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PROGRAMMABLE LOGIC CONTROL WITH HIGH ACCURACY TO CONTROL THE SPEED OF DC MOTOR

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ABSTRACT

PLC is proposed as the essential tool in many different applications. In this paper, the PID controller is designed to manage Motor Speed based on incoming information of system and Auto tuning. The manage system is simulated by powerful software Matlab and Simulink. Simulation results also show better performance of motor that decrease the rise time, steady state error and overshoot and increase system stability.

KEYWORDS: PMDC Motor, Programmable Logic Controller, PID Controller, DC Drive, HMI Monitor, High Speed Counter, GMWIN Programming, Matlab Software.

I. INTRODUCTION

Due to the fast performance of DC motors, these motors are regulated in a wide range of speeds and can be used in many applications. The main advantage of using DC motors in today's world is the ability to easily control the speed and angle of the motor. This project is about controlling the speed of DC motor by using Programmable Logic Controller. The controller has more advantages than conventional control circuits. The benefits can be noted such as reducing the size of the control panel, very low energy consumption, Durable Equipment, Proper operation in the worst cases. Using PLC for controlling industrial systems is initiated in 1968 and, its development has been greatly accelerated in recent years.

II. CONTROL SYSTEM DESIGN

PLC is an important part of industrial systems. We used PLC to control motor speed. At first, motor speed is transferred to PLC by shaft encoder, then PLC according to the program and PID controller generate the control signal to reach the desired speed. The analog signal from the D/A module is transmitted to the DC drive. According to the received control signal, drive transfer required voltage to the motor. Every moment, signal of shaft encoder is received by PLC and PLC measures motor speed at any moment and produces signals for having optimum speed in the shortest time and low steady state error and low overshoot in stable state. HMI monitor display the coefficients of the PID controller and desired speed and motor speed and motor speed versus time graph. Also by using HMI keys, this capacity is provide that PID coefficients and desired speed of the motor is changed. PLC used for this project is G7M-DR20U that manufactured by LS . One of the direct current motors are motors with permanent magnet direct current (PMDC). In this project, we used MFA56VL model that is the direct current motor with permanent-magnet motor. Wiring scheme of control system is shown in fig.1.

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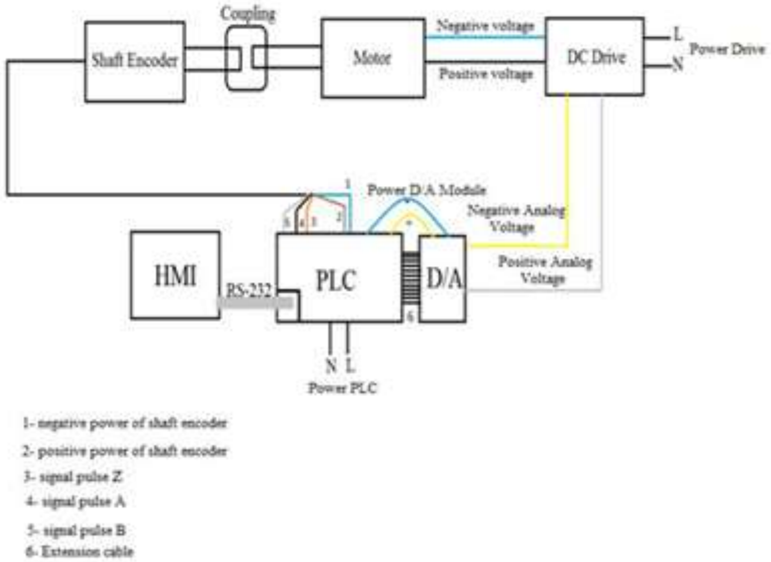

Figure 1 Wiring scheme

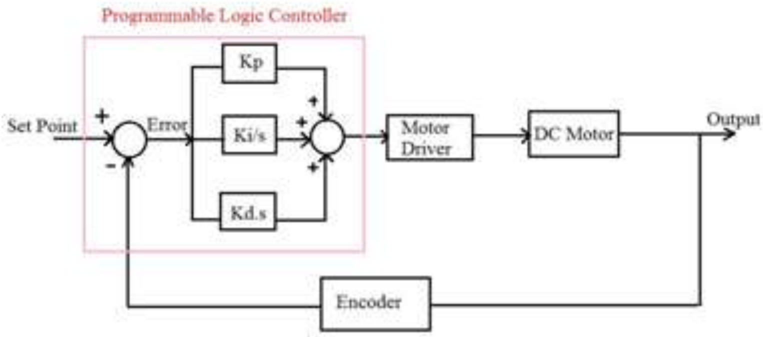

Figure 2 The PID controller diagram

The PID controller diagrom in this circuit is shown in fig.2.We should tuned PID parameters for receiving best stability and overshoot and settling time at manual and simulation. Shaft encoder sense the speed and set the suitable speed

