by principle of superposition and linear theory assumptions, it is possible to compute the system's response to any input. However, the transient response of a system to a unit step input depends on initial conditions. If the inputs to a control system are gradually changing functions of time, then a ramp function of time may be a good test signal. If the inputs to a control system are gradually changing functions of time, then a parabolic function of time may be a good test signal.

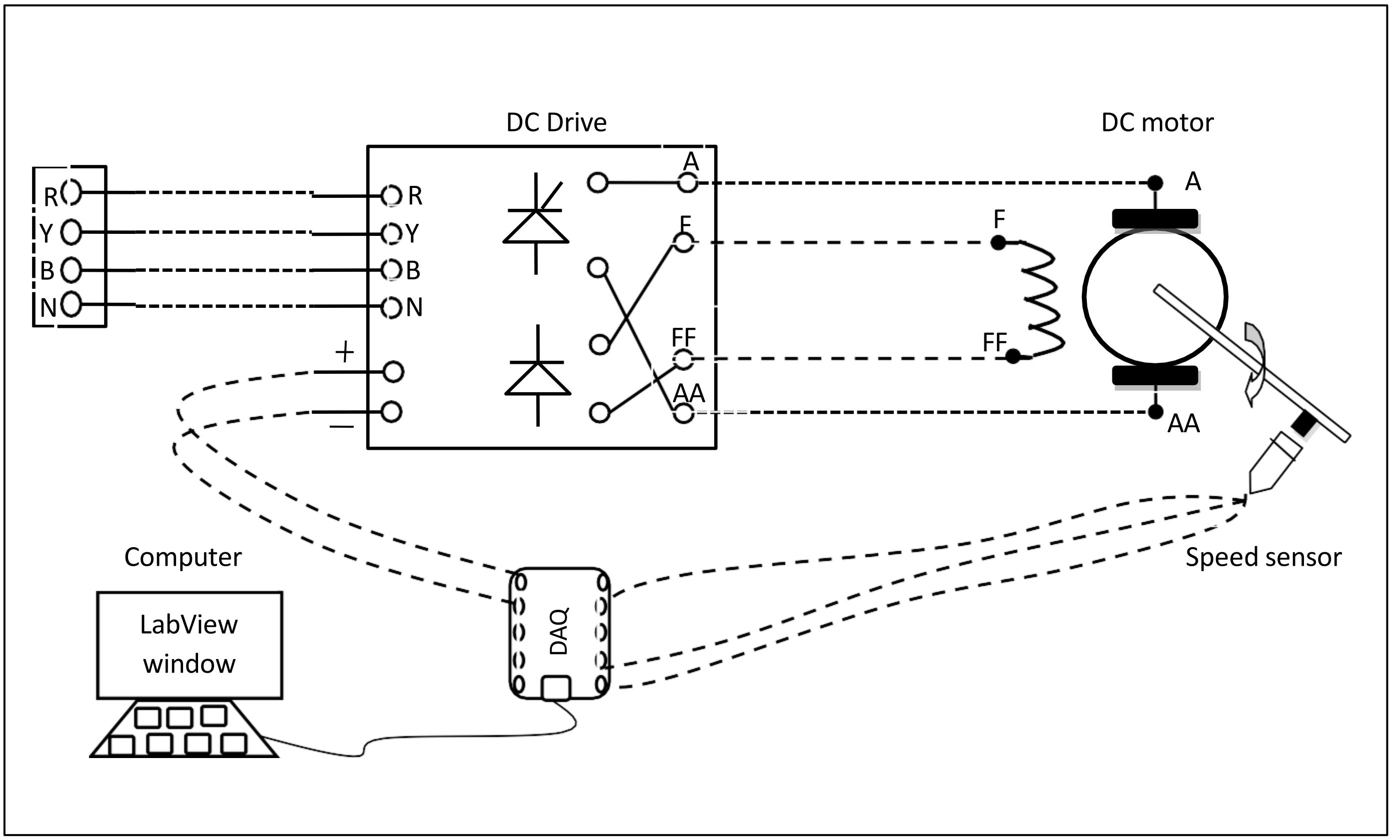


Fig.4.1 Circuit diagram for step, ramp, parabolic response of second order DC motor system

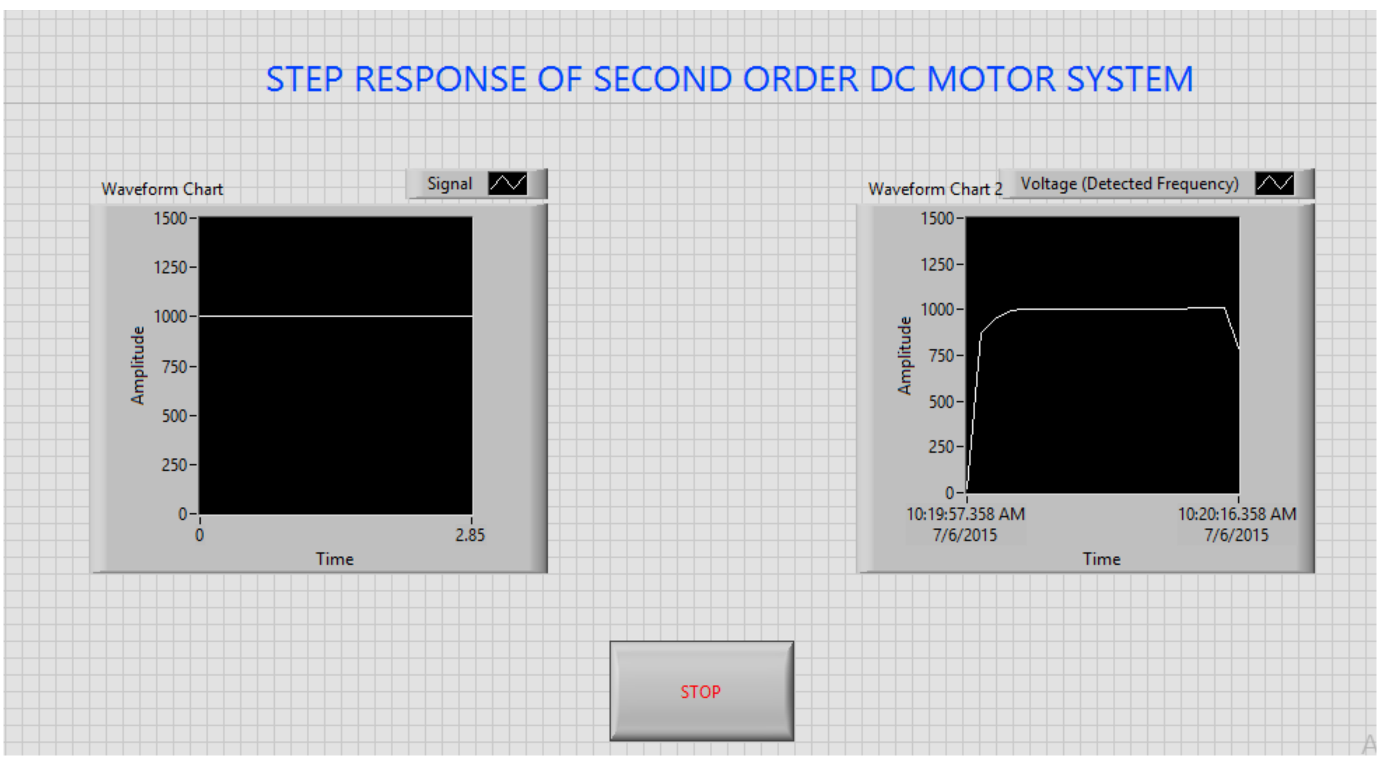


Fig.4.2 front panel diagram of step response of second order DC motor system

Step Function: Mathematically, a unit step function can be described by

$$f(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$$

In order to determine the response of a dynamic system to a step function, it is convenient to use Laplace Transform. The Laplace Transform of a unit step function is

$$L\{u(t)\} = \frac{1}{S}$$

The unit Step response of second order system is given by

$$C(s) = G(s)R(s) = \frac{w_n^2}{s(s^2 + 2\xi w_n s + w_n^2)}$$

Ramp Function: The Ramp signal is a signal which starts at a value of zero and increases linearly with time. Mathematically, a unit ramp function can be described by

$$r(t) = \begin{cases} At, & t > 0 \\ 0, & t < 0 \end{cases}$$

In order to determine the response of a dynamic system to a step function, it is convenient to use Laplace Transform. The Laplace Transform of a unit ramp function is

$$L\{u(t)\} = \frac{1}{S^2}$$

The unit Ramp response of second order system is given by

$$C(s) = G(s)R(s) = \frac{w_n^2}{s^2(s^2 + 2\xi w_n s + w_n^2)}$$

Parabolic Function: The Parabolic signal is a signal which starts at a value of zero and increases linearly with time. Mathematically, a unit parabolic function can be described by

$$r(t) = \begin{cases} At^2/2 & t \geq 0 \\ 0 & t < 0 \end{cases}$$

In order to determine the response of a dynamic system to a step function, it is convenient to use Laplace Transform. The Laplace Transform of a unit parabolic function is $L\{u(t)\} = \frac{1}{S^3}$

The unit parabolic response of second order system is given by $C(s) = G(s)R(s) = \frac{w_n^2}{s^3(s^2 + 2\xi w_n s + w_n^2)}$

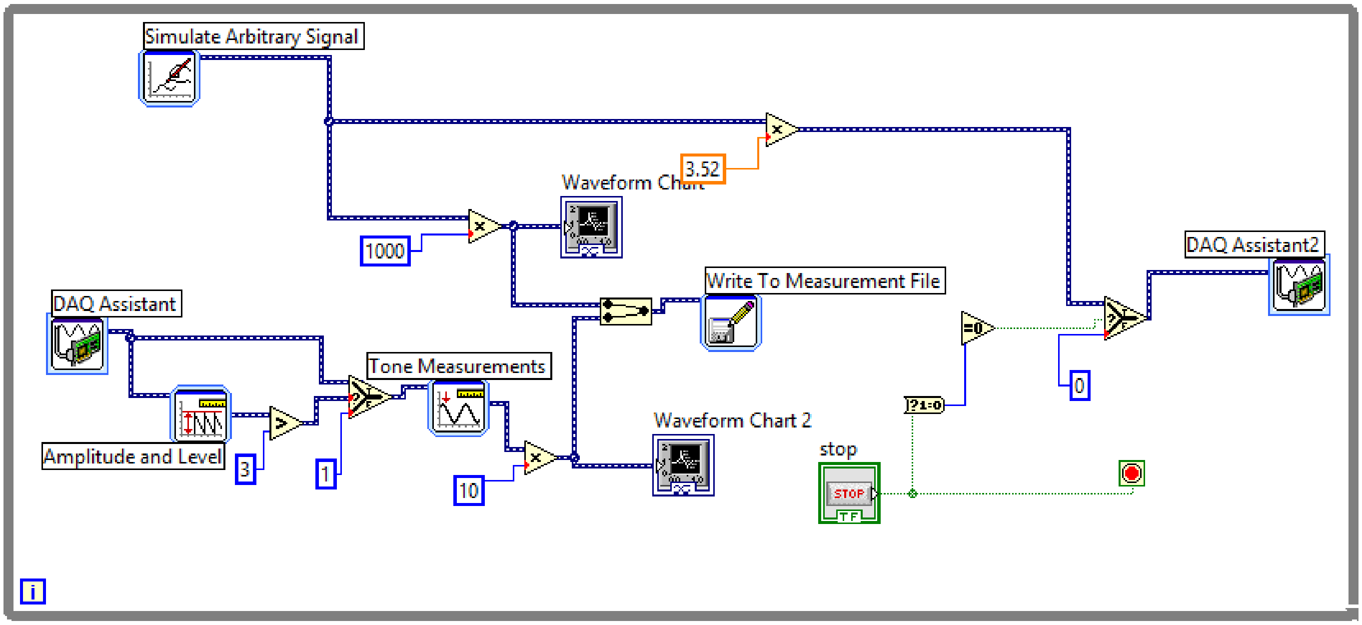


Fig.4.3 block diagram of step response of second order DC motor system

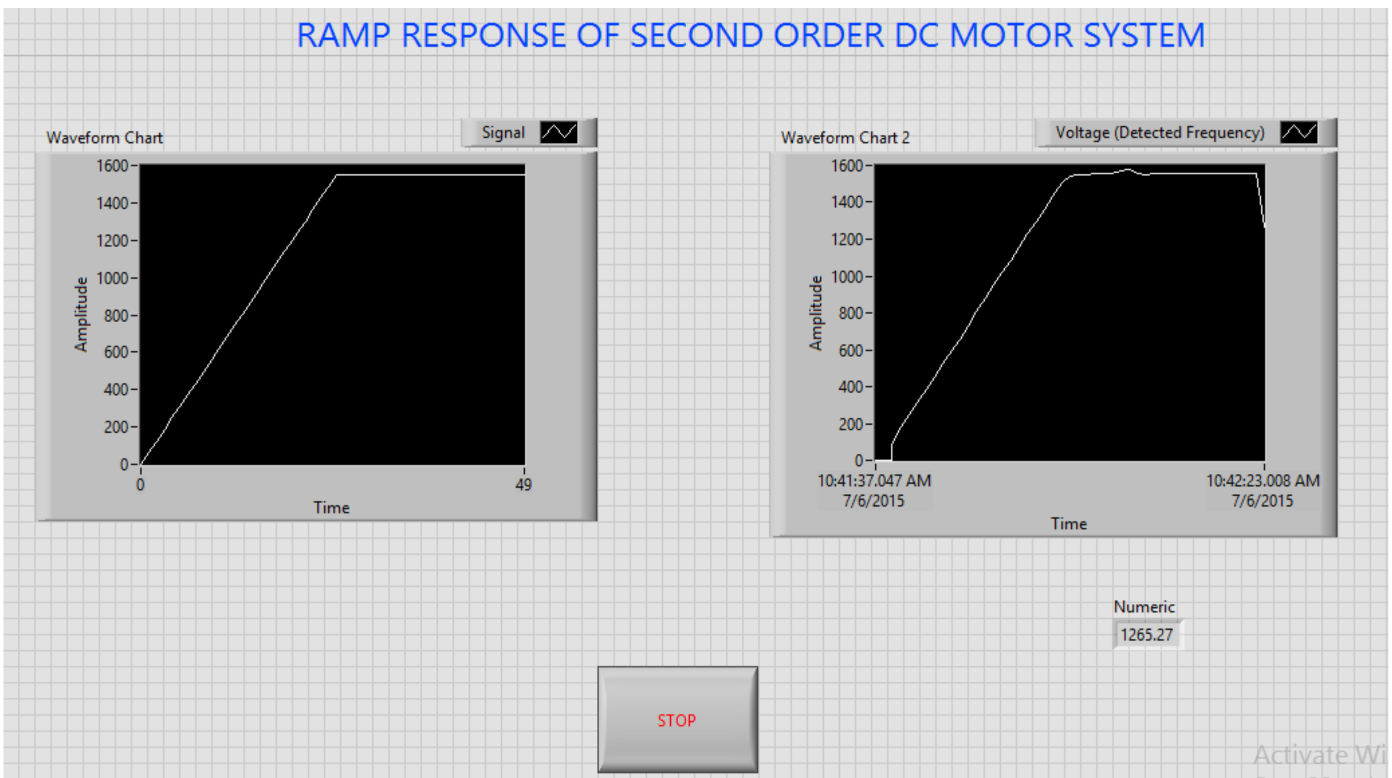


Fig.4.4 front panel of ramp response of second order DC motor system

Circuit diagram for step response of second order DC motor system is shown in fig4.1 it consists of same elements present in block diagram 2.1, power modulator control power flow from source to motor. Controlled voltage is generated from the step response of second order system i.e developed in LAB VIEW. Step signal is taken as reference speed signal. DC Motor receives the proportional voltage according to the step signal designed in LAB VIEW. We can observe the step speed response of second order DC Motor by speed characteristics. Circuit diagrams for ramp, parabolic is same as step signal and response of second order DC motor is obtained.

