

“Performance Testing of HC900 Controller based Speed control system for DC Motor”

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Abstract:

In process control industries the concept of multiple input, multiple output control systems is the key work now days. The control variables are analog nature as well as digital nature. To control these mixed type of variables hybrid controller is popularly used. The hybrid controller is a basic platform of SCADA. In which monitoring recording and display of variables with respect to time, animation of various control components is possible. Therefore, a project is taken up to establish a speed control system of the motor by controlling the power input from a dedicated motor controller through discrete controller as a process. Hybrid controller Make of Honeywell Model HC-900 having 8-Analog I/P, (4-20mA) Analog O/P, 16-Digital I/P, 16-Digital O/P, 8-Control loop; as a controller and Honeywell Plants cape is taken as SCADA software. In this phase all these control components shall be properly arranged on a table top setup. The HMI (Human Machine Interface) shall be used through HC 900 to set the desired speed. The output of HMI is 4-20 mA this will act as one of the analog input of HC900. The tachometer signal (4 - 20 mA) shall provide the feedback input, and accordingly the output i.e. 4-20 mA shall drive the DC motor controller through HC900 Controller. After motor shall output the rpm, depending upon the load to the motor as it is coupled to eddy current dynamometer. Varying the input 4-20 mA of Eddy current dynamometer shall vary the load on the motor. A fairly large amount of experimentation shall be carried out on motor coupled with dynamometer and tachometer. The family of operating curves that is speed (mA) as Abscissa, motor controller input (4-20mA) as ordinate and various torque lines. The linearization of this figure shall evaluate the block diagram of the plant.

Applying appropriate analysis methods HC900 shall be configured along with the SCADA peripherals. Every attempt shall be implemented to achieve the performance as per theoretical calculations.

Introduction:

The Hybrid Controller from Honeywell is a general purpose controller. It contains analogue as well as digital inputs and outputs, hence the name hybrid controller. The programming is similar to ladder diagram in case of Programmable logic controllers (PLC) but the function block diagrams are used to program. The basic configuration of the controller used and the basics of the programming are detailed in this chapter.

Few of the other components like i/v converter, v/i converter, Tacho-generator, etc., are discussed in next sessions. Though it is not the part of hybrid controller programming but interfacing these with HC900 shall requires the insight of each component. Hence these are addressed in this chapter.

Experimental Analysis

The Honeywell Hybrid Controller is very simple to use and program. But for the beginner, it is essential to know the various function blocks used, the method to upload and download the program, and put the program to work. The all function blocks are not possible to be covered. But the function blocks which are

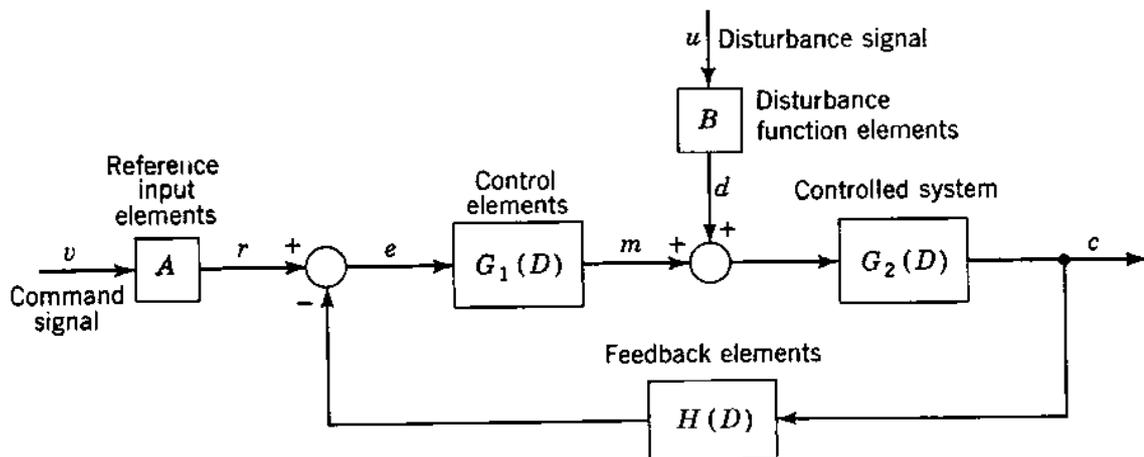
used are briefly mentioned in this chapter. Also this chapter focuses on the interfacing formalities and procedure to experiment on the set up. The trial observation table is produced for orientation only. The preliminaries of programming i.e. selection of controller, downloading, uploading, what is function block, etc., are placed in Annexure I entitled as “HC900 formalities.”