Simulation

In this section, the PID controller is used to control the PMDC motor. The simulation is obtained by calculating the system transfer function. To better evaluate the performance of the controller system, the change of control coefficients in the simulation are shown in fig.3, fig.4, fig.5, fig.6

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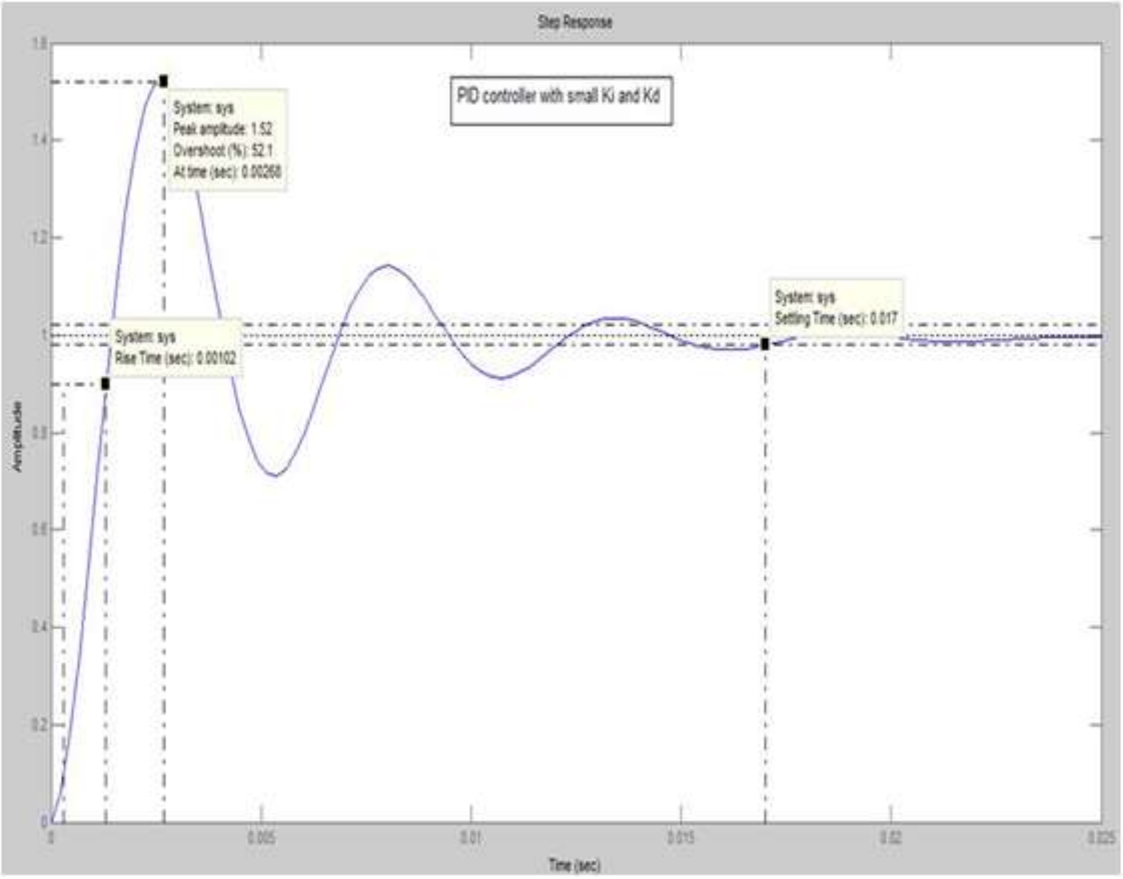