The closed loop transfer function of second order DC Motor is given by

$$\frac{\theta(s)}{R(s)} = \frac{K_p K_m}{s^2 T_m + s + K_p K_m}$$

Procedure:

1. Connect circuit as per circuit diagram
   i. Connect supply to DC drive
   ii. Connect output of DC drive to armature and field supplies of DC motor
   iii. Connect speed sensor & DC drive variable point to DAQ assistant
2. Develop LabView diagram in back panel consists of reference speed signal and speed feedback.
3. Construct reference speed signal as step signal using simulate arbitrary signal.
4. Run the LabView diagram for some time duration say 2mins.
5. Ensure that motor speed follows the set speed or reference speed.
6. Take the data to excel file, draw the set speed and actual speed on a single plot
7. Observe the response of speed control loop using plot
8. Construct Ramp & Parabolic signals and repeat the step 4 to 7.

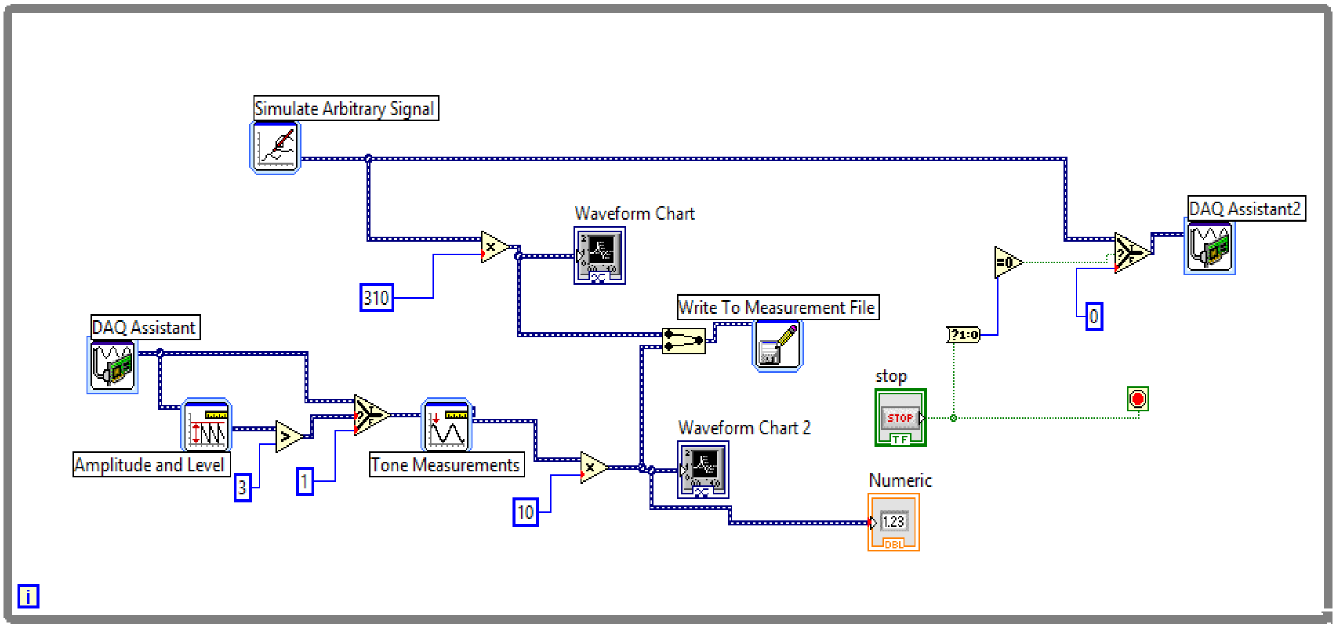


Fig.4.5 block diagram of ramp response of second order DC motor system

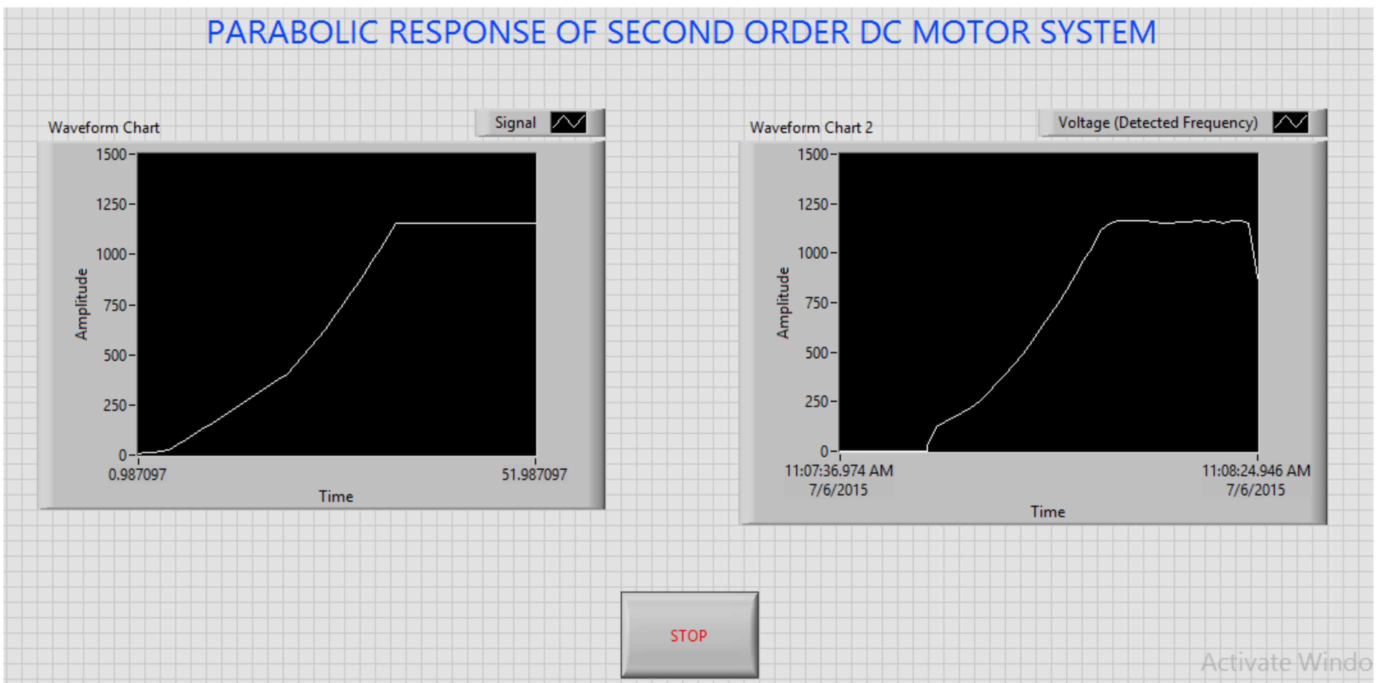


Fig.4.6 front panel of parabolic response of second order DC motor system

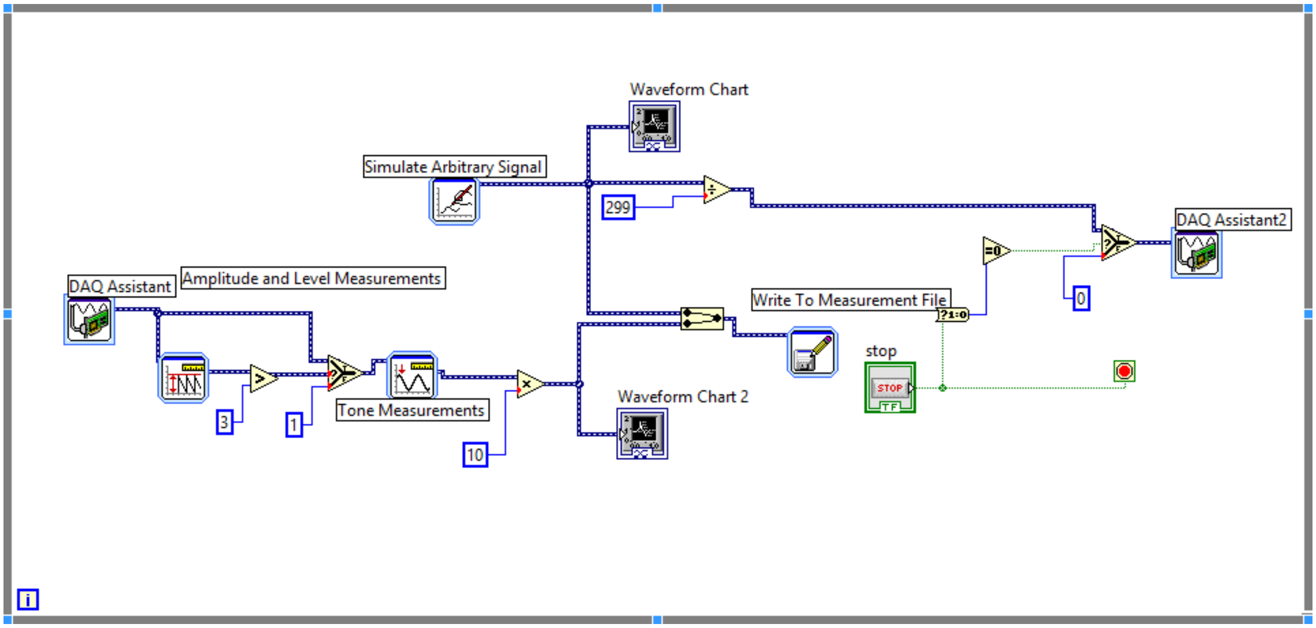


Fig.4.7 block diagram of parabolic response of second order DC motor system

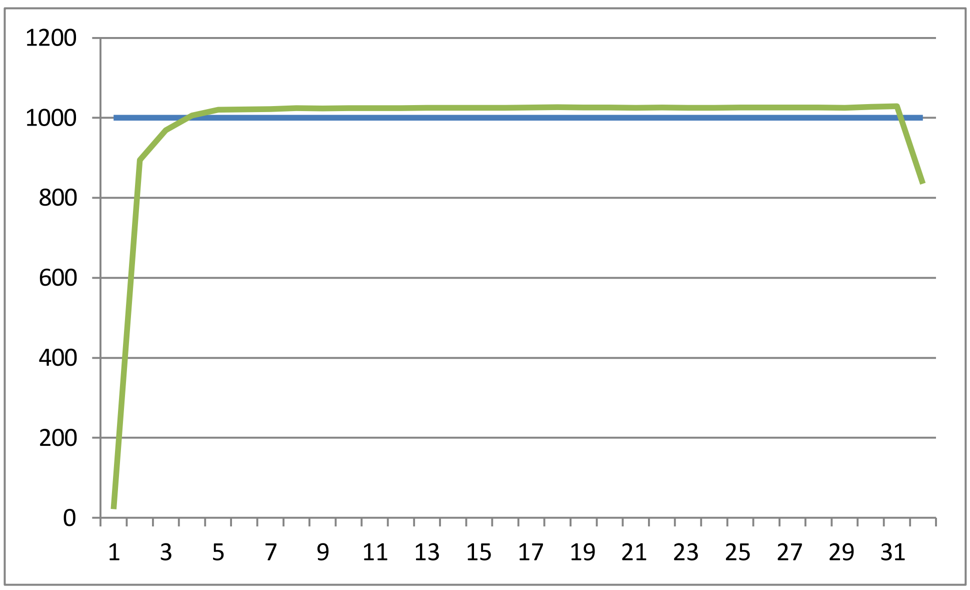


Fig.4.8 speed response plot of second order DC motor system with step input

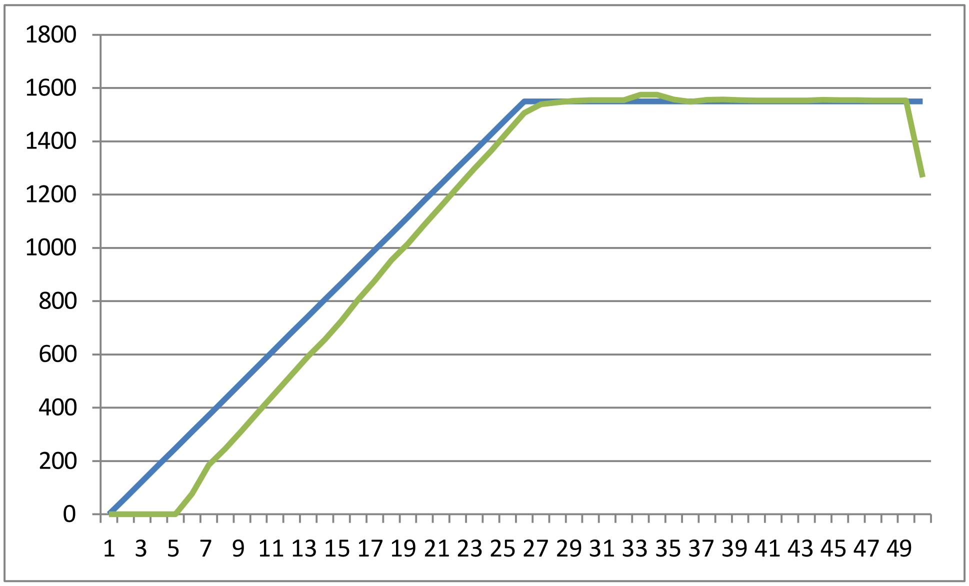


Fig.4.9 speed response plot of second order DC motor system with ramp input

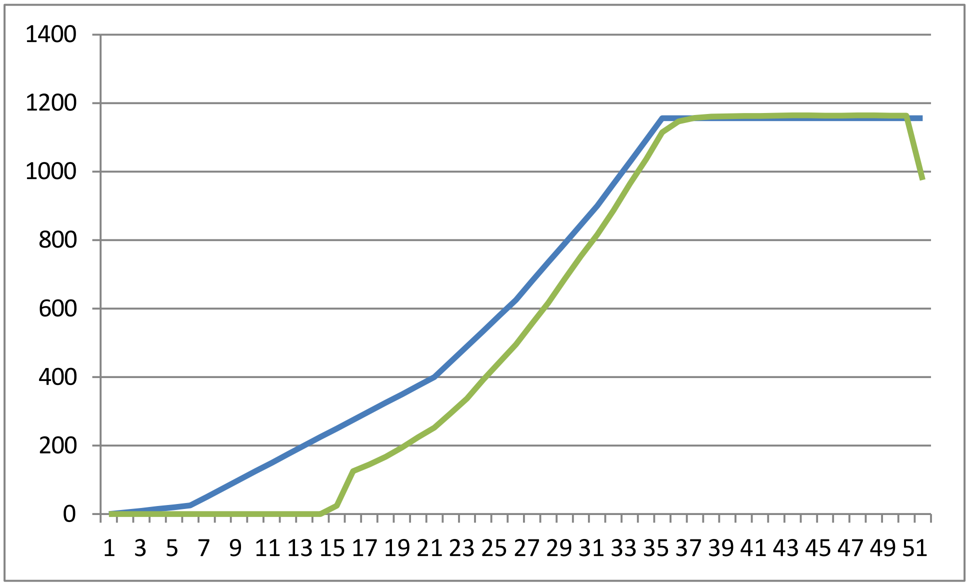


Fig.4.9 speed response plot of second order DC motor system with parabolic input

Result: speed response of second order DC motor system with step, ramp, parabolic inputs is obtained and speed response is plotted.

4. INDIRECT SPEED CONTROL OF DC MOTOR USING ARMATURE VOLTAGE CONTROL WITH PI,PID CONTROLLERS

AIM: To design and tune proper PI, PID controllers for indirect speed control of DC motor Drive using armature voltage control method.

Apparatus:

i. NI LabView Software, DAQ
ii. Control design and simulation tool kit
iii. Thyristorised DC drive
iv. DC motor
v. Voltage sensor.
vi. Proximity Sensor.