Layout of Experimentation:

The experiment “Design of Speed Control System” is based on the Hybrid Controller. The programming in brief of Hybrid Controller of the essential blocks is introduced earlier. The speed control system is described next. The entire experimentation is based on generalized block diagram representation. Figure 4.1 details the general control system. The *desired input* v is processed to *reference input elements* usually a scale factor (A), amounts to *reference input* r . The *feedback signal* b representing *controlled variable* c through *feedback elements* $H(D)$ is compared to result the *error signal* e . The *error signal* e is input to *control element* $G_1(D)$ to amount *manipulated variable* m . This together represent Controller portion of block diagram. The Plant or System to be controlled starts next. The *manipulated variable* m and load or *disturbing function* u through disturbing function elements ($-B$) is compared and input to plant i.e. $G_2(D)$ to result into *controlled variable* c .

The lowercase letters i.e. v , b , m , u , c indicate change in quantities. The total quantities are indicated by uppercase letters. This is because the controller acts on deviation and not on total quantities. For example for temperature control system, to control the temperature at say 300C shall work on deviation in 30 and not on 330C.

Figure 1: The Generalized Block Diagram



Speed Control System:

The control system works on desired input, disturbance function, and controlled variable. For speed control system obviously, controlled variable is speed in this case it is rpm. The desired input is indicator dial or speed setting dial. The disturbing function i.e. load on the system is load torque.

The Prime Mover:

The speed i.e. rpm has to be generated by prime mover. The prime mover represents plant or system to be controlled in the present discussion. It accepts the input from controller and generates the mechanical power i.e. torque. This prime mover is coupled to mechanical application, which requires the torque. When torque required by the application and torque generated by prime mover are same, the speed remains constant as desired. But when application torque i.e. load torque increases than torque developed by prime mover, the speed decreases. The power is given by the formula

$$P = \frac{2 \cdot \pi \cdot N \cdot T}{60}$$

It is obvious that speed has to decrease when torque increases, for same power. To maintain the speed the power input to prime mover should be increased. In the present control system, the prime mover is selected to be DC motor of 1 HP i.e. 746 W. It works on and controller (referred as M Controller herein after.) When 4 mA is supplied to M Controller the motor outputs 0 rpm and no torque. And corresponding to 20 mA supplied to M Controller, the motor outputs to 300 rpm at 746 W. The performance of the motor i.e. speed torque characteristics are fairly linear in the entire span. The details are revealed in the figure 4.2.

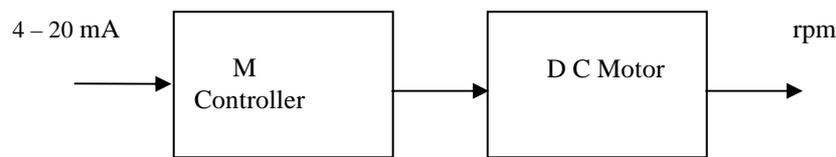


Figure: 2 The Block Diagram of Plant (Prime mover) or System to be controlled.