Figure 3 The step response of system With Ki and Kd small

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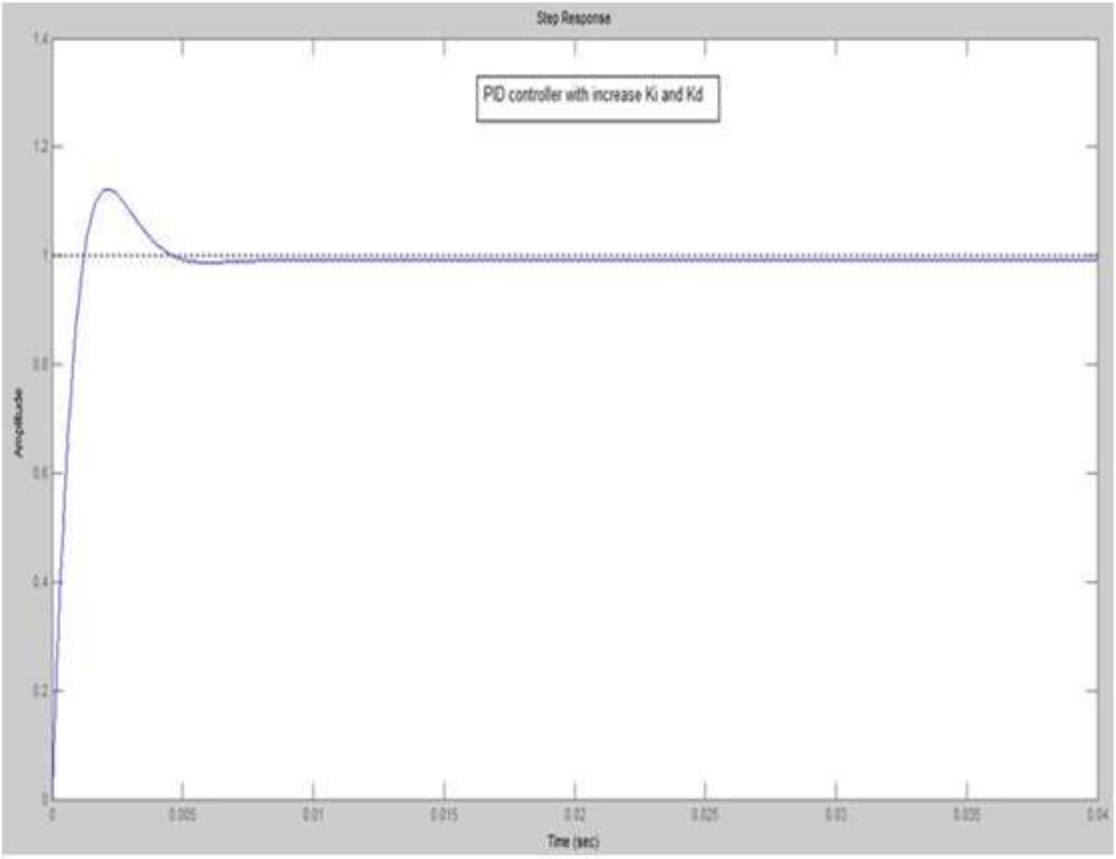

Figure 4 The step response of system With increasing Ki and Kd

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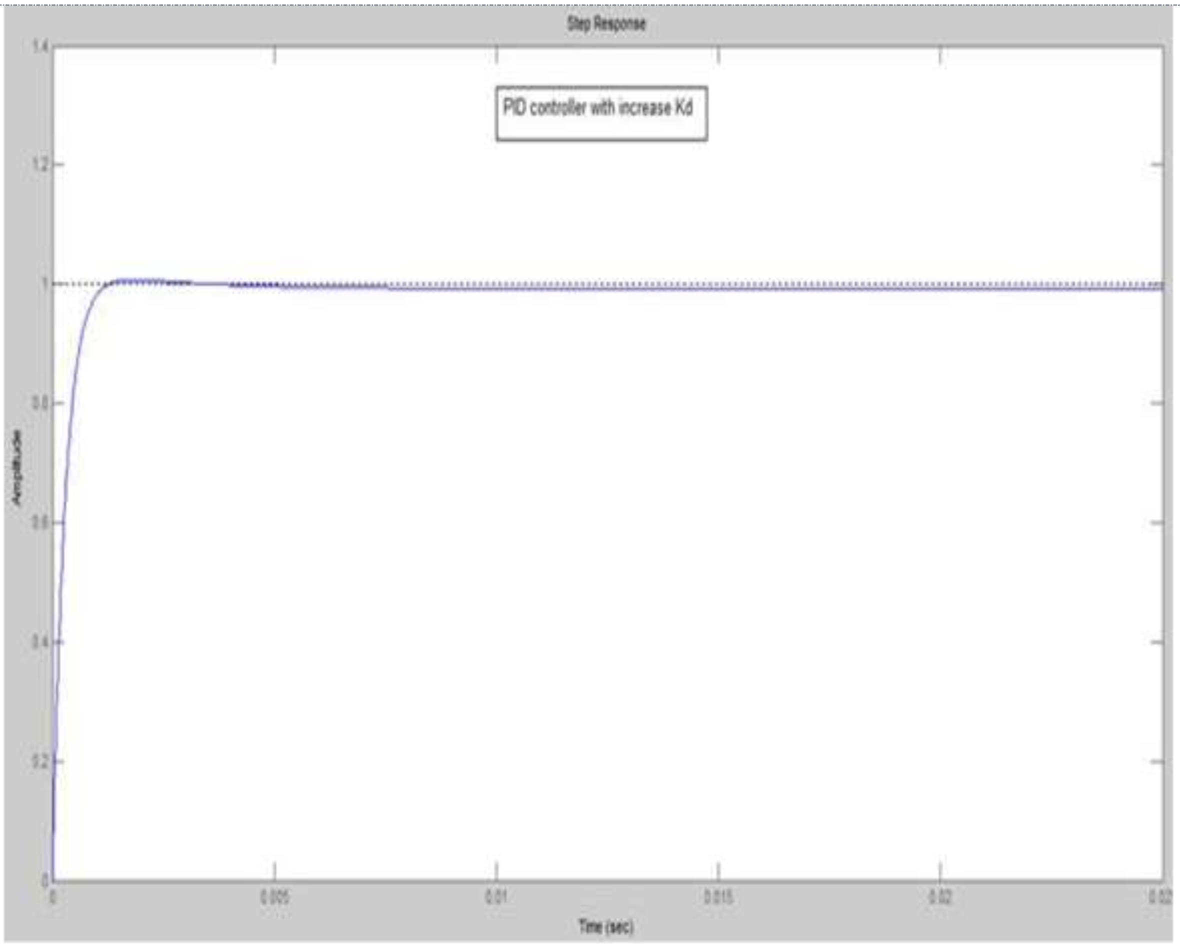