Specifications:

DC Drive	***DC motor***
Thyristorized Bridge Rectifier: 0-220V DC	*Armature voltage:* 220V DC
Diode Bridge Rectifier : 220V DC	*Current:* 2Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

Speed of DC motor can be controlled by armature voltage control method. The speed of DC motor is directly proportional to armature voltage and inversely proportional to flux in field winding. In armature controlled DC motor the desired speed is obtained by varying the armature voltage. This speed control system is an electromechanical control system. The electrical system consists of the armature and the field circuit. Armature circuit is taken for analysis with field excitation is constant. The mechanical system consists of the rotating part of the motor and load connected to the shaft of the motor. The transfer function of armature controlled dc motor can be expressed in another standard form as shown below.

$$\frac{\theta(s)}{V_a(s)} = \frac{K_t}{s\left[(1+sT_a)(1+sT_m)+\frac{K_b K_t}{R_a B}\right]}$$

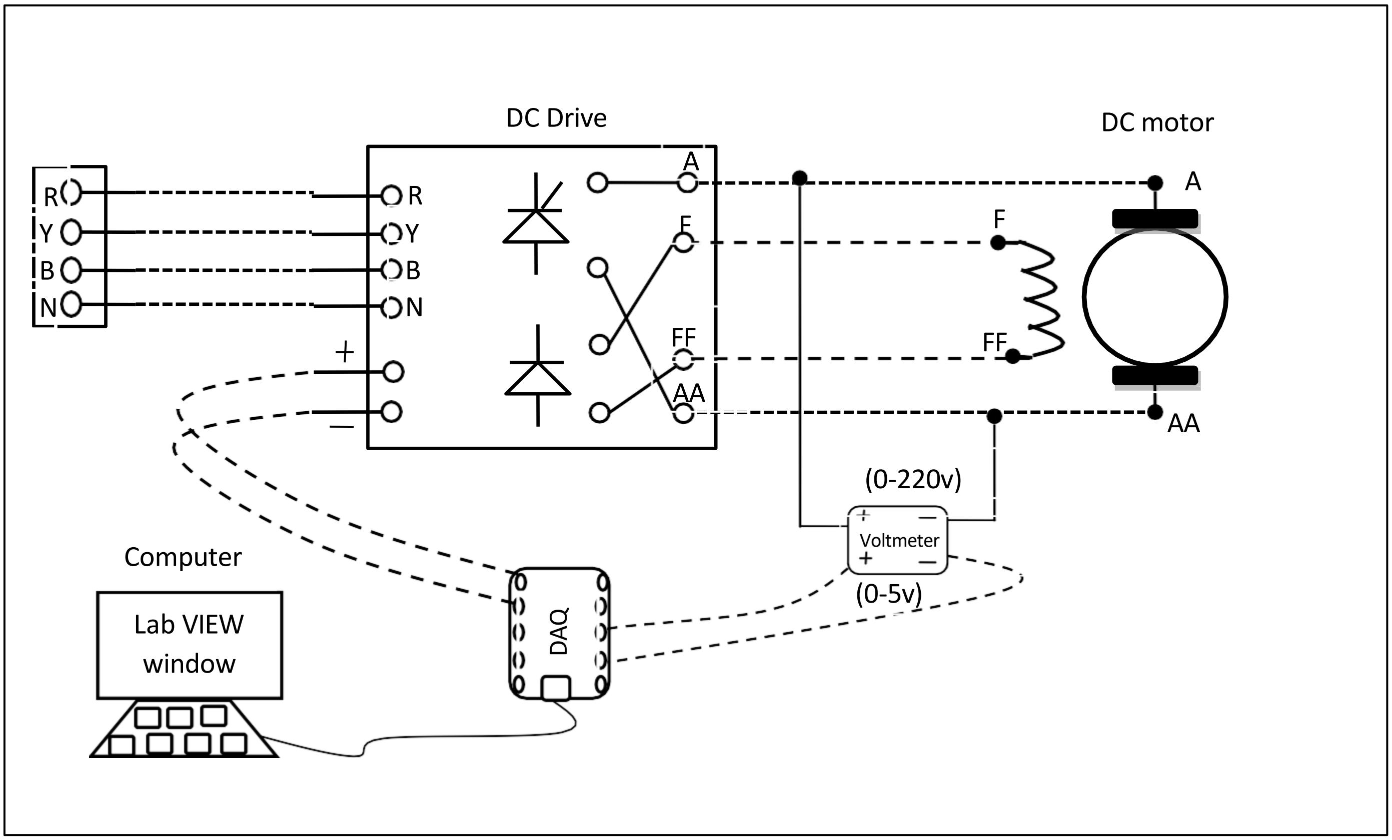


Fig.6.1 circuit diagram for voltage control of DC motor

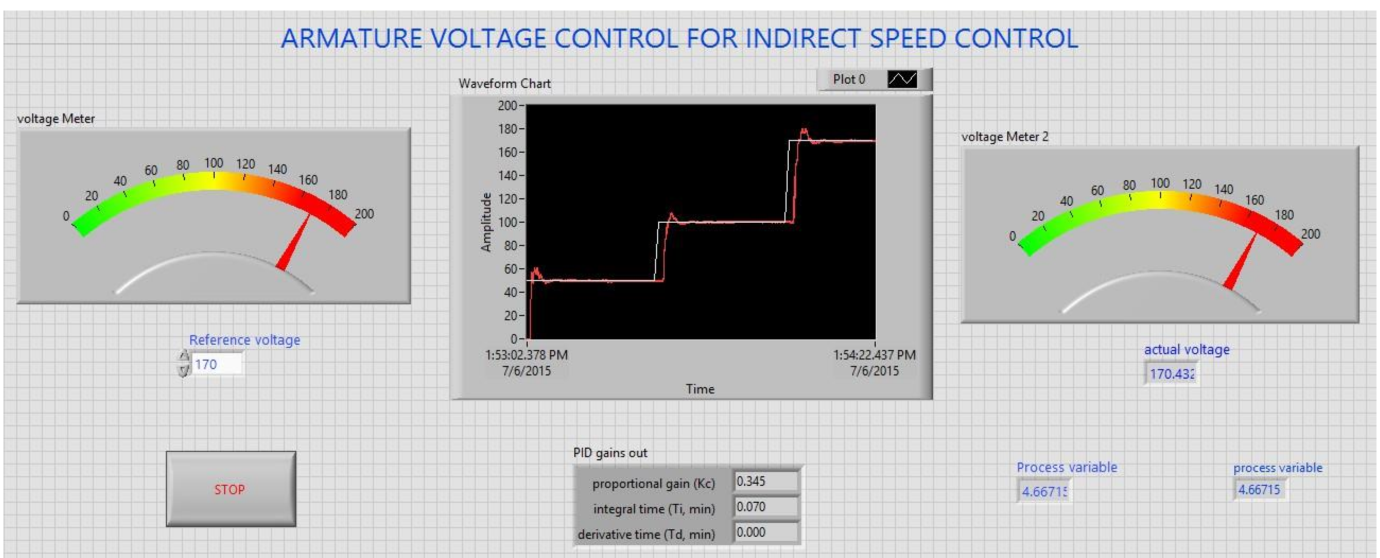


Fig.6.2 front panel diagram of armature voltage control of DC motor in LabVIEW

Closed loop indirect speed control of DC motor is shown in fig.6. Thyristor drive gives the required DC voltage to drive motor at desired voltage according to output voltage variable from PID controller. PID controller adjusts the output voltage variable till the motor armature voltage reaches desired voltage.

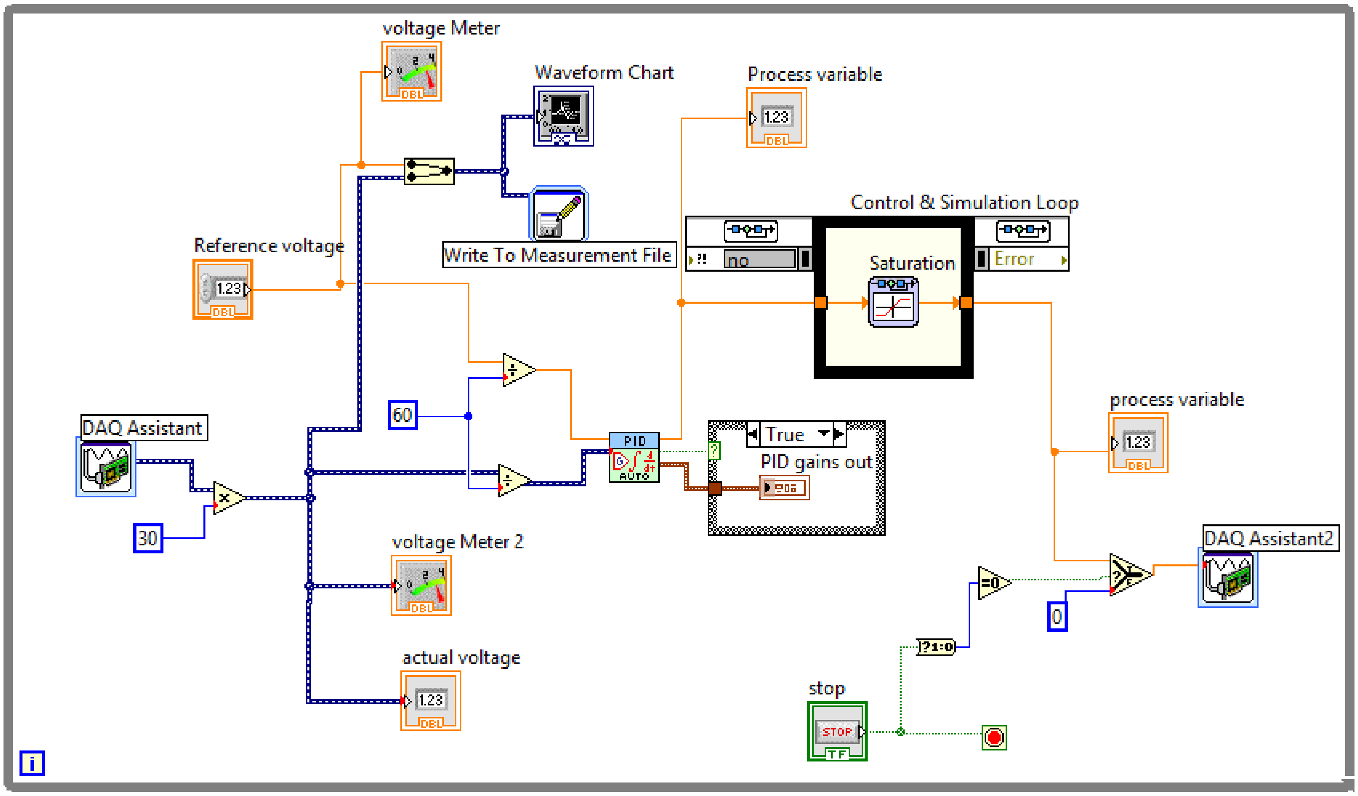


Fig.6.3 block diagram of armature voltage controlled DC motor in LabVIEW

Procedure:

1. Connect circuit as per circuit diagram
   i. Connect supply to DC drive
   ii. Connect output of DC drive to armature and field supplies of DC motor
   iii. Connect voltage sensor & DC drive variable point to DAQ assistant
2. Develop LabView diagram in back panel consists of reference voltage, PID controller design and voltage feedback.
3. Set the reference voltage to some value say 2 volts.
4. Run the LabView diagram Tune the PID controller using auto-tune block till we get desired P, I , D values.
5. Ensure that motor voltage follows the set voltage or reference voltage.
6. Take the data to excel file, draw the set voltage and actual voltage on a single plot

7. Observe the response of voltage control loop using plot
8. Vary the P, I, D gains around the tune values and see the response.

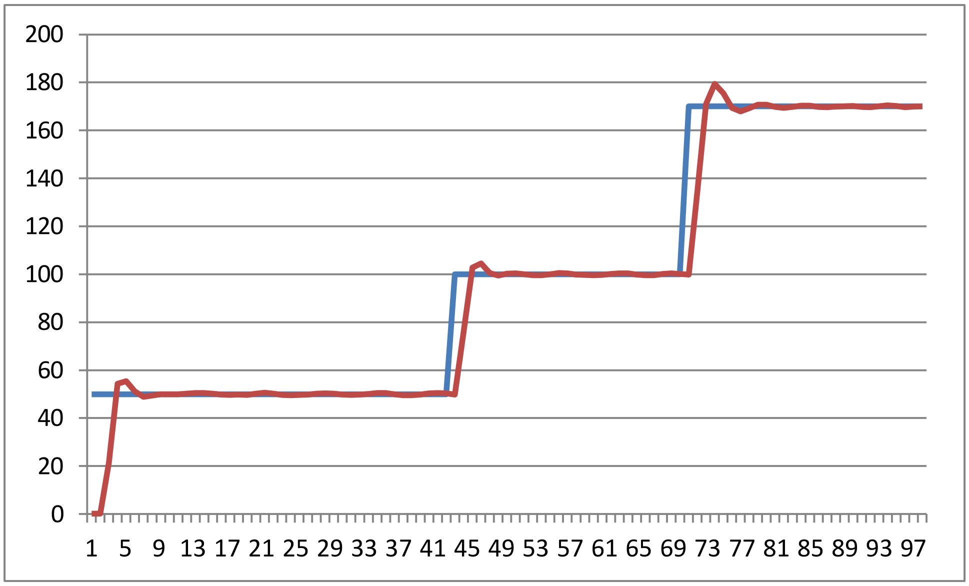


Fig.6.4 voltage response of DC motor in armature voltage control

Result: indirect speed control of DC motor with armature voltage control is done and speed response is plotted.

5. V/F CONTROL OF AC DRIVE CONNECTED TO AC MOTOR SYSTEM ON LABVIEW

AIM: To obtain V/F control of AC drive connected to AC motor system on LabView.

Apparatus:

i. NI LabView Software, DAQ
ii. V/F AC drive
iii. Induction motor
iv. Proximity Sensor

Specifications:

AC Drive	***Induction motor***
Three phase Inverter: 0-415V AC	*Armature voltage:* 415V AC
	Current: 0.9Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

The Principle of Constant V/Hz for AC Induction Motor is explained as follows:

Applied voltage to armature is proportional to frequency and air gap flux of induction motor. i.e.

$$V \approx \phi . f$$

$$V/f \approx \phi \text{ = constant}$$

If we maintain voltage to frequency ratio constant than flux in machine is constant. And torque is independent of supply frequency. The ratio between the magnitude and frequency of the stator voltage is usually based on the rated values of these variables, or motor ratings. However, when the frequency and hence also the voltage are low, the voltage drop across the stator resistance cannot be neglected and must be compensated. At frequencies higher than the rated value, the constant V/Hz principle also have to be violated because, to avoid insulation break down, the stator voltage must not exceed its rated value.

The figure 7.1 shows an AC drive with V/F control concept inbuilt in the drive. By varying controlled voltage to the drive from 0-10V speed of induction motor connected to AC drive varies from 0 to 1500 rpm.