The Disturbance Function: For the control system to act there has to be a deviation in the controlled variable. The control system works on deviation and not on total value. This means for speed control system, let the controlled variable i.e. speed is to be controlled at 300 rpm. In case the speed deviates to 330 rpm, the control system comes into picture and acts on 30 rpm i.e. deviation and not on 330 rpm. For deviation, for speed control system, the motor is coupled with an eddy current dynamometer. The dynamometer works on 0 – 10 V DC control voltage. For 0 V the dynamometer outputs to zero torque and at 10 V DC the dynamometer outputs to approximately 5 kg.m or 48 N.m at 1440 rpm. At 300 rpm, the torque developed is 10 N.m. The corresponding control voltage required is 2 V DC. Figure 4.3 shows the block diagram of operation.

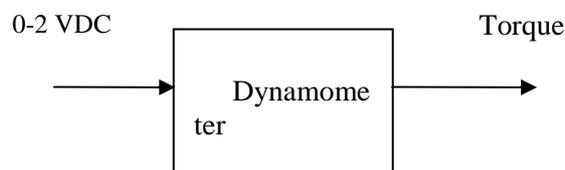


Figure 3: Block Diagram of Dynamometer

The Feedback:

The eddy current dynamometer has a built in tacho-generator for integral check. The output of the tacho-generator is 0 – 10 V DC corresponding to 0 – 1440 rpm. For 300 rpm, the tacho-generator output voltage is approximately 2 V DC.

Interfacing with desired input:

The set point is implemented by Human Machine Interface (referred as HMI herein after.) The HMI is configured so as to output 4 mA at 0 rpm indication and 20 mA at 300 rpm indication. For example for 150 rpm indicated value, the HMI shall output to 12 mA.

The HC900 Controller:

The control elements role is played by HC900 controller. The output of HMI is interfaced with analog input channel no 2. The rpm is sensed by tacho-generator of the eddy current dynamometer, and it is configured to analog input channel no 3. A voltage to current converter is required to be employed as HC900 requires mA input for analog input channels. Depending upon the PID block configuration, the HC 900 controller outputs a control current i.e. 4 – 20 mA at analog output channel no 2. This is interfaced with M Controller for DC motor. Figure 4.4 shows the details.

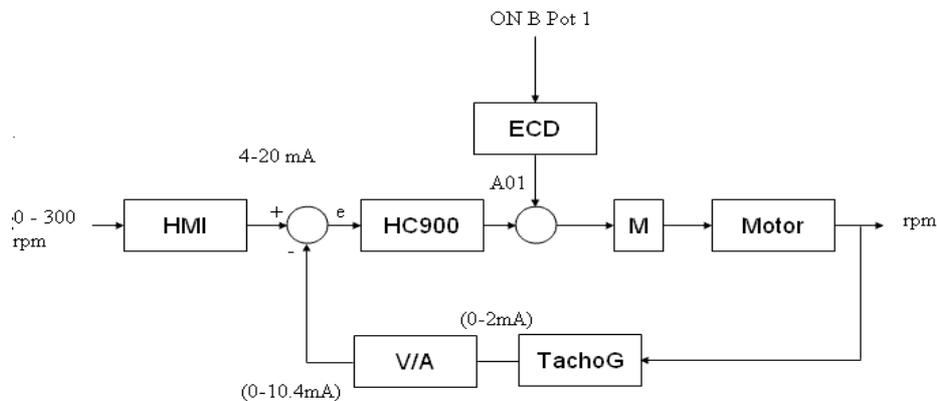


Figure 4: The Block Diagram of operation for speed control system.

Experimental Set up- The dynamometer has a pot as discussed earlier for variation of torque imposed on the shaft. One side of the shaft is coupled to the prime mover i.e. DC motor and other end coupled to pulley to ensure the defined torque is imposed on it or not. Figure 5.7 shows the experimental set up. The DC motor controller i.e. M controller is seen as green box. The eddy current dynamometer controller is seen as white box fit on the table. It has a pot to vary the torque imposed on the motor. Simultaneously, a rope brake indicator is also seen, which ensures the physically torque imposed. The HC900 is placed to the left of the experimental setup. It shows a small display on the top of the panel, which is HMI, to set the desired speed. The entire experimental setup was tried in three steps. The manual control of DC motor, manual control of torque imposed and all together with HC900 controller. All these three steps of experimentation are discussed next.