Figure 5 the step response of system with increasing Kd

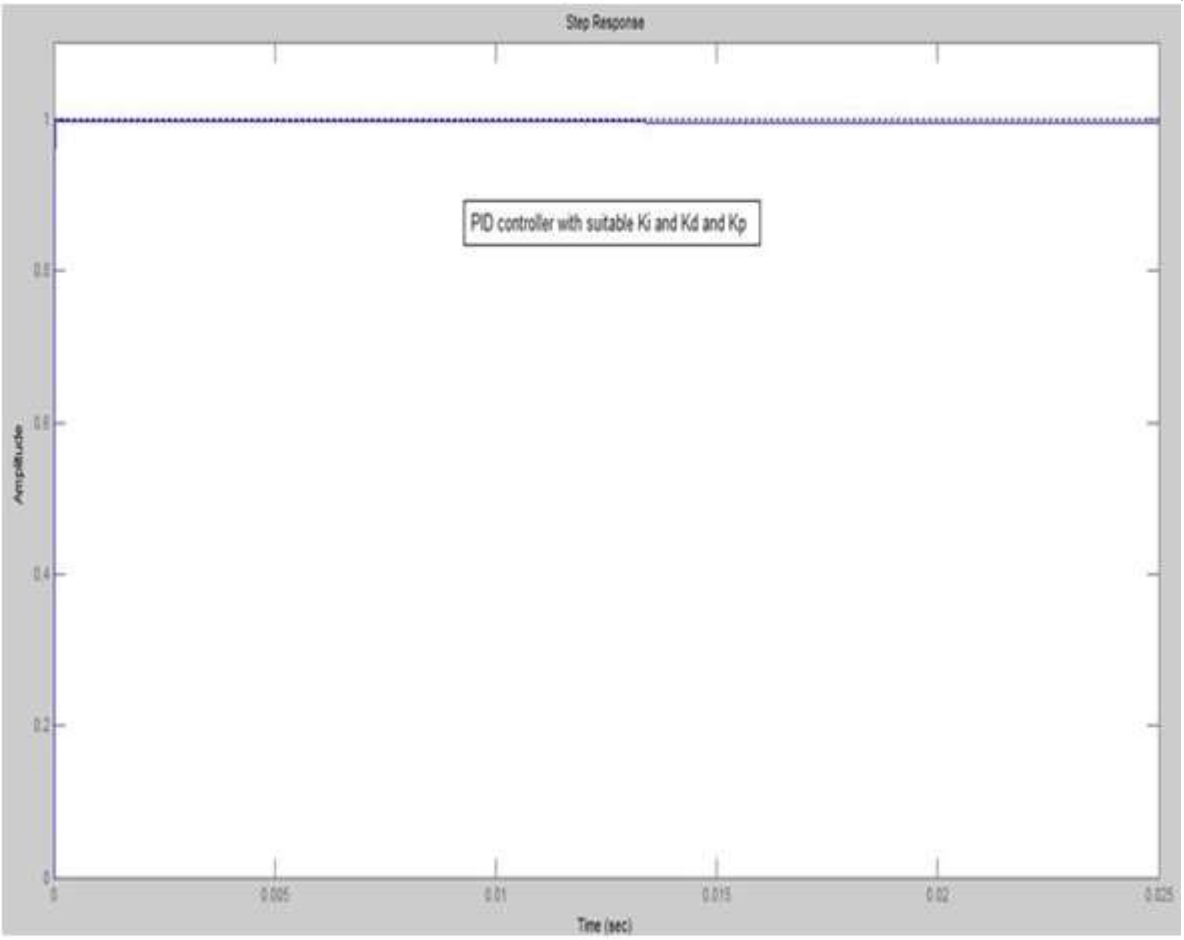

Figure 6. The step response of system with final obtained KD, Ki, Kp

According to fig.3, fig.4, fig.5, fig.6, improvement the system performance is highly visible and significant. By suitable setting coefficients Ki and Kd and Kp, setting time, steady state error and overshoot is reduced. Step response of the system which holds approximately 52.1% overshoot is shown in fig.3, has been changed to fig.6 that shows appropriate control of system.