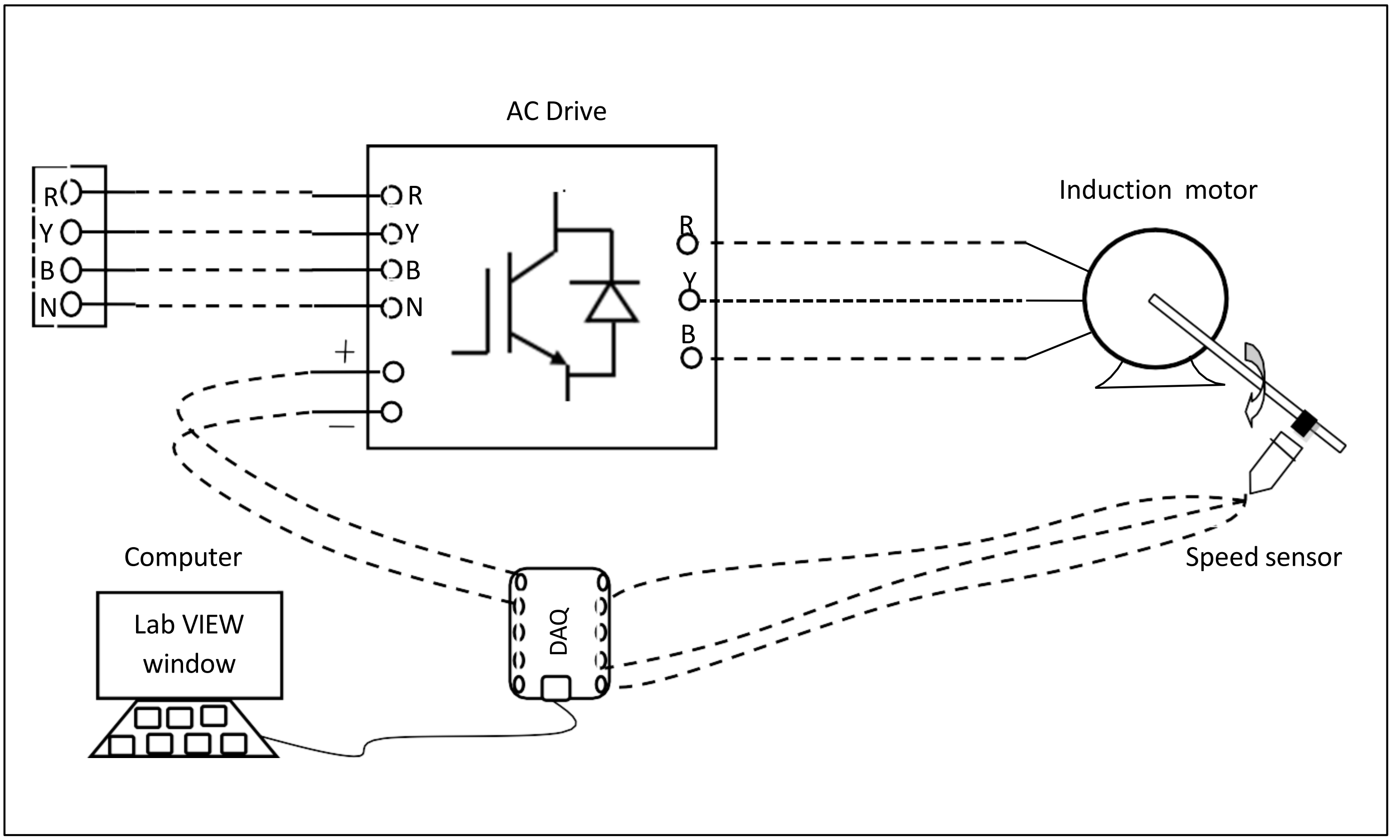


Fig.7.1 circuit diagram of V/F control of AC motor

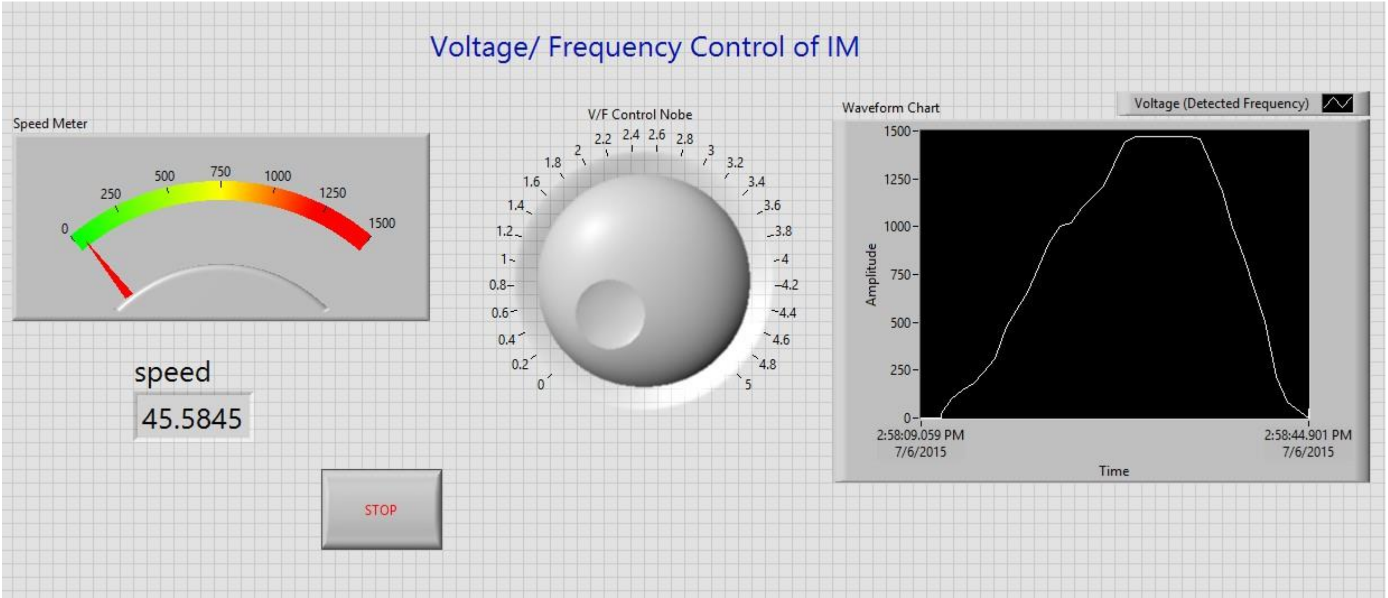


Fig.7.2 front panel diagram of V/F control of AC motor in LabVIEW

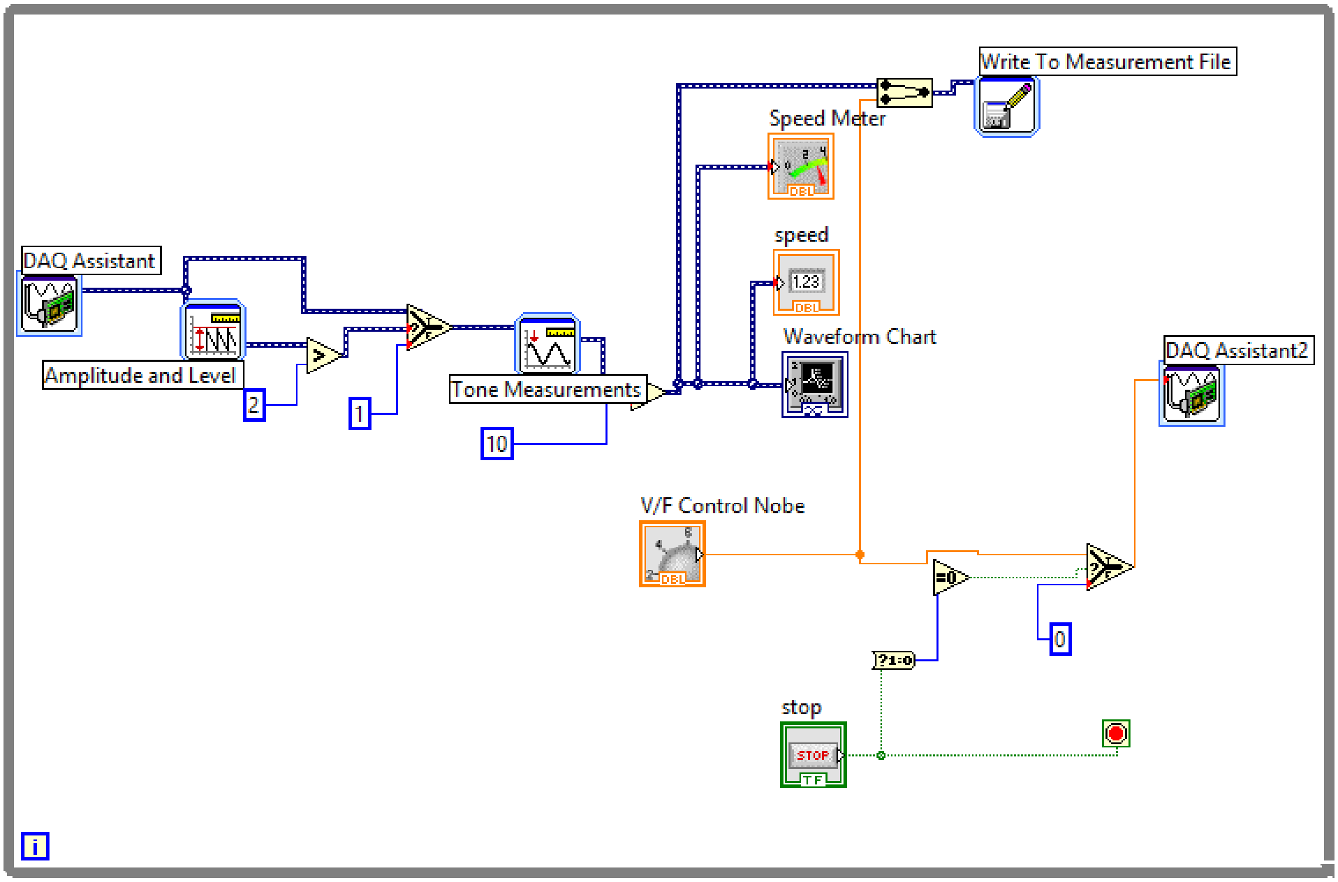


Fig.7.3 block diagram of V/F control of induction motor

Procedure:

1. Connect circuit as per circuit diagram

    i. Connect supply to AC drive

    ii. Connect output of AC drive to armature and field supplies of Induction motor

    iii. Connect speed sensor & AC drive variable point to DAQ assistant

2. Develop LabView diagram in back panel consists of V/F nobe and speed feedback.

3. Obtain the speed response by adjusting V/F nobe and plot the speed response.

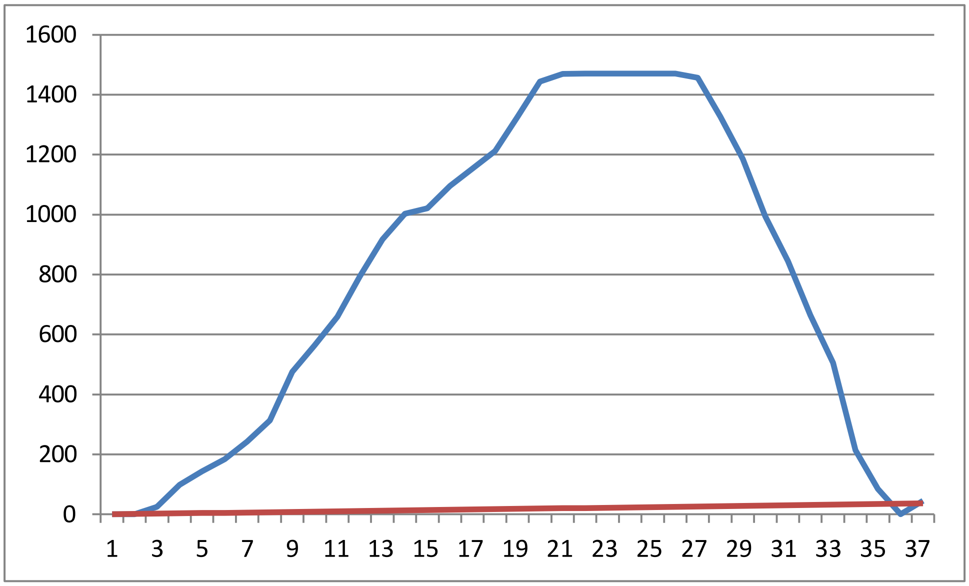


Fig.7.4 speed response of V/F control of induction motor

Result: V/F control of AC motor is done and speed response is plotted

6. CLOSED LOOP SPEED CONTROL OF AC MOTOR USING STEP, RAMP, PARABOLIC INPUTS AND PI, PID CONTROLLERS

AIM: To design and tune proper PI, PID controllers for speed control of AC motor Drive with step, ramp and parabolic as reference inputs.

Apparatus:

i. NI LabView Software, DAQ
ii. Control design and simulation tool kit
iii. V/F AC drive
iv. Induction motor
v. Proximity Sensor

Specifications:

AC Drive	***Induction motor***
Three phase Inverter: 0-415V AC	*Armature voltage:* 415V AC
	Current: 0.9Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

The proportional integral derivative (PID) controller is the most common form of feedback used in the control systems. It can be used for various Industrial applications. One of the applications used here is to control the speed of the AC motor. Controlling the speed of a AC motors is very important as any small change can lead to instability of the closed loop system. The aim of this experiment is to show how AC motor can be controlled by using a Step,ramp, parabolic inputs and PID controller in LabVIEW.

Closed loop speed control of AC motor is shown in fig11.1 it consists of same elements present in block diagram 8.1, power modulator control power flow from source to motor. Power modulator is a AC drive consists of inverter where output voltage is varied based on controlled voltage given as input to gating circuit, as input voltage varies from 0 to 10V DC drive output varies from 0-220V. Controlled voltage is generated from closed loop with PID control implemented in LabView based on reference speed signal either step, ramp and parabolic.

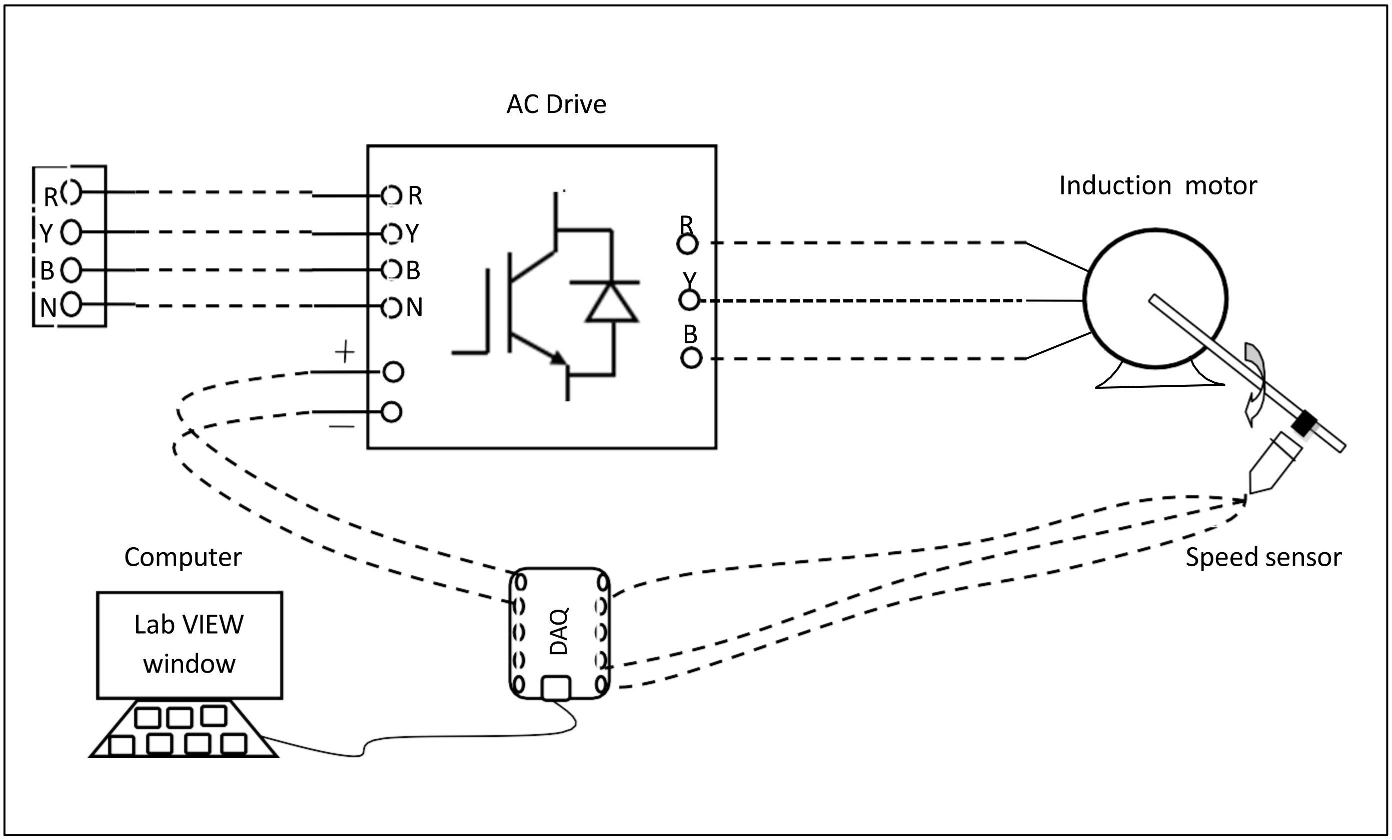


Fig.11.1 circuit diagram of closed loop speed control of second order AC motor system