Procedure for Experimentation:**figure 5 :** Experimental set up.

The experimentation is required to be carried out in three different phases. The working with HC 900 was initially very difficult as there was no expert assistance available. The interfacing of DC motor with HC 900 controller was really a tough job. However the entire experience was very struggling yet rewarding. The DC motor was tested manually. This is possible by forcing the motor in manual control mode toggle switch available on M Controller control panel. By varying the pot on the motor control panel, the range of speed of DC motor was seen to be achieved. Then, the eddy current dynamometer was tried. The readings were taken in open loop mode. The step by step experimental procedure is discussed as below.

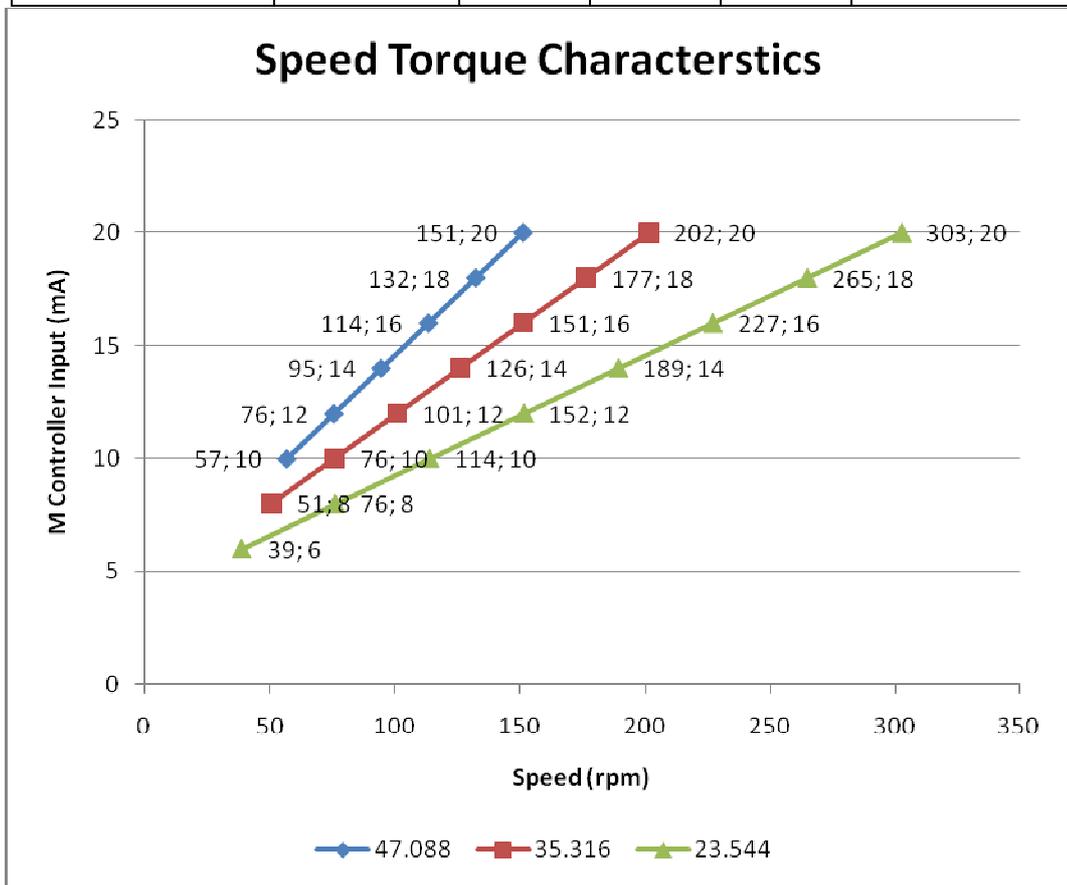
Speed Torque Curve:

The speed torque curves for the DC motor are fairly linear over the range of operation. Still for the experimentation the procedure is adopted to obtain the same. The power input to the motor is plotted as Y axis, speed obtained is plotted as X axis. The curves are then obtained for various torque ratings. Now in this case, instead of power input, the input to M Controller i.e. 4 – 20 mA is plotted as Y axis, the rpm, which is measured as DC voltage, which in turn is converted in to equivalent mA readings is plotted as X axis. The torque imposed is measured on dial is plotted as range of operating curves. The procedure adopted is as follows.