If a DC motor equivalent circuit is as follows:

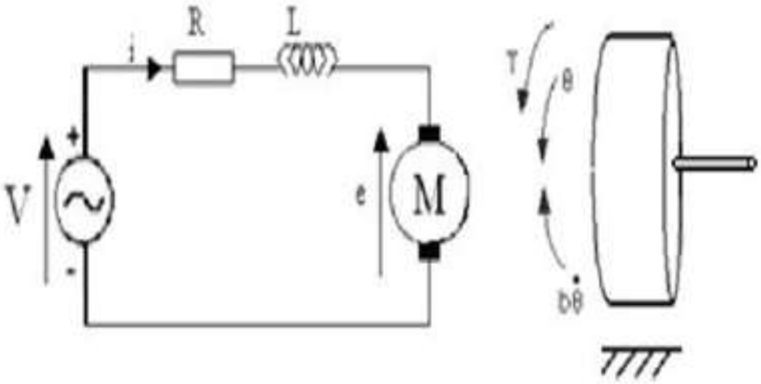

Figure 7 Equivalent circuit of DC motor

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Relations between the torque and the returned magnetic field are as follow:

$$T = K_t i \qquad (1)$$

$$e = K_e \, d\theta/dt \qquad (2)$$

Ke and Kt are equal amount in SI. According to fig.7 and

Relationships based on Newton's law and Kirchhoff have:

$$J\frac{d^2\theta(t)}{dt^2} + b\frac{d\theta(t)}{dt} = k\,i(t) \qquad (3)$$

$$L\frac{di(t)}{dt} + R.i(t) = V(t) - k\frac{d\theta}{dt} \qquad (4)$$

By taking the Laplace from the parties of relations (3) , (4)

have:

$$s(Js + b)\theta(s) = K.I(s) \qquad (5)$$

$$(Ls + R)\,I(s) = V(s) - Ks\,\theta(s) \qquad (6)$$

According to the (5), the current is:

$$I(s) = \frac{s(Js + b)\theta(s)}{K} \qquad (7)$$

According to the (6) , (7):

$$\frac{s(Ls + R)(Js + b)\theta(s)}{K} = V(s) - Ks\,\theta(s) \qquad (8)$$

According to (8), Voltage input to output speed ratio is as follow:

$$\frac{\dot{\theta}(s)}{V(s)} = \frac{K}{(Ls + R)(Js + b) + k^2} \quad [\frac{rad/\sec}{V}] \qquad (9)$$

As a result, we have:

$$\frac{\dot{\theta}(s)}{V(s)} = \frac{0.6}{0.000042S^2 + 0.01443S + 0.666} \qquad (10)$$

Dc motor parameters are given in Table 1. The parameters and the amount of these are determined.

Ziegler and Nichols proposed rules for determining values of the proportional gain Kp, integral time Ti, and the derivative time Td based on transient response characteristics of a given plant. For the Ziegler-Nichols

Frequency Response Method, the critical gain, Kcr and the critical period, Pcr have to be determined first by setting the Ti = and Td = 0. Increase the value of Kp from 0 to a critical value, Kcr at which the output first exhibits sustained oscillation

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Table1. DC motor parameters

parameters	value
R	[illegible]
L	[illegible]
J	[illegible]
b	[illegible]
K	[illegible]

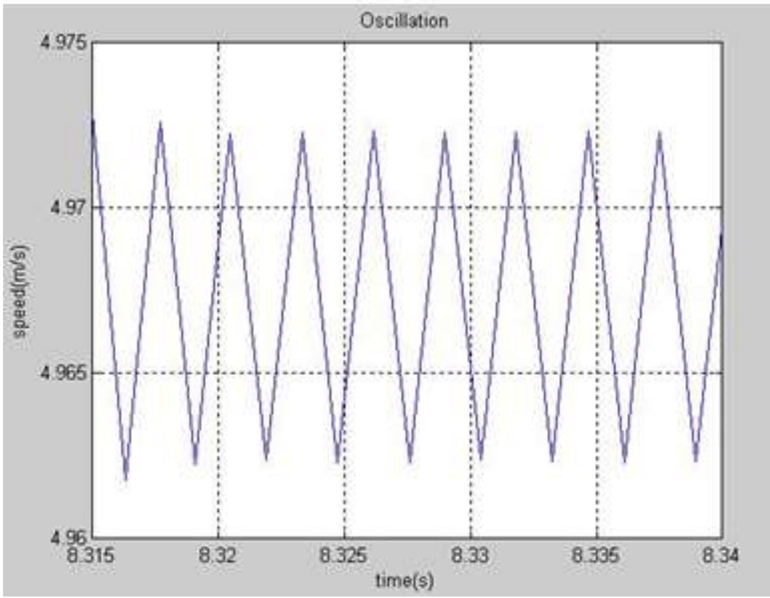

Figure 8. speed versus time graph

Hardware Implementation

In this article, speed control of direct current electric motor designed and simulated and made. The main Required components to make are shown in fig.9

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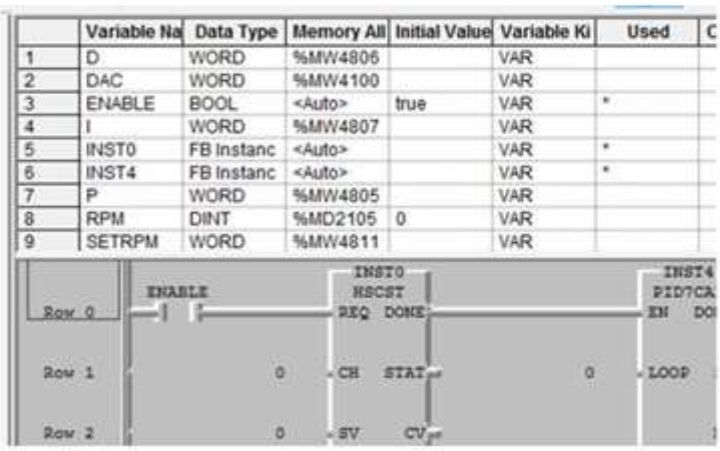
Figure 9 The overall structure of speed controlling DC motor



	Variable Na	Data Type	Memory All	Initial Value	Variable Ki	Used	C
1	D	WORD	%MW4806		VAR		
2	DAC	WORD	%MW4100		VAR		
3	ENABLE	BOOL	<Auto>	true	VAR	*	
4	I	WORD	%MW4807		VAR		
5	INST0	FB Instanc	<Auto>		VAR	*	
6	INST4	FB Instanc	<Auto>		VAR	*	
7	P	WORD	%MW4805		VAR		
8	RPM	DINT	%MD2105	0	VAR		
9	SETRPM	WORD	%MW4811		VAR		

Figure 10 part of GMWIN program

Initially, PLC and HMI should be programmed. We used GMWIN for programming PLC.We used high speed counter and auto tuning for programming PLC. Part of the program in GMWIN is shown in fig.10. For connecting PLC to pc, we used USB to RS-232 converter that shown in fig.11

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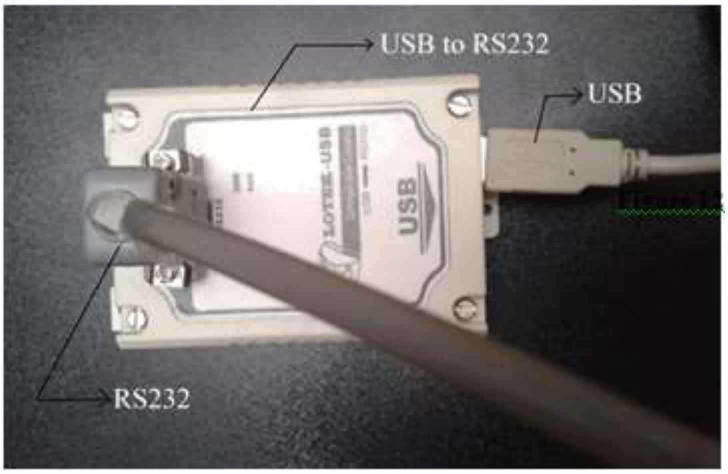

Figure 11.USB to RS232 Converter

We used Pannel Editor software for programming HMI. HMI allows to us, display moment to moment status of process and important parameters and displays the error online. In general, to create and implement a program for setting up HMI and PLC, the following steps shown in fig.12 are performed.

For receiving and transmission motor speed used shaft encoder. Here's another piece are used that called coupling. For the coaxial and transmission motor speed to shaft encoder because of heterogeneous between two shaft diameter, we need to coupling. This piece was designed so that the input inner diameter 12mm and output inner diameter 6mm. Two screws at the junction of the two shafts are considered to prevent of freewheeling. The basis for the shaft encoder is used. Due to the lower elevation shaft encoder, we needed to a base for strength and to prevent vibrations. Also a board made of MDF for mounting all components were considered, until all pieces are sturdy and without translocation. Fig.13 shows the connection of motor shaft and shaft encoder.

Output signals A, B, Z of shaft encoder is connected to the PLC and PLC power supply 24 VDC is connected to shaft encoder. Overarching theme construction of the project is shown in fig.14.

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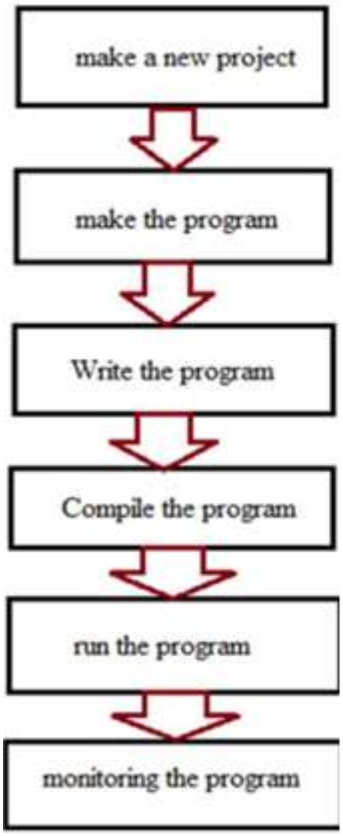

The general trend of setting up

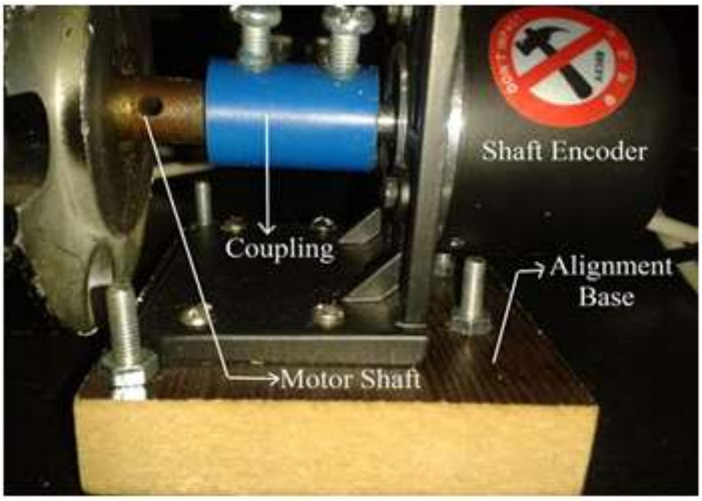

Figure 13. Shaft encoder connected to the motor shaft

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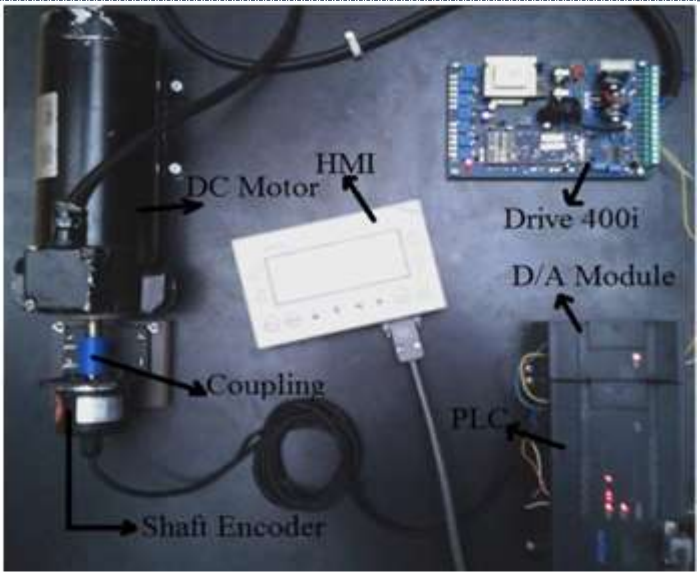

Figure 14. hardware implementation

GMWIN software has the capability that during the connecting to the PLC, traced the graph of the operation and system performance. Fig.15 shows the graph traced by GMWIN software for set value 60 r.p.m that shows that system reaches quickly to set point with less error and overshoot

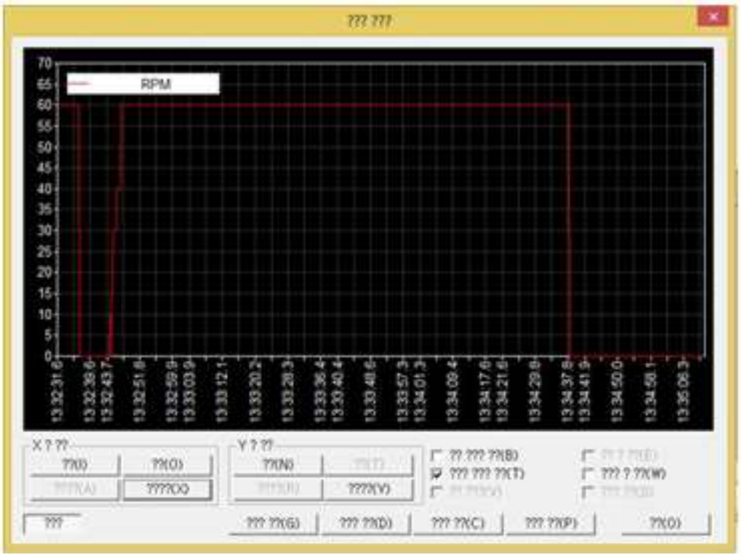

Figure 15. Velocity versus time graph for 60r.p.m

Also, Velocity versus time graph with P,I,D Coefficients are adjusted and set value and current value are shown in HMI for monitoring. For example, the graph of motor speed for set value 260 r.p.m is shown in fig.16. HMI's key perform defined operation. This key will not work if the function is not defined. Keys F1, F2, F3, F4 are set for a defined operation. The F1 key is set for increasing the Kp value by step 10. The F3 , F4 keys are set for decreasing kp and set value, respectively. The F2 key is set for increasing the current value by step 10

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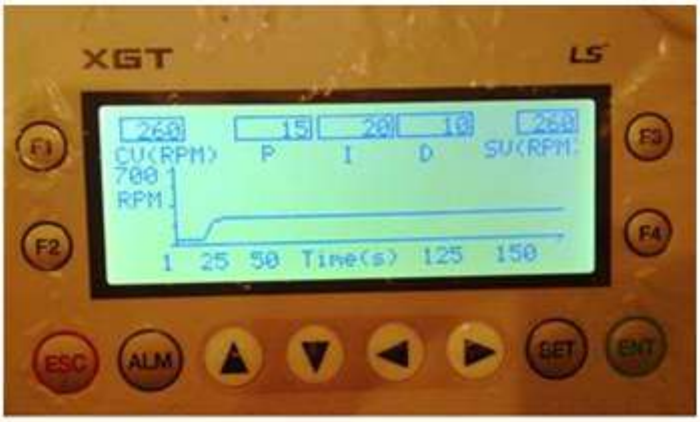

Figure 16. HMI monitor

We used the suitable power supply that equipped with filter and isolatation to noise from AC power don't transfer to the controller and its input and output and we used Shield of cable that one side of these are connected to ground. We designed path the cables properly. We consider the two ground systems, one for the PE and CE else that although both are ultimately connected to the ground network, but there are two distinct pathways. Control equipment is connected to CE ground.

To determine the allowable temperature rise of the motor, we should the ambient temperature Subtract from 130ºc. Class F is motor insulation type. With information such as load operational, motor efficiency and thermal increasing coefficient, the ambient temperature can be measured. Ramp function as a control system to prevent engine operation at extremely low temperatures required.

It is a negative value describing loss of velocity as a function of increased torsional load. From the motor data sheet, it can be seen that the no-load speed of the motor at 200 volts is 2000 rpm. If the torque load is not coupled to the motor shaft, the motor would run at this speed. The motor speed under load is simply the no-load speed less the reduction in speed due to the load. The proportionality constant for the relationship between motor speed and motor torque is the slope of the torque vs. speed curve, given by the motor no-load speed divided by the stall torque.

The motor current under load is the sum of the no-load current and the current resulting from the load. For DC motors, the output torque is proportional to the current going into the motor no matter what the motor speed. The straight-line relation between torque and current is the torque-current curve as shown in fig.17. This graph is plotted for proposed circuit that is shown in fig.18

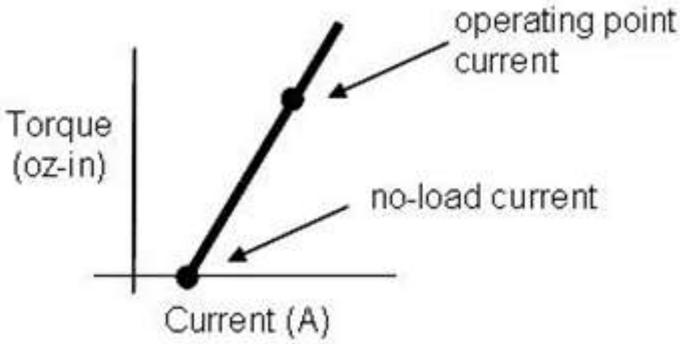

Figure 17. Torque versus Current graph

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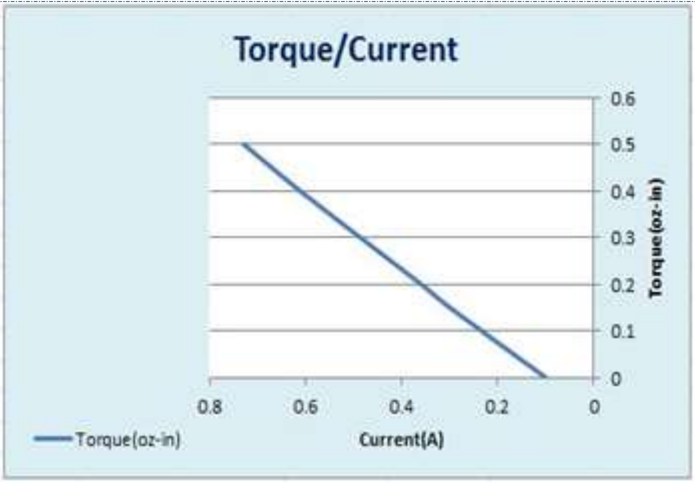

Figure 18. Torque versus Current graph for proposed circuit

III. CONCLUSION

The designed control system can control the motor speed very quickly. The motor speed (current value) reaches to set value in a short time and very less overshoot and it is very useful for controlling speed in industrial to avoid damage to the parts. By comparing the simulation results of the system, before controlling and after that, we can conclude that many of the desired characteristics such as rise time and overshoot improve. The results of simulation and hardware implementation show the improved performance of the system

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