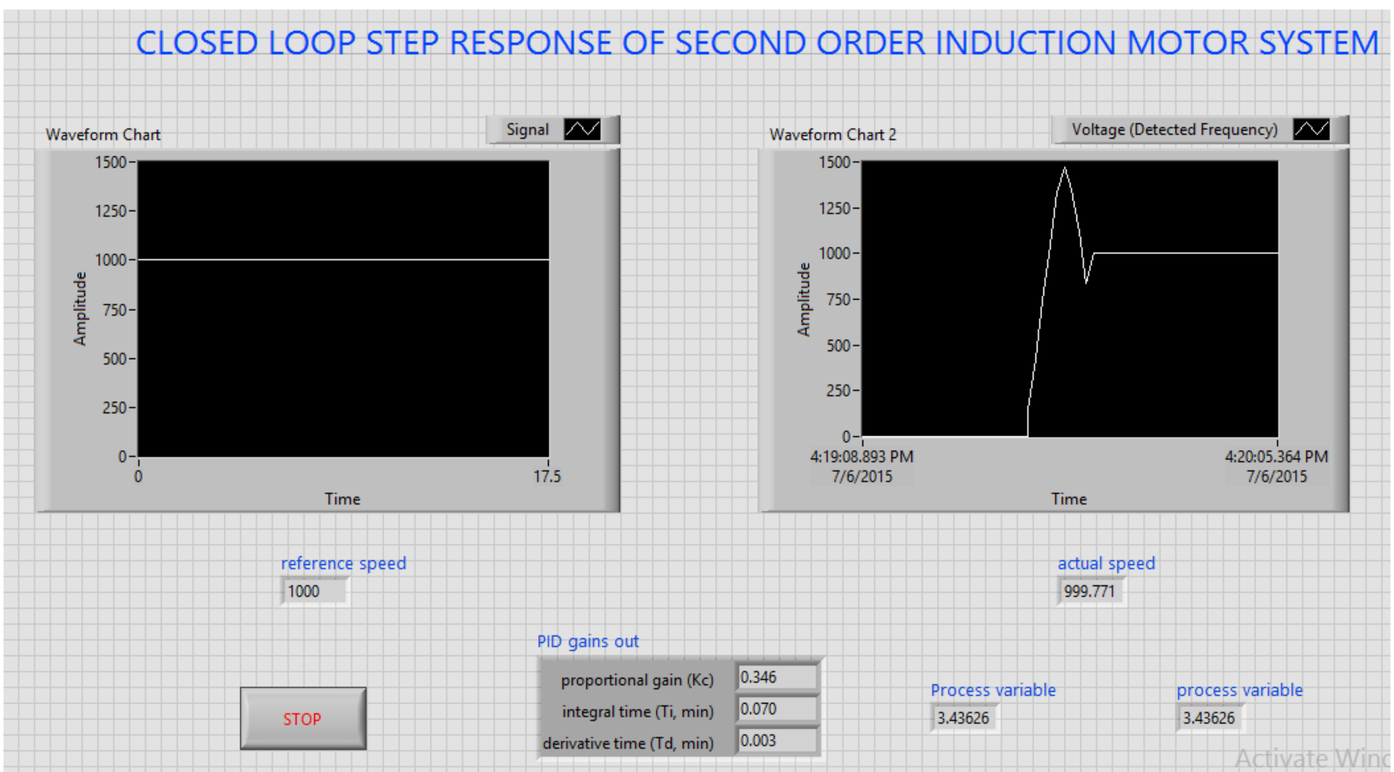


Fig.11.2 LabVIEW front panel diagram of closed loop speed control of second order AC motor system with step input

Step signal is taken as reference speed signal. Reference speed is set by the designing of step signal in LabView. Actual speed is sensed using proximity speed sensor and compared with reference speed an speed error is generated, if error is positive PID controller increases controlled voltage and if error is negative it decreases the controlled voltage till the motor speed attains set reference speed. Saturation limiter is limits the output voltage always in between 0 -5V even though PID controller output varies 100 to +100. PID controller is tuned using auto tune blocks available in control design & simulation tool box.

A graph is plotted between step signal speed and actual speed of motor by getting data from LabView using LVM file and drawn in Excel sheet, we can observe the step speed response of second order AC Motor with PID controller by speed characteristics. Similarly response of ramp and parabolic signals obtained.

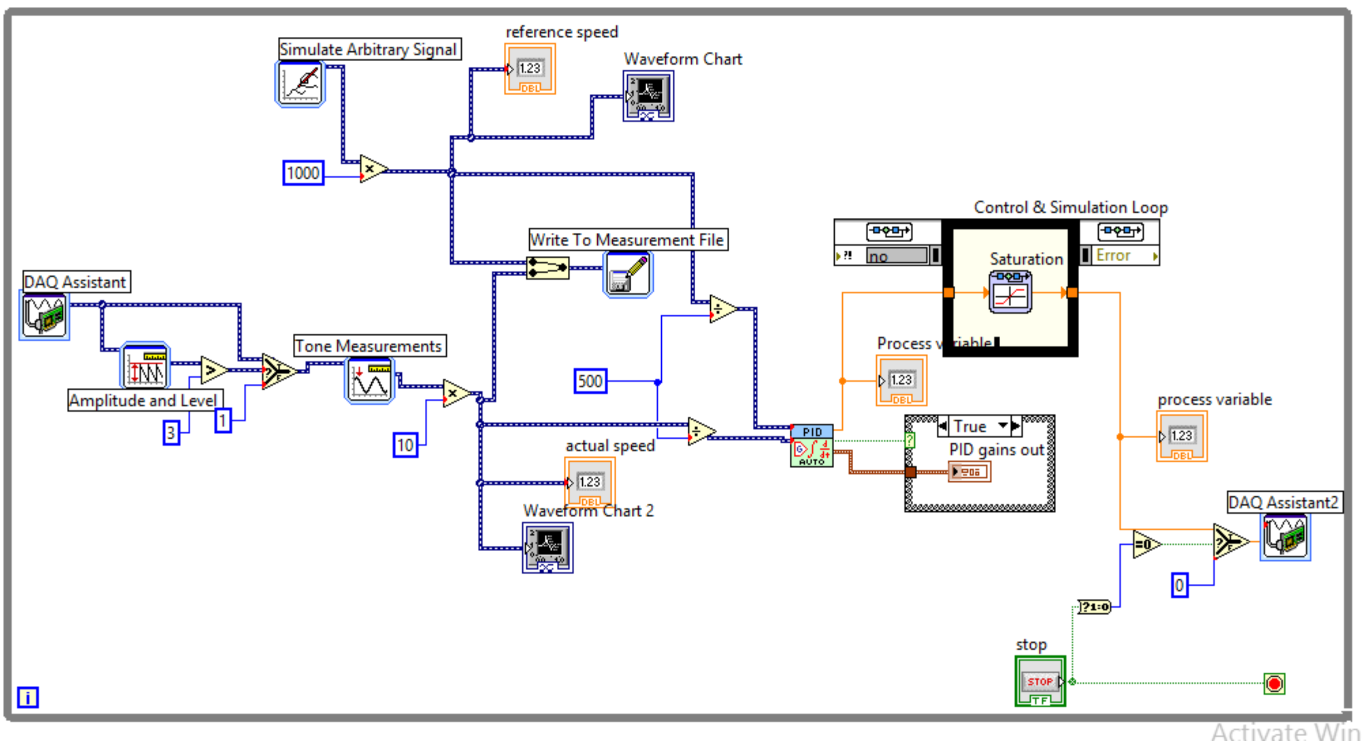


Fig.11.3 LabVIEW block diagram of closed loop speed control of AC motor with step input

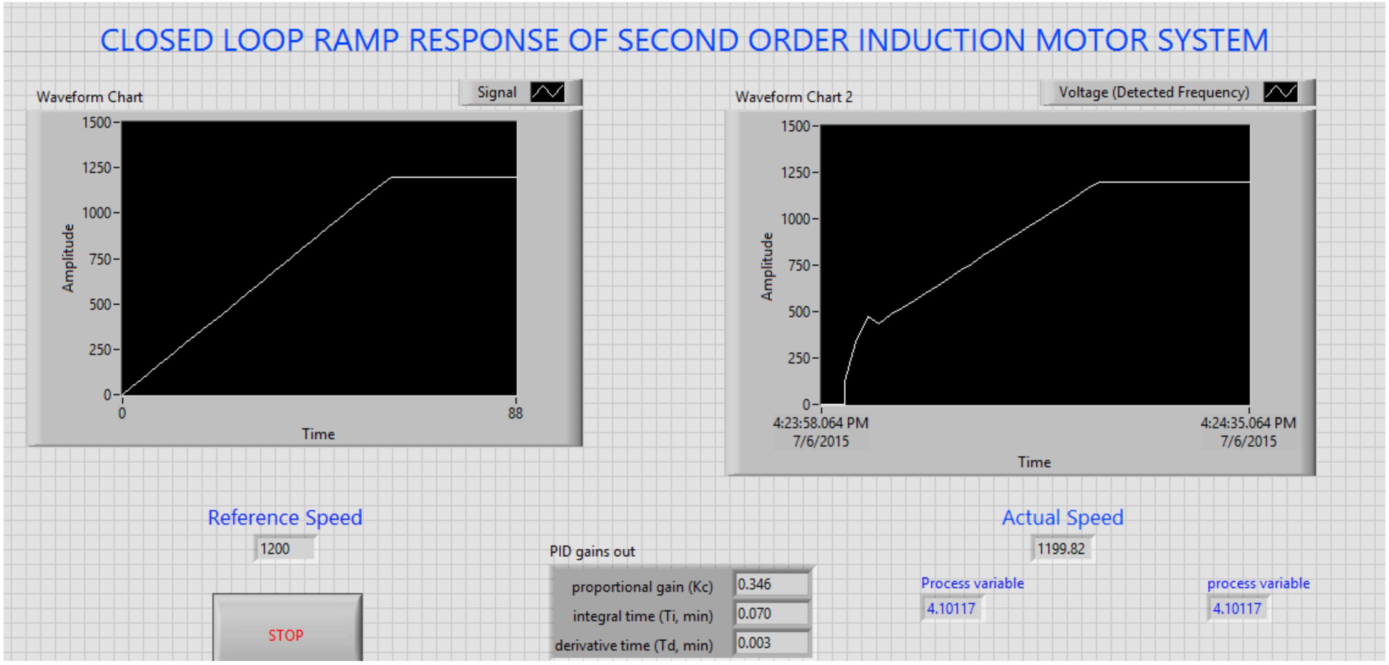


Fig.11.4 LabVIEW front panel diagram of closed loop speed control of second order AC motor system with ramp input

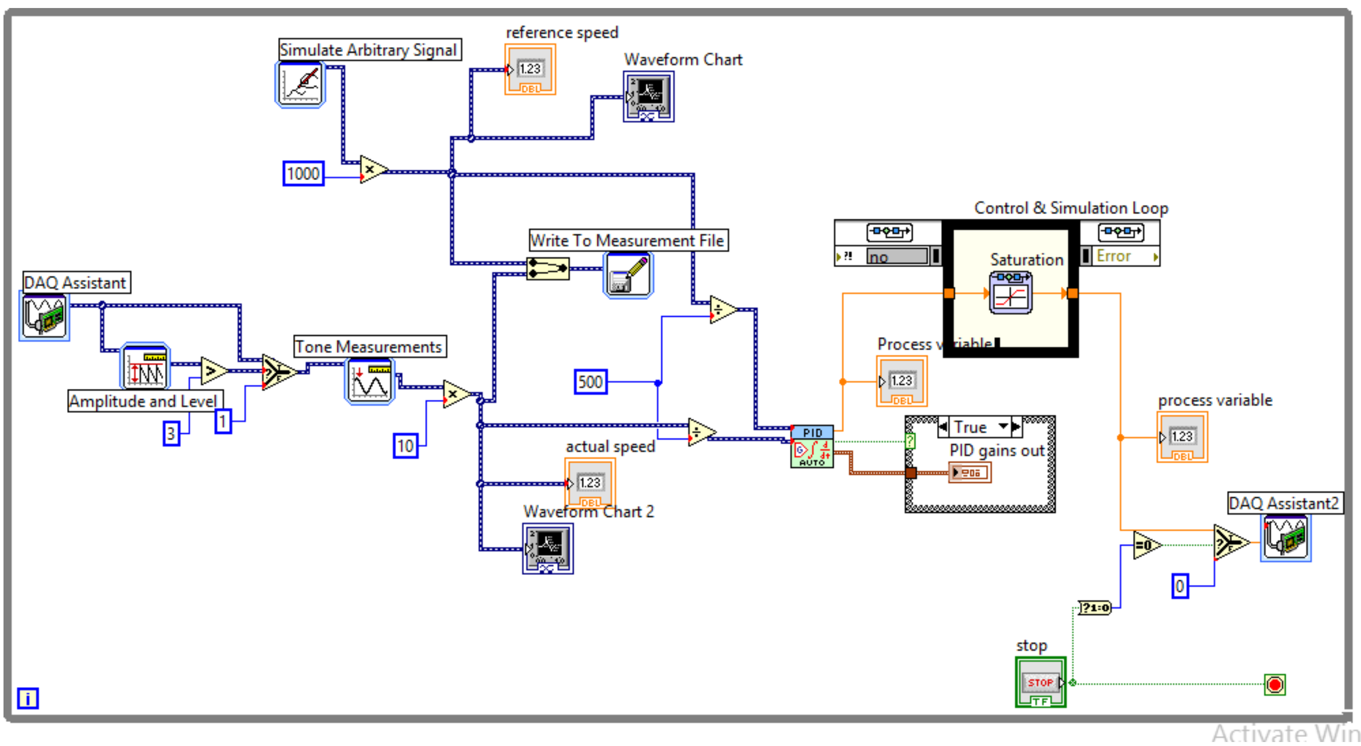


Fig.11.5 LabVIEW block diagram of closed loop speed control of second order AC motor system with ramp input

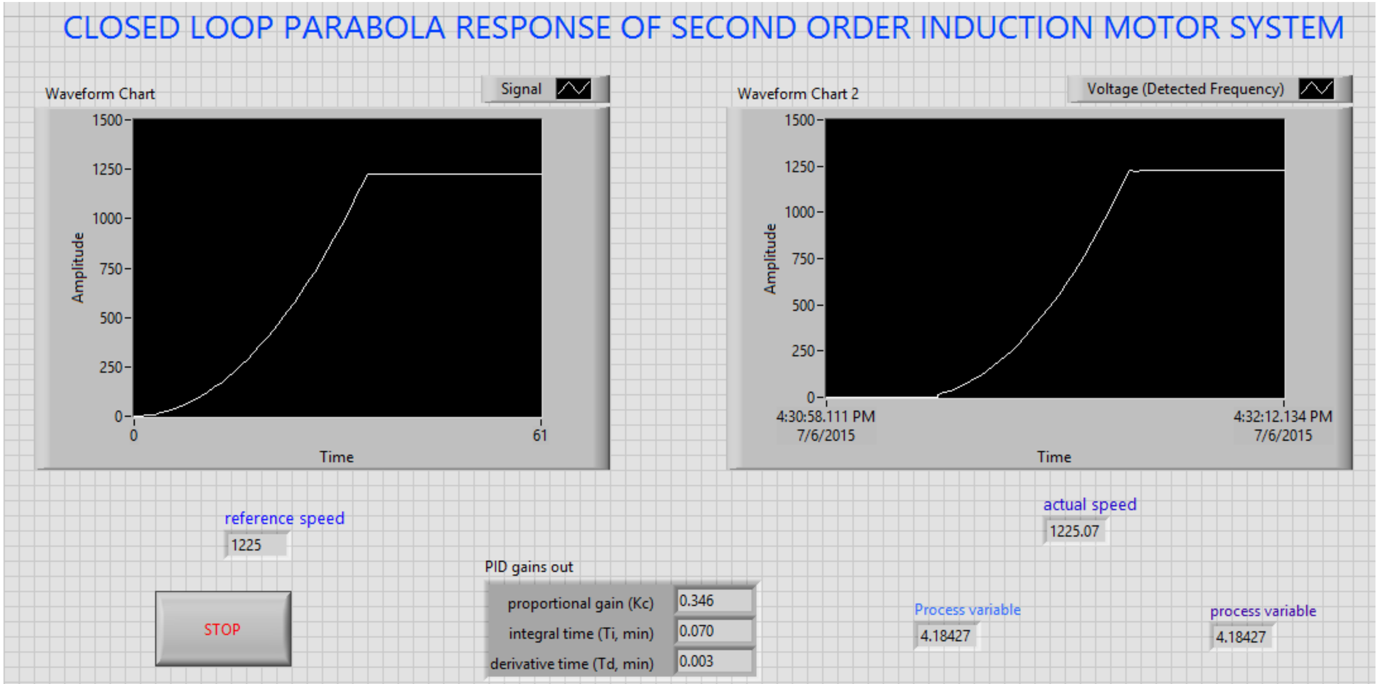


Fig.11.6 LabVIEW front panel diagram of closed loop speed control of second order AC motor system with parabolic input