1. Turn on the power supply to HC900, DC Motor, and eddy current dynamometer.
2. Adjust the torque of eddy current dynamometer to required value.
3. Vary the manual input to M Controller of DC motor.
4. Note down the steady state reading of speed and its corresponding value in mA as given in the HC900 controller.
5. Repeat the steps from 2 to 4 by adjusting different torque values of eddy current dynamometer. The observation table is as given below.

Table 1

		Torque			
M Controller	N.m	47.0 88	35.3 16	23.5 44	11.772
Input	Kg.m	4.8	3.6	2.4	1.2
mA		Speed (rpm)			
20		151	202	303	
18		132	177	265	
16		114	151	227	
14		95	126	189	
12		76	101	152	300
10		57	76	114	172
8			51	76	153
6				39	77



Speed torque characteristics of DC Motor.

Table 2

		Torque			
M Controller	N.m	47.0 88	35.3 16	23.5 44	11.772
Input	Kg.m	4.8	3.6	2.4	1.2
mA		Speed (mA)			
20		1.01	1.35	2.02	
18		0.88	1.18	1.77	
16		0.76	1.01	1.51	
14		0.63	0.84	1.26	
12		0.51	0.67	1.01	2.00
10		0.38	0.51	0.76	1.18
8			0.34	0.51	1.02
6				0.26	0.51