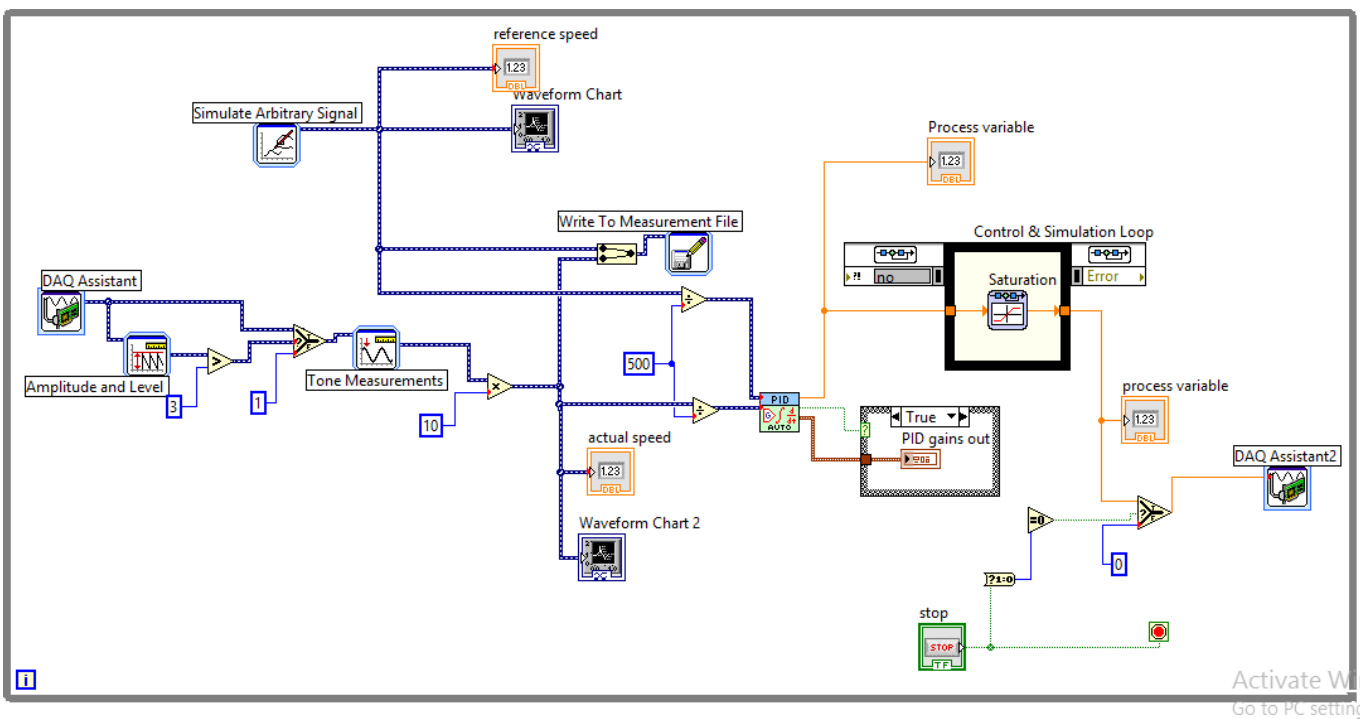


Fig.11.7 LabVIEW block diagram of closed loop speed control of second order AC motor system with parabolic input

Procedure:

1. Connect circuit as per circuit diagram

    i. Connect supply to AC drive

    ii. Connect output of AC drive to armature and field supplies of Induction motor

    iii. Connect speed sensor & AC drive variable point to DAQ assistant

2. Develop LabView diagram in back panel consists of reference speed, PID controller design and speed feedback.

3 .Construct reference speed signal as step signal using simulate arbitrary signal.

4 . Run the LabView diagram Tune the PID controller using auto-tune block till we get desired P, I , D values.

5 Ensure that motor speed follows the set speed or reference speed.

6 Take the data to excel file, draw the set speed and actual speed on a single plot

7 Observe the response of speed control loop using plot

8 Vary the P, I, D gains around the tune values and see the response

9 Construct the ramp, parabolic signals and repeat the step 4 to 7

10 Design the PI controller and repeat the step 3 to 9.

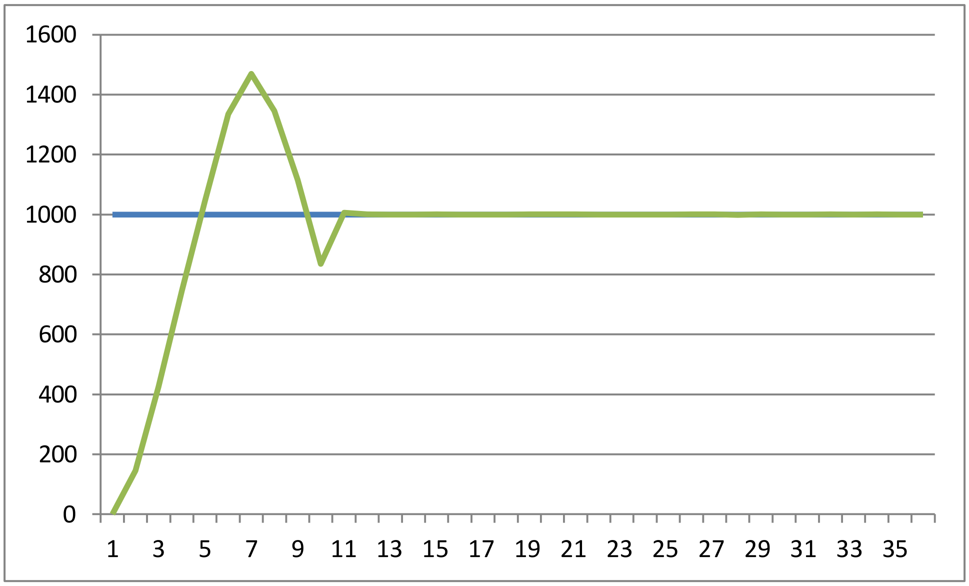


Fig.11.8 speed response of second order AC motor system with step input

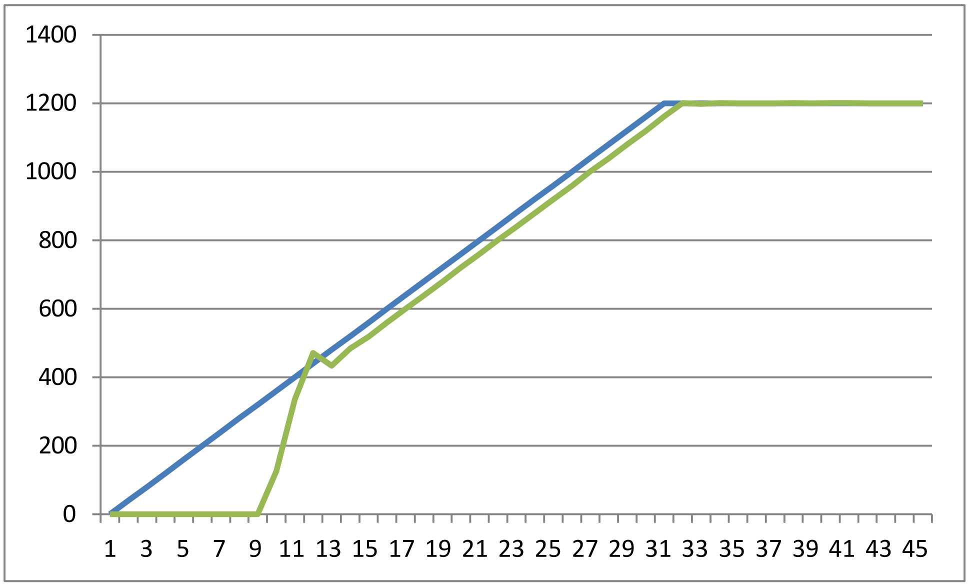


Fig.11.9 speed response of second order AC motor system with ramp input

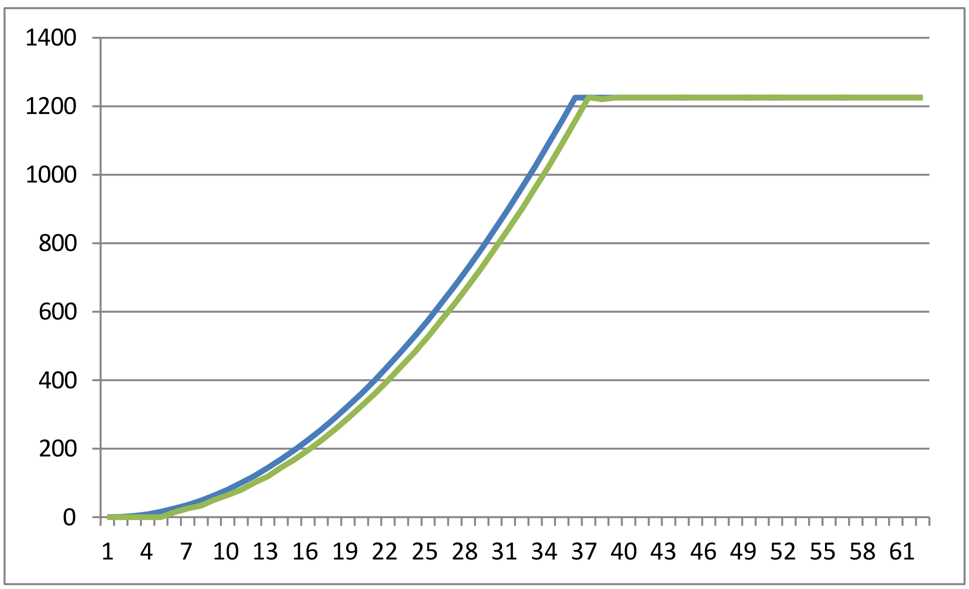


Fig.11.10 speed response of second order AC motor system with parabolic input

Table:

Reference Speed	PI gains	PD gains
	P= I=	P= D=
	P= I=	P= D=

Table 1: Different set speeds & P, I, D gains

Result: closed loop speed control of second order AC motor with step, ramp and parabolic inputs is done and speed response plotted.

7. CLOSED LOOP SPEED CONTROL OF AC MOTOR-GENERATOR SET WITH LOAD USING PI, PID CONTROLLERS

AIM: To design and tune proper PI, PID controllers for speed control of DC motor-generator set with load.

Apparatus:

i. NI LabView Software, DAQ
ii. Control design and simulation tool kit
iii. V/F AC drive
iv. Induction motor
v. Proximity Sensor

Specifications:

AC Drive	***Induction motor***
Three phase Inverter: 0-415V AC	*Armature voltage:* 415V AC
	Current: 0.9Amps
	Speed: 1500 RPM
	Power: 0.5 HP

Theory:

Closed loop speed control of AC motor –DC generator system is shown in fig 9.1 it consists of same elements present in block diagram 8.1, power modulator control power flow from source to motor. Power modulator is a AC drive consists of inverter where output voltage is varied based on controlled voltage given as input to gating circuit, as input voltage varies from 0 to 10VDC drive output varies from 0-440V. Controlled voltage is generated from closed loop with PID control implemented in LabView based on reference speed set value. Actual speed is sensed using proximity speed sensor and compared with reference speed an speed error is generated, if error is positive PID controller increases controlled voltage and if error is negative it decreases the controlled voltage till the motor speed attains set reference speed. Saturation limiter is limits the output voltage always in between 0 -5V even though PID controller output varies -100 to +100. PID controller is tuned using auto tune blocks available in control design & simulation tool box.

DC generator is connected to AC motor, which generates DC voltage according field supply voltage to generator and motor actual speed. Loading of DC generator is done by using lamp load, as load on generator increases which indirectly loads the motor there by motor speed reduces.

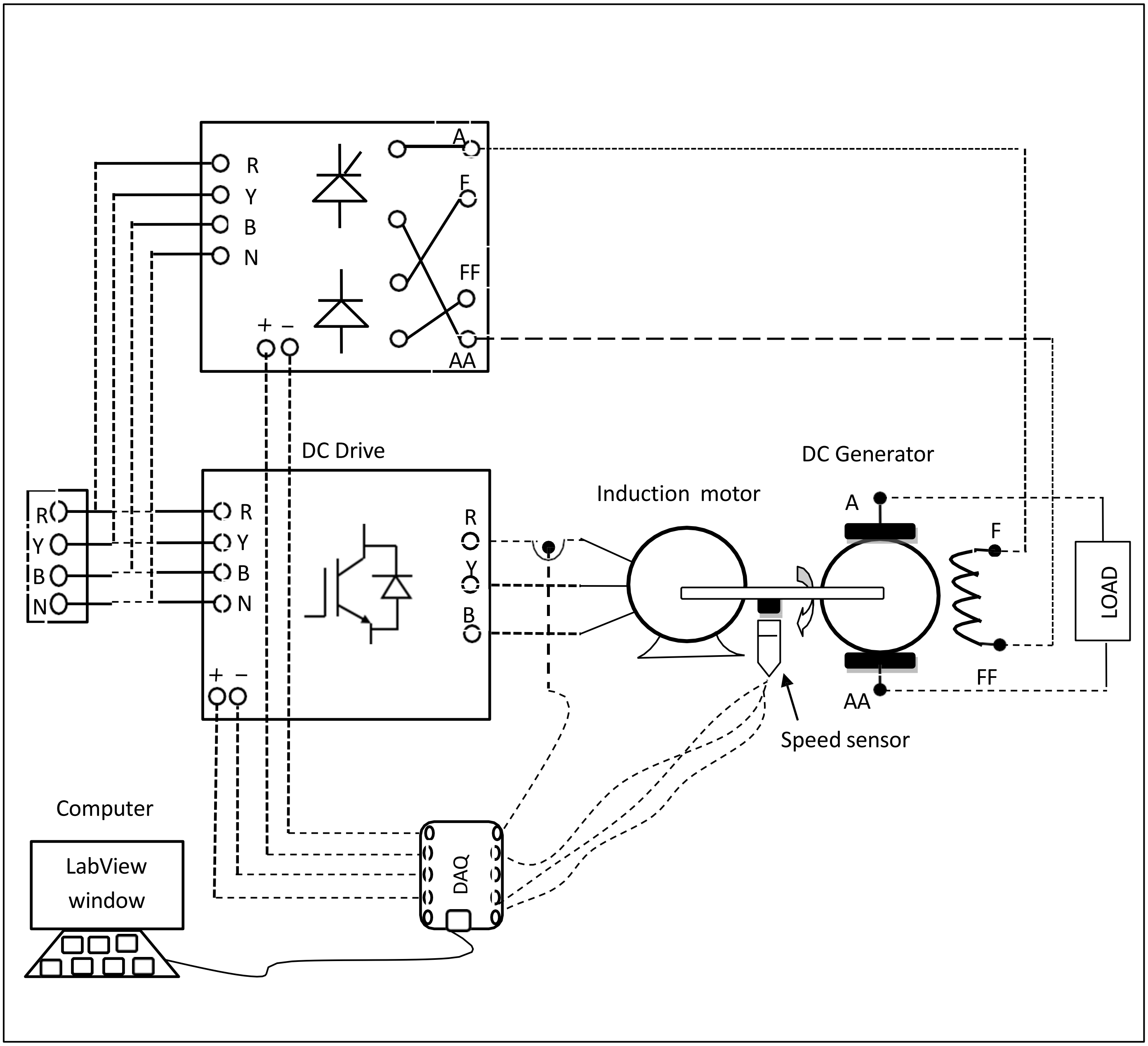


fig.9.1 circuit diagram of closed loop speed control of AC motor –DC generator set with load

PID control always sees the motor speed following set speed or not. As motor speed reduces due to loading speed error becomes positive then PID controller increases the controller voltage till motor reaches set speed. A graph is plotted between set speed and actual speed of motor by getting data from LabView using LVM file and drawn in Excel sheet, we can observe variation in speed from the plot very easily. This experimental setup can be used as constant speed drive system in industry even load varies on the system.

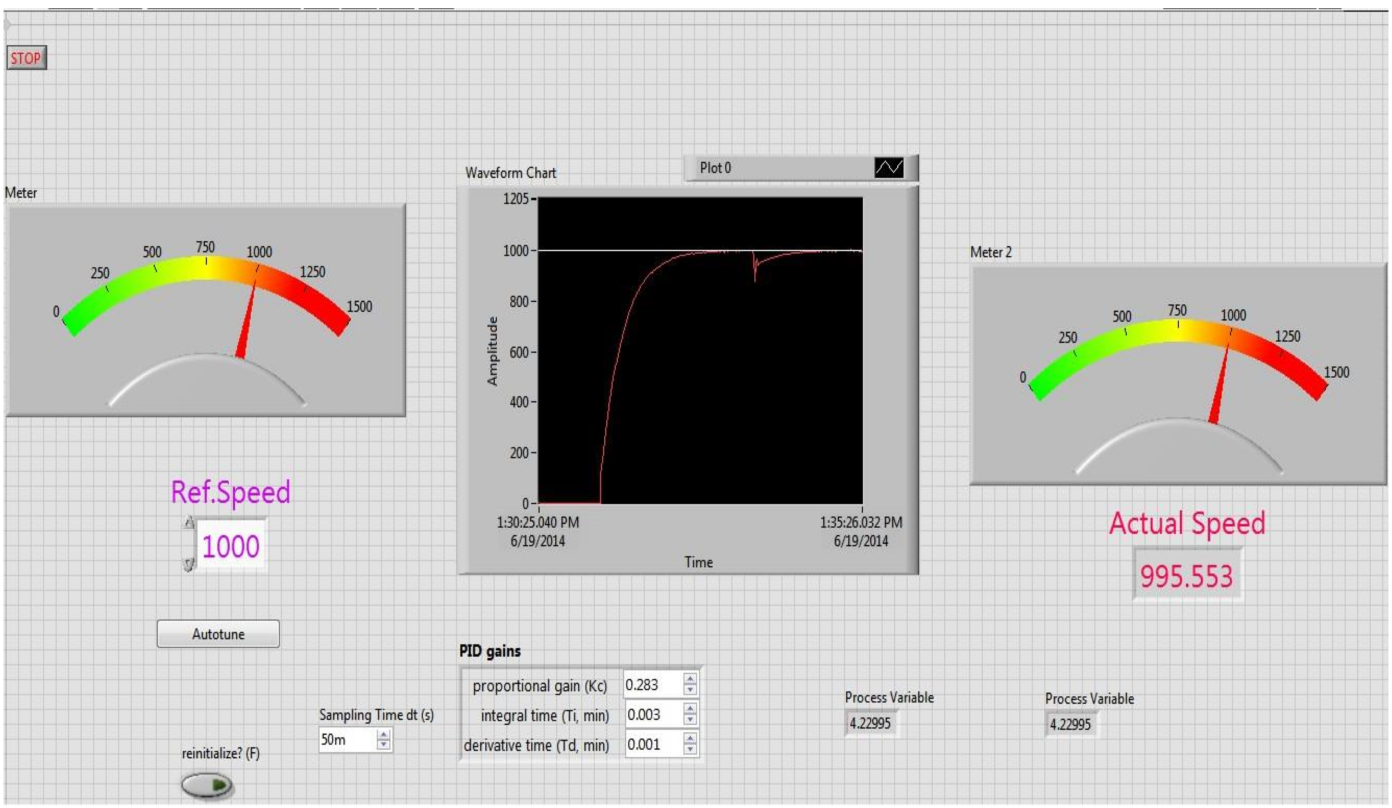


Fig.9.2 LabVIEW front panel diagram of closed loop speed control of AC motor – DC gen.set with load

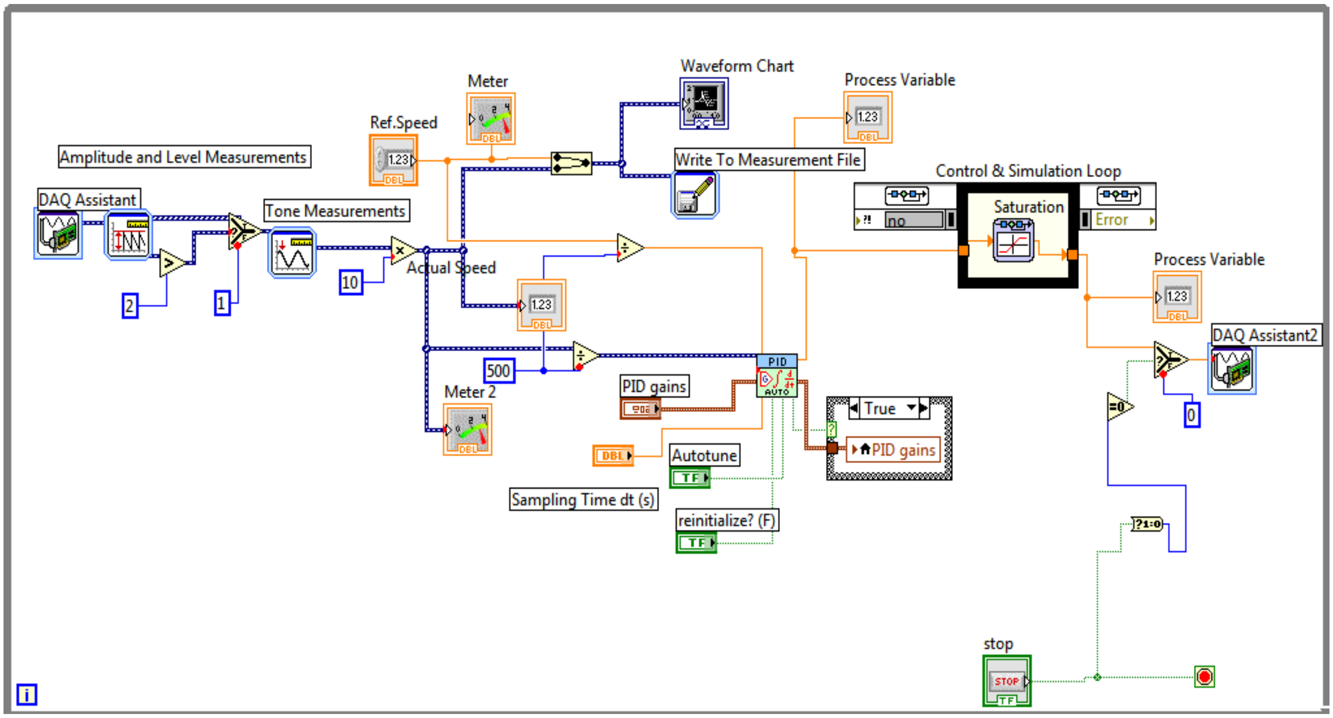


Fig.9.3. LabVIEW block diagram of closed loop speed control of AC motor-DC gen.set with load

Procedure:

1. Connect circuit as per circuit diagram

   i. Connect supply to AC drive

   ii. Connect output of AC drive to armature and field supplies of Inuction motor

   iii. Connect field supply to DC generator

   iv. Connect speed sensor & AC drive variable point to DAQ assistant

2. Develop LabView diagram in back panel consists of reference speed, PID controller design and speed feedback.
3. Set the reference speed to some value say 1000 RPM
4. Tune the PID controller using auto-tune block till we get desired P, I , D values.
5. Ensure that motor speed follows the set speed or reference speed.
6. Add load on DC generator in steps
7. Take the data to excel file from LabView, draw the set speed and actual speed on a single plot
8. Observe the response of speed control loop using plot
9. Vary the P, I, D gains around the tune values and see the response.
10. Design the PI controller and repeat the step 3 to 9.

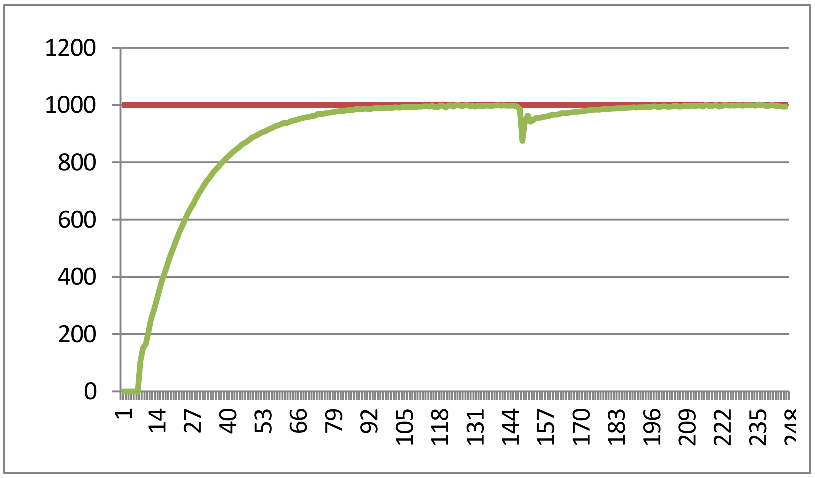


Fig.9.4 speed response of closed loop AC motor –DC gen. set with load

Table:

Reference Speed	PI gains		PD gains	
	P=	I=	P=	D=
	P=	I=	P=	D=

Table 1: Different set speeds & P, I, D gains

Result: closed loop speed control of AC motor-DC generator set with load is done and speed response plotted.

Experiment 12:

TITLE: **permanent magnet synchronous motor drive fed by PWM inverter using software.**

OBJECTIVE:

To study the permanent magnet synchronous motor drive fed by PWM inverter using MATLAB/SIMULINK

Theory:

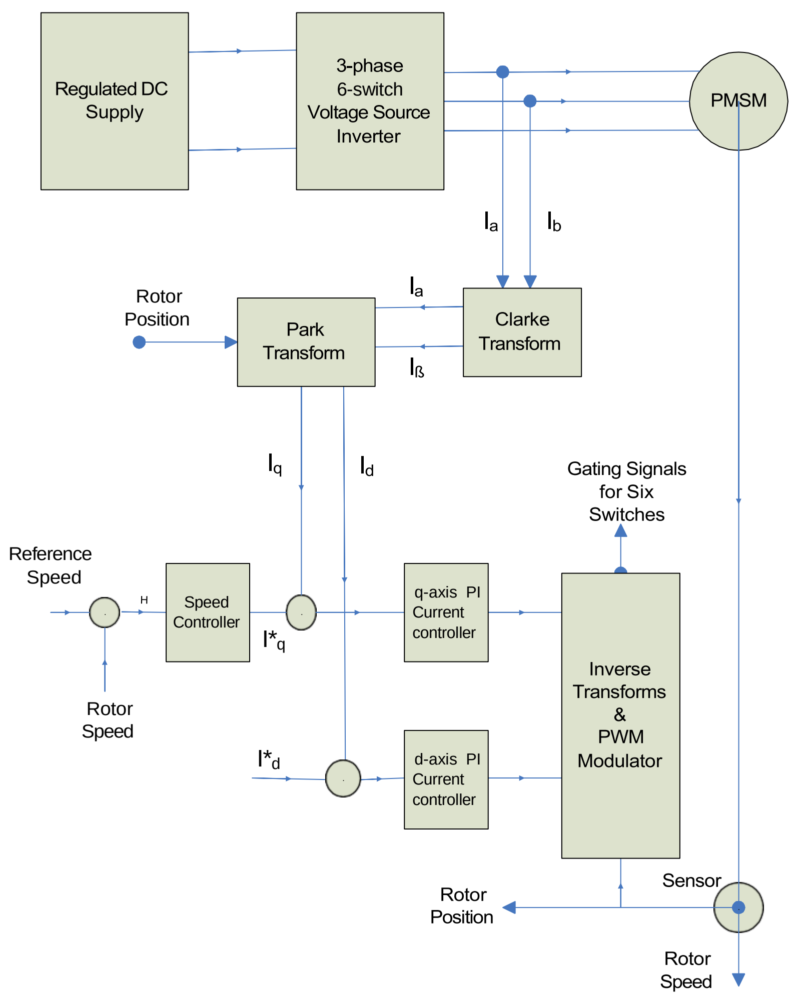


Fig: Vector control of PMSM drive

- Block diagram of Vector or field oriented control of PMSM motor is shown Vector controlled ac motor drive emulates the dynamic characteristics of the separately excited dc motor.

- The co-ordinate transformation is the heart of the control strategy, the instantaneous position of voltage, current, and flux space vectors are controlled, ideally giving correct orientation both in steady state and during transients.
- Vector controlled ac drives are equivalent to the dc drives in the independent control of torque and flux.
- The stator currents are resolved into torque and flux producing components through co-ordinate transformation and the two current components are controlled independently and thereby imparting the ac motor with the characteristics of a separately excited dc motor.

The three-phase stator currents are:

$$i_{as} = i_s \sin(\omega_r t + \delta)$$
$$i_{bs} = i_s \sin\left(\omega_r t + \delta - \frac{2\pi}{3}\right)$$
$$i_{cs} = i_s \sin\left(\omega_r t + \delta + \frac{2\pi}{3}\right)$$

Were,

- ω_r is the electrical rotor speed
- δ is the angle between the rotor field and stator current phasor and known as the torque angle

The q- and d- axes stator currents in the rotor reference frames are obtained through the transformation matrix as

$$\begin{bmatrix} i_{qs}^r \\ i_{ds}^r \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos \omega_r t & \cos\left(\omega_r t - \frac{2\pi}{3}\right) & \cos\left(\omega_r t + \frac{2\pi}{3}\right) \\ \sin \omega_r t & \sin\left(\omega_r t - \frac{2\pi}{3}\right) & \sin\left(\omega_r t + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix}$$

$$i_{as} = i_s \sin(\omega_r t + \delta)$$
$$i_{bs} = i_s \sin\left(\omega_r t + \delta - \frac{2\pi}{3}\right)$$
$$i_{cs} = i_s \sin\left(\omega_r t + \delta + \frac{2\pi}{3}\right)$$

$$\begin{bmatrix} i_{qs}^r \\ i_{ds}^r \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos \omega_r t & \cos\left(\omega_r t - \frac{2\pi}{3}\right) & \cos\left(\omega_r t + \frac{2\pi}{3}\right) \\ \sin \omega_r t & \sin\left(\omega_r t - \frac{2\pi}{3}\right) & \sin\left(\omega_r t + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix}$$

Substituting the three phase stator currents in the abc-dq transformation equations we get,

$$\begin{bmatrix} i_{qs}^{r} \\ i_{ds}^{r} \end{bmatrix} = i_s \begin{bmatrix} \sin\delta \\ \cos\delta \end{bmatrix}$$