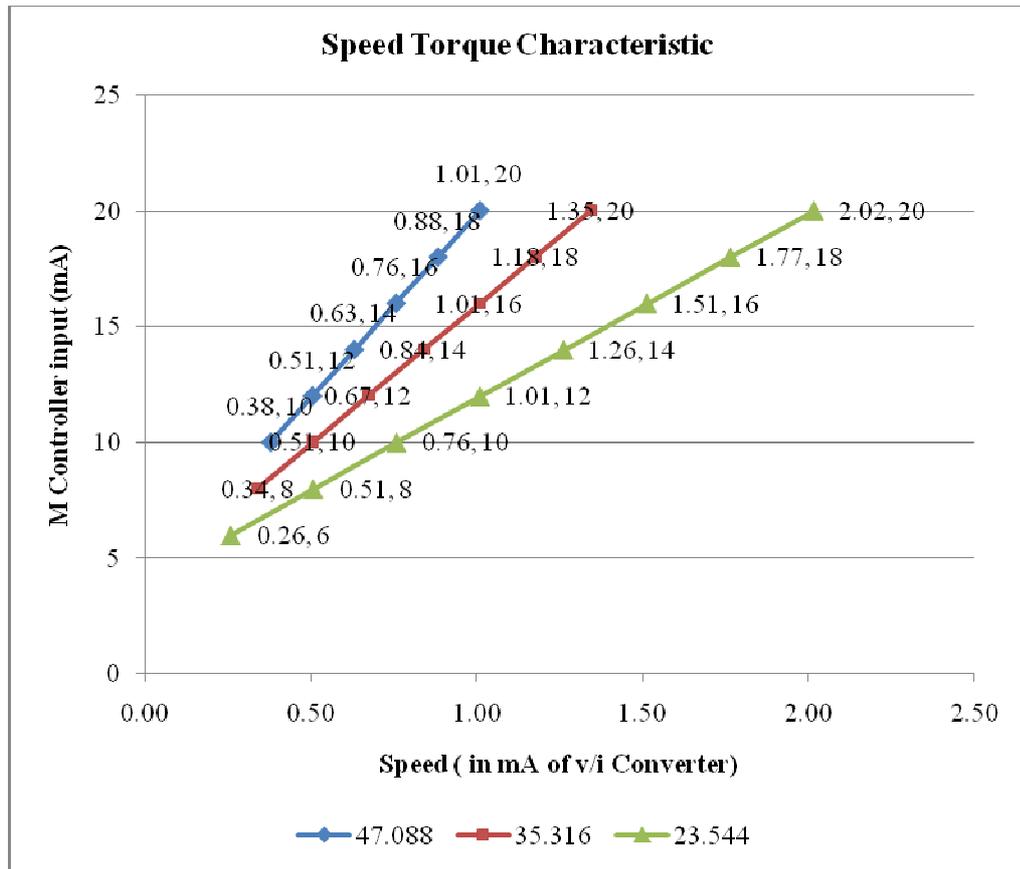


Figure - Speed Torque characteristics of DC Motor. (mA equivalent)

Results and Discussion

The prime motive of speed control system was to introduce the HC900 controller and proportional error introduced by load change. As discussed earlier, the proportional controller is subjected to offset error due to load change. The load change is introduced by the change in torque. The amount with which the load change

should be introduced is explained next as result and discussions. The linearization technique as explained by the control theory books is implemented here as demonstration. The interpretation by hybrid controller is straight forward. The meaning of control system counterpart is explained with relevant details. This chapter focuses the modifications in experimentation for desired performance and achievement of the project.

The Controller Performance:

The offset error is the steady state error followed by a load change. When the torque is increased than initial value the speed of the motor decreases slightly and this decrement resides as long as load change continues. The integral controller when combined with proportional controller, counteracts on residual steady state error, and resets the set point, hence the name resetting or floating controller.

The proportional band is normally in percent of set point. Similarly offset error is also in percent of the set point value. For example for 1000 rpm set point, the proportional band of 20 percent would mean the controller outputs maximum set value for 900 and minimum set value for 1100 rpm. The offset error of 10 percent means, following a increase in load torque, the speed would set to 950 rpm and will continue to operate on this new value with this load.

The slope of controller lines is nothing but proportional band, and offset error definition enables to work out the value. The motor maximum speed is 300 rpm. The set point is usually taken as 50 % of full range, i.e. 150 rpm. As discussed earlier, the 150 rpm corresponds to 12mA of M Controller output. And 1.01 mA of V/I converter employed in series with tacho generator output.

For 30 % of proportional band, maximum speed would be 172 rpm and minimum speed would be 128 rpm, for 150 rpm set point. This band value is entered in Tuning tab of PID function block properties. The corresponding controller output is 18 mA and 16 mA from table 5.1. The V/I output for these speeds is 1.18 mA and 0.84 mA respectively. When the load changes from 23.554 N.m (2.4 kg.m) to 35.316 N.m (3.6 kg.m) the speed droops down to 101 rpm as discussed.

Downloading the program to HC900 Controller:

In HC900 program interface, the speed file is opened. Then clicking on download icon, the download window appears. Accepting the network adapter and default settings the start button is clicked. The processes of downloading the program starts. After completing the process the Close button is clicked. Then the program is put in Run mode from the software itself. To make the program work in different modes following digital inputs are checked.

- (a) Checking digital input no 4, the program, starts running in auto mode. This means, the controller starts working on the feedback value of speed and outputs the appropriate output to M Controller depending on the speed.
- (b) Checking digital input 5, the program starts following the remote i.e. HMI defined set point instead of the working set point given in the controller program by analog variable.
- (c) Checking digital input 2, the program is forced into auto tuning mode. In this the program finds itself the values of proportional band, resetting gain and rate gain of tuning tab of PID function block properties. The procedure followed is Ziggler Nikolus Method.
- (d) Checking digital input 3, the PID set 1 is executed. To execute PID 2 set, the similar digital input is required to be configured to Tun2 pin of LPSW switch in the function block program.

Conclusion

- (a) As discussed earlier, the speed of the AC motor keeps on varying with respect to voltage and current conditions of the power supply. The 1440 rpm, with 10 % of fluctuations, it is very difficult to demonstrate the proportional band. This difficulty is overtaken by using DC motor.
- (b) The proportional band of 30 % means speed ranges from 172 to 128 rpm. This is clearly seen while experimentation. The 300 rpm DC motor was selected because the 5 % fluctuations mean 7 rpm on either side. The offset error is taken as 15 rpm, hence the fluctuations in the motor speed matters very little as against high speed motors.
- (c) The concepts of control system i.e. mathematical modeling, steady state analysis are better proved in the experimentation. The entire modeling is not presented in the report, but only important milestones are browsed quickly.
- (d) After auto tuning, the controller sets the P, I, and D parameters on its own. These values are so selected by the controller that the output remains in line with the input to controller. Following a change, the new operation line of controller reaches faster as compared to proportional controller alone.
- (e) The experiment demonstrates all types of Mechatronics concepts. This includes digital inputs, digital outputs, analog input and outputs. The controller is also robust and programming with function block diagram goes very simple as compared with PLC ladder programming.

Future Scope:

The experimentation though very successful, but suffered a lot on following grounds.

- (a) The auto tuning of the controller did not support the theoretical tuning parameters for the still unknown reasons.
- (b) The variation in the feedback signal was varying from 0 – 2 V, hence very less resolution. This had an impact on the steady state of the controlled variable i.e. motor speed.
- (c) The detailed analysis of working set point and remote set point was not available even on the net or with the Honeywell professionals. However the experimentation was carried out on remote set point concept.

Naturally this shall be the step in for the next experimentation of the continuation of work done on this set up.

Technical papers

- 1 Woe Wan Tan, Junwei Lai. "Development of a type – 2 fuzzy proportional controller." O-7803-8353-2/04/\$ 20.00 © 2004 IEEE. PP No. 1305-10.
- 2 Chao- Ying, Liu, XUE Chuan Hov, Yu- Long CUI, Jiao, Min Liu "Research for speed controller of switched Reluctance motor using F-PID controller" O-7803-7865-2/03/\$17.00 © 2003 IEEE PP No. 2530-33.
- 3 Hailong Song, Yong yu, Ming Yang, Dianguo Xu " Hybrid Adaptive Fuzzy Variable Structure speed controller for brushless D.C. motor." O-7803-7474-6/02- \$17.00 © 2002 IEEE PP 2126-310.
- 4 K. S. Tang and K.F. Man, G. Chen "Solar plant control using Genetic fuzzy PID controller." O-7803-

6456-2/00 / \$ 10.00 © 2000 IEEE PP1686-91.

- 5 Thomas Brehm & Kuldip S. Rattan “Hybrid Fuzzy Logic PID controller” proceeding of the IEEE No. 1 Aerospace and Electronic system conference (NAECON 92) May 18-22.

Reference Books

- 1 “Feedback Control System” Dr. S. D. Shinde, S. Narayanan, N. A. Jagaonkar, Tachnova Publications. 1/e.
- 2 “Modern Control Engineering” K. Ogata, Prentice Hall Publication. 2/e.
- 3 “Automatic Control Engineering”, F. H. Raven, Mc Graw Hill international editions. 5/e
- 4 “Automatic Control System”, George J Thaler Jaico Publication House 1/e.
- 5 “Liner Control System Engineering” Morris Driels; Mc Graw Hill International editions.
- 6 “Process Control Instrumentation Technology” C. D. Johnson, Prentice Hill International; 4/ e.
- 7 “Control System Engineering ” L. T. Nagarth. 2/e.
- 8 “Mechanical Measurement and Control” Metropolitan Book Co. New Delhi. 3/e.
- 9 “Mechanical Measurement” Beckwith, Marangoni, Lienhard, Addison Wesley Longman. 5/e.
- 10 “Feedback Control System” Dr. S.D. Bhide, S. Satyanarayan, N. A. Jalgankar Tachova Publication. 4/e.