The electromagnetic torque expression is

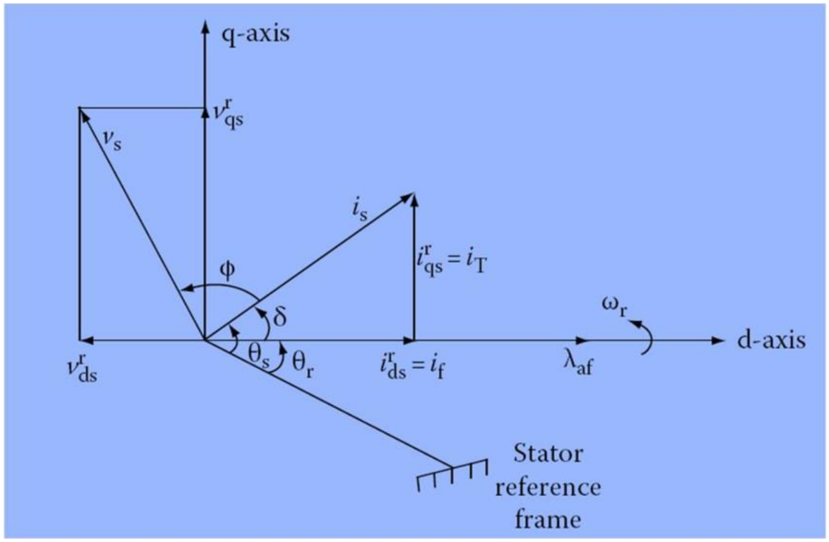
$$T_e = \frac{3}{2} \cdot \frac{P}{2} \left[\lambda_{af} i_{qs}^{r} + (L_d - L_q) i_{qs}^{r} i_{ds}^{r} \right]$$

Assuming that the stator flux current component is zero by making the torque angle, zero,

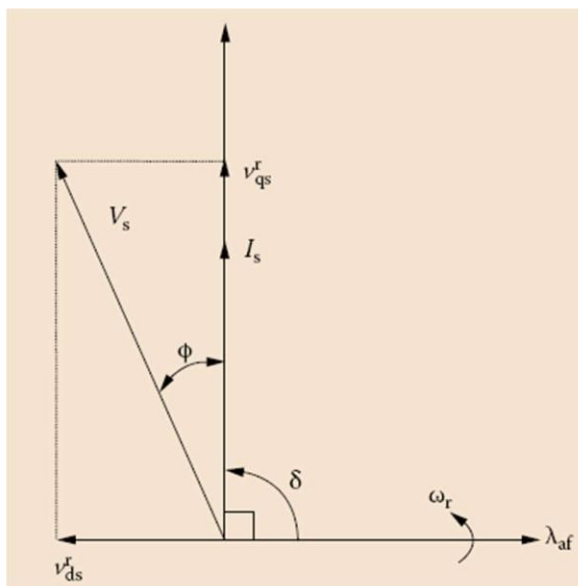
i.e; idsr = 0, we get the electromagnetic torque as

$$T_e = \frac{3}{2} \cdot \frac{P}{2} \lambda_{af} i_{qs}^{r} = K_1 \lambda_{af} i_s$$
$$\text{where} \quad K_1 = \frac{3}{2} \cdot \frac{P}{2}$$

CONSTANT (δ = 90°) TORQUE ANGLE CONTROL:

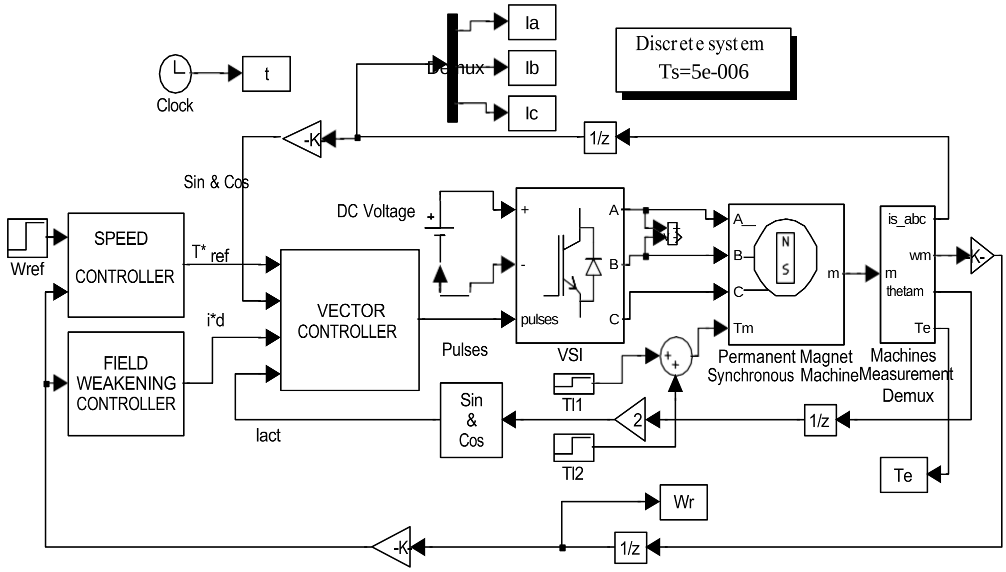


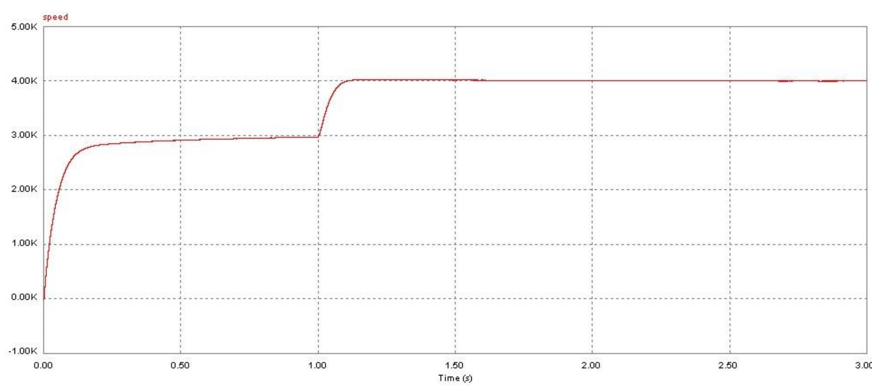
Phasor diagram of PMSM

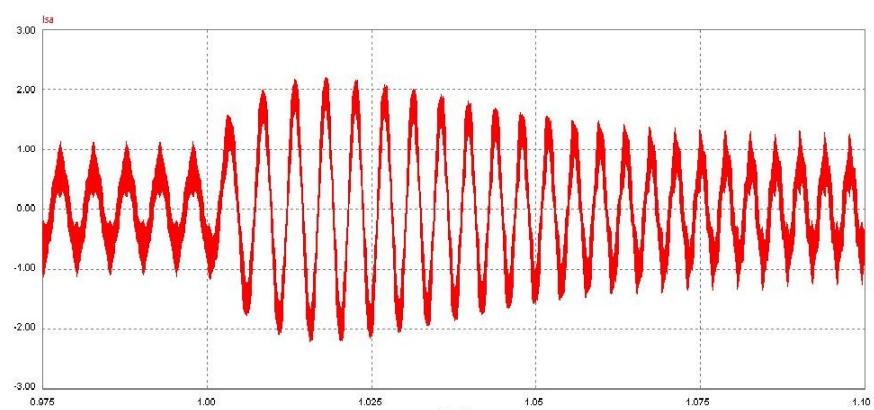


PMSM with δ = 90°

PMSM Simulation Model:


Clock
t
Demux
Ia
Ib
Ic
Discrete system
Ts=5e-006
-K-
1/z
Sin & Cos
DC Voltage
Wref
SPEED
CONTROLLER
T* ref
VECTOR
CONTROLLER
i*d
FIELD
WEAKENING
CONTROLLER
Pulses
pulses
VSI
A
B
C
Tm
m
Permanent Magnet
Synchronous Machine
is_abc
wm
thetam
Te
Machines
Measurement
Demux
K-
Tl1
Tl2
2
Sin
&
Cos
Iact
Wr


speed
5.00K
4.00K
3.00K
2.00K
1.00K
0.00K
-1.00K
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Time (s)


Isa
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
0.975
1.00
1.025
1.05
1.075
1.10
Time (s)

Observation Table:

Sno	Set Speed	Actual speed	Kp & Ki values in speed loop	KP & Ki Values in Current loop	Torque
1					
2					
3					
4					
5					
6					
7					

Conclusion:

Experiment 13:

TITLE:

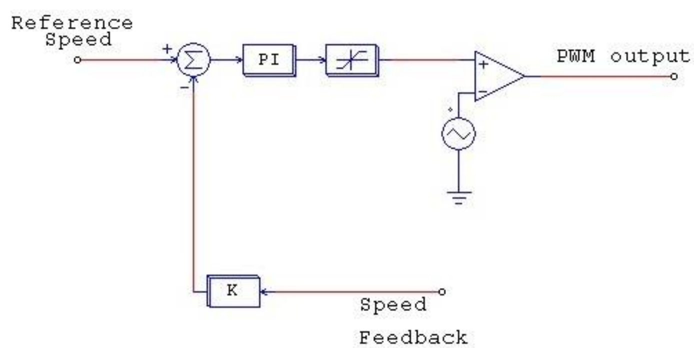
Study of different speed and current control algorithms of PMBLDC motor and SRM using MATLAB/SIMULINK/ PSIM software

Objective:

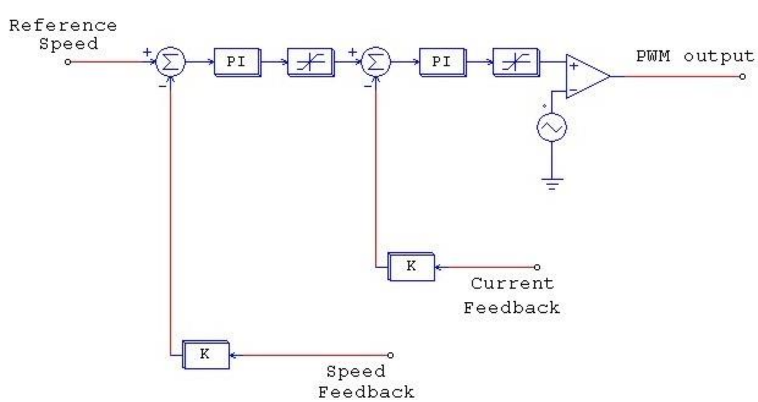
To study the different speed control algorithms in PMBLDC motor and SRM

Theory:

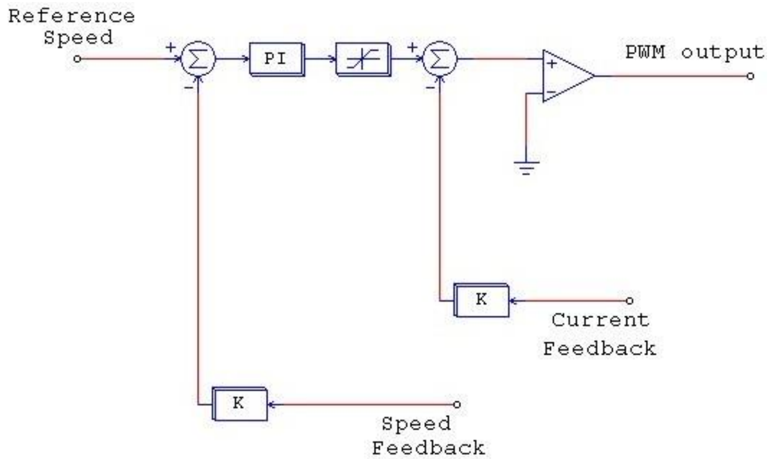
Different speed control loops in PMBLDC motor:



Single loop speed control

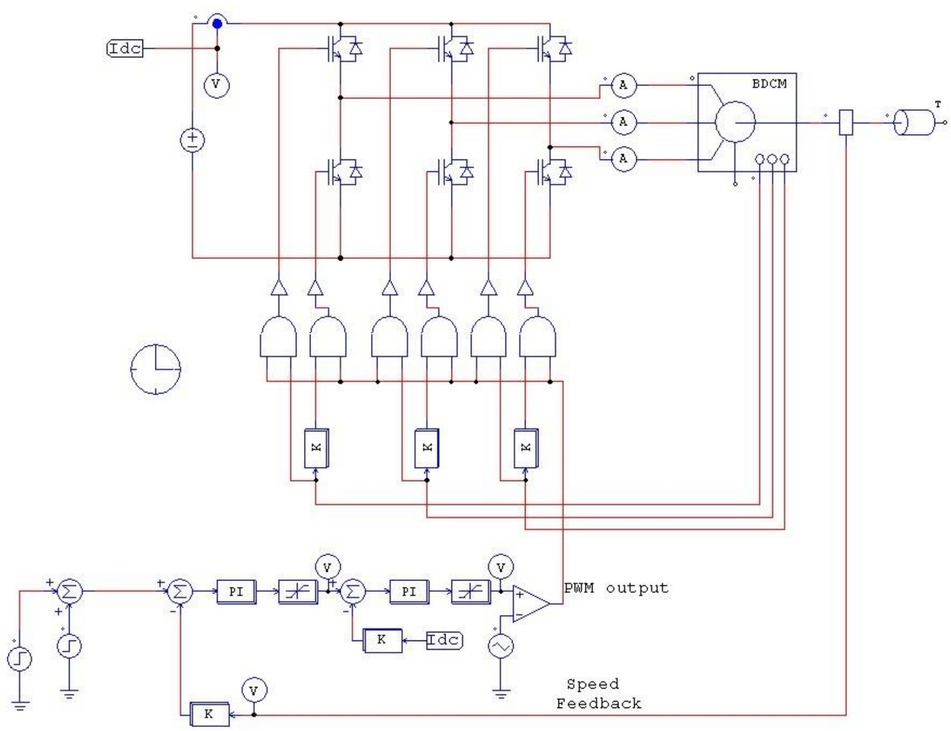


Outer loop speed control and inner loop current control



Outer loop speed control and inner loop Hysteresis current control

Control of PMBLDC motor:



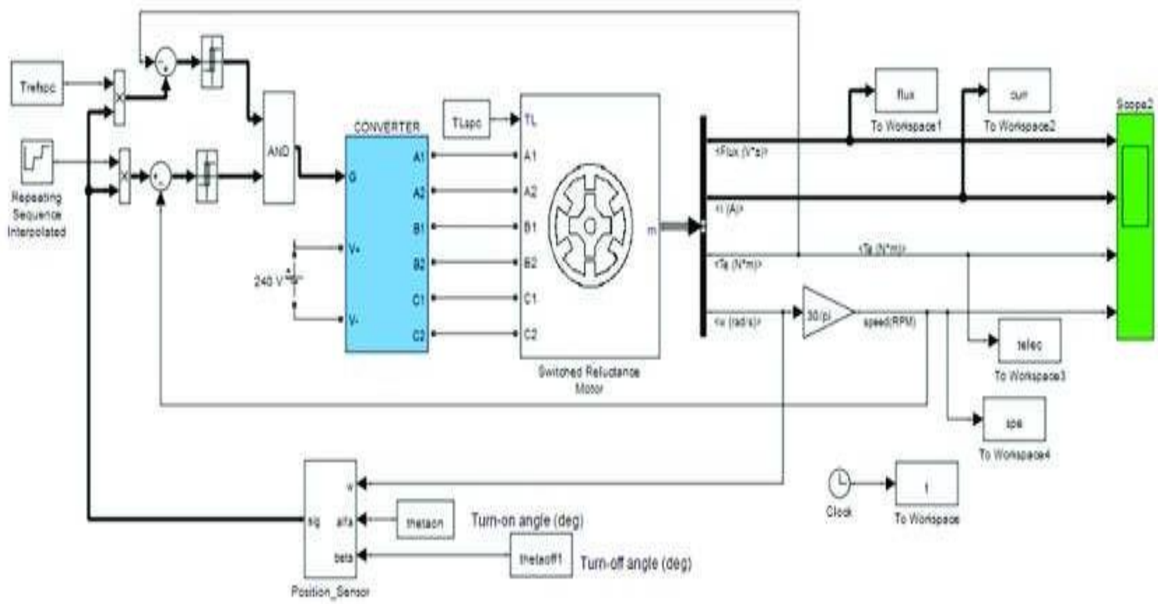
Observations:

Observation Table:

Sno	Set Speed	Actual speed	Kp & Ki values in speed loop	KP & Ki Values in Current loop	Torque
1					
2					
3					
4					
5					
6					
7					

Conclusion:

Speed control of SRM:



Observation Table:

Sno	Set Speed	Actual speed	Kp & Ki values in speed loop	KP & Ki Values in Current loop	Torque
1					
2					
3					
4					
5					
6					
7					

Conclusion: