International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Programming of HC900 Controller based Speed Control System for D.C. Motor

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Abstract: ***In process control industries the concept of multiple inputs, 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***

Keywords: HC 900, SCADA, HMI, PID Function Block, Programming

1. 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.

2. Hybrid Controller HC900

The Honeywell HC900 Hybrid Controller is an advanced loop and logic controller offering a modular design sized to satisfy the control and data acquisition needs of a wide range of process equipment. When combined with the optional, performance rich 1042 or 559 Operator Interfaces that fully integrate the controller database, configuration and setup time is minimized. This powerful combination together with Honeywell's performance proven control technology provides users an ideal solution for process control. Open Ethernet connectivity also allows network access using a variety of HMI/SCADA software. Easy-to-use Windows-based Hybrid Control Designer software, operable over Ethernet, an RS232 port or modem connection, simplifies controller and operator interface configuration. It provides advanced monitoring functions for debug, allows run-mode configuration changes while limiting process interruption uploads the complete, annotated graphic controller and operator interface configuration, plus supplies an array of printouts for enhanced documentation.

The HC900 Controller provides superior PID loop control and more robust analog processing than most logic controllers without compromising logic performance. A separate, fast scan cycle is available to execute a rich assortment of logic and calculation function blocks. Logic blocks may also execute synchronous with analog function blocks. These function blocks may be fully integrated into a combined analog and logic control strategy for uncompromising control performance. Some of the features of HC900 are listed as follows:

3. HC900: CPU

The rack based HC900 Controller is available in 3 rack sizes with 4, 8 or 12 I/O slots each to support a wide range of requirements. The C30 CPU supports a single rack with 4, 8 or 12 I/O slots and can accommodate up to 96 analog inputs or 192 total I/O points. A standard Ethernet communication port on the C50 and C30 CPUs provides open connectivity to PCs or other supervisory interfaces and supports peer data exchanges to other controllers.

4. HC900: Inputs and Outputs

A variety of I/O modules are available for selection in creating a custom control solution. These include:

a) 8 point universal analog input cards: Inputs may be mixed on a card and may include multiple thermocouple types, RTDs, ohms, voltage or milli-voltage types – all easily assigned using the Hybrid Control Designer configuration tool. High point to point isolation simplifies installation and saves the expense of external isolation hardware.

b) 4 point isolated analog output card: Supports from 0 to 20mA each.
c) 16 point digital input cards: Contact closure type, DC voltage and AC voltage types.
d) 8 point AC or 16 point DC digital output cards
e) 8 point relay output card: four form C type and four forms A type relays.

5. Function Blocks

Each HC900 Controller can support up to 2000 analog or digital function blocks. Each function block algorithm may be used a ny number of times in a control strategy unless specifically identified with quantity limits. Of the more than 100 function blocks available, 12 block types have limits imposed. These include

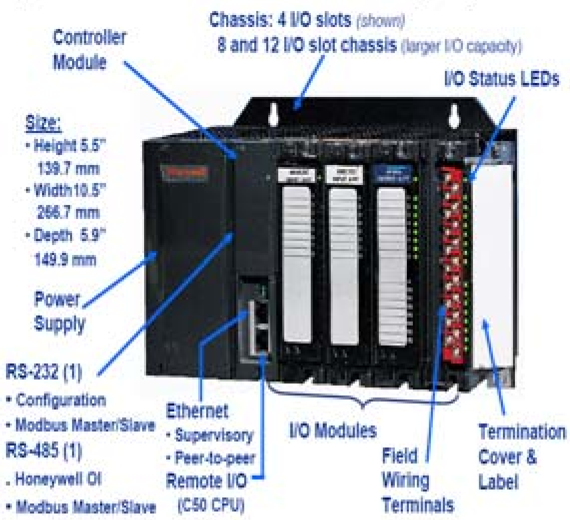

Figure 1: HC900 Controller with details

6. HC900 Hybrid Controller Design Software

Following are some of important points about the HC designer software features.

The HC900 Hybrid Control Designer software expands on the field proven concepts of the UMC800 Control Builder program. The user-friendly graphic development environment allows partitioning of the control strategy into up to 20 “worksheets” of 20 pages each. This allows the configuration to be organized according to process function, providing faster configuration access, and improved documentation. In addition, OEMs may apply additional security to specific worksheets to prohibit access to proprietary operations while allowing their customers to modify unprotected worksheets. Blocks are selected from a categorized list, dropped on a selected worksheet page, and soft-wired to other blocks directly or via tag references. Editing tools such as box copy and paste speed development. The copy and paste is also possible for the portions of strategies from other configurations.

7. Function Block Used in Programming

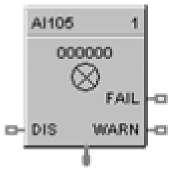

Figure 2: The AI Function Block

The AI label stands for Analog Input. This block is part of the I/O Blocks category. The function of the block is as follows. It reads value of an Analog Input from a specified real I/O address. Convert analog input value to corresponding output (OUT) in engineering units based on the necessary scaling and conversions performed. LINEAR - Converts analog input value to corresponding output in units based on a linear 0 % to 100 % scale and specified high and low range values. The Output is calculated as OUT = Scale x Input value + Bias where Scale = (High range value - Low range value)/100 where Input value = Analog Value in percent. The T/C or RTD tab is used to convert analog input value in engineering units using the range of Input Type. The figure 3 shows the details.

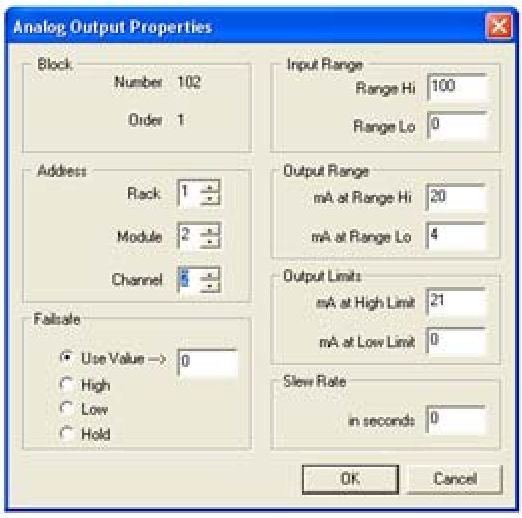

Figure 3: The Analog Input Properties

Input Analog value from specified real I/O address. DIS = disable the AI channel Output OUT = Analog Input value in engineering units. WARN = Warning Input Indication - Sensor failure possibility FAIL = Digital status of channel Digital Low (0) = OK Digital High (1) = Open sensor or failed input channel. The analog input and output work is similar fashion where in input HC900 scans or reads the channel and in output channel sends the 4 – 20 mA signal output.

8. Analogue Output (AO) Function Block

In this function block, range High and Range Low are used to specify the Engineering Unit values for 100 % and 0 % of this block’s input span. For reverse outputs, Range High may be set to a value less than Range Low. The output range high and range low values (0-20 maximum) set the milliamp output values that correspond to the 0 % to 100 % span limits of the inputs. The input IN is Analog value. The output is converted value sent to specified real I/O address. FAIL = Failed Output indication i.e. Module Error

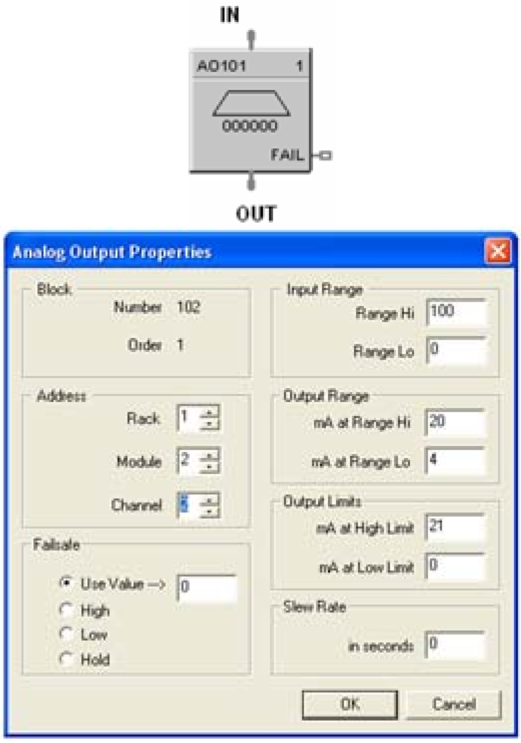

Figure 4: Analogue Output Block

9. The PID Function Block

The PID block function is to provide Proportional (P), Integral (I) and Derivative (D), (3-mode) control action based on the deviation or error signal created by the difference between the set point (SP) and the Process variable analog input value (PV). It provides two digital output signals for alarms based on configured parameters.

PID block provides for Feed forward, Cascade, and Ratio control. Automatic tuning with Fuzzy Logic Overshoot Suppression can be configured. Digital inputs may be used to set control mode, select the set point source, change control action plus other discrete actions. The various inputs and outputs are quickly mentioned below.

The main components of PID General tab are algorithm, i.e. PID A represents the PID algorithms in use. It may be PID-A and PID-B. The HC900 controller may be put into two PID settings with different set-points, different proportional bands, integral action times and different derivative action times. Here PID-A algorithm is employed. DIRECT - PID action causes output to increase as process variable increases. And the REVERSE - PID action causes output to decrease as process variable increases. In the present control system discussed, the REVERSE PID action is selected. This is because as the controlled variable speed if decreases the manipulated variable i.e. output of HC900 should increase and vice a versa.

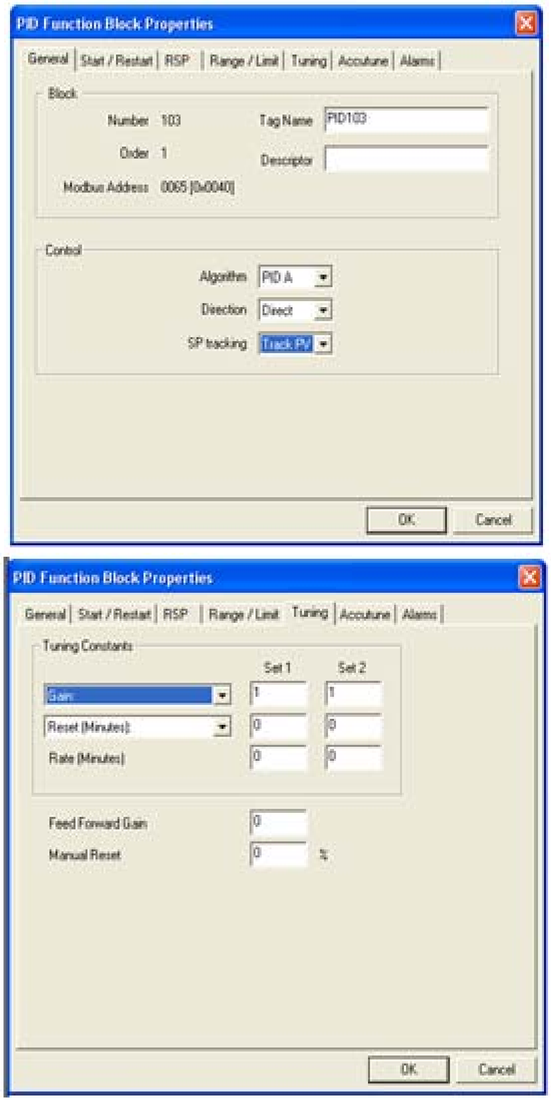

Figure 5: PID Function Block Properties

The Start/ Restart, Range/ Limit, and RSP (Remote Set Point) are set to default values, i.e., as it is. This suffices the purpose. The Tuning tab is configured as follows. The Gain indicates the proportional gain, or in other words the proportional band. It decides the action taken with respect to size of error. The Reset (Min) indicates the integral action time. Similarly Rate (Min) indicates the derivative action time. The integral action time and derivative action time are explained later in the chapter. The General and Tuning tab details are shown in Figure.

10. Introduction

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."

11. 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 6 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.

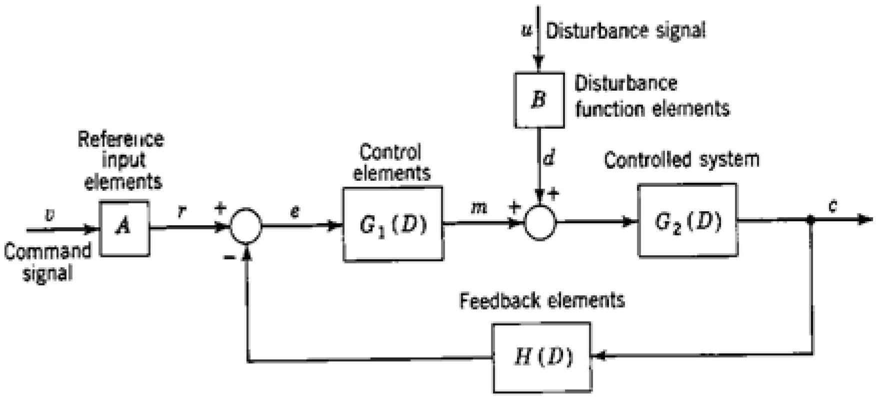

Figure 6: The Generalized Block Diagram

12. Speed Control Systems

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.

13. 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

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

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 7.

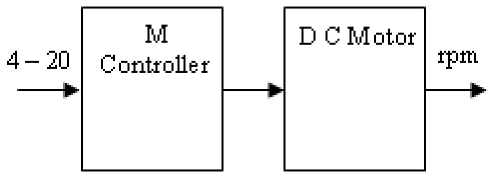

Figure 7: The Block Diagram of Plant (Prime mover) Or System to be controlled.

14. 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 8 shows the block diagram of operation.

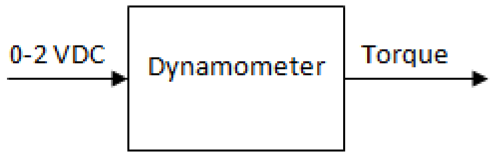

Figure 8: Block Diagram of Dynamometer

15. 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.

16. 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.

17. 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 9 shows the details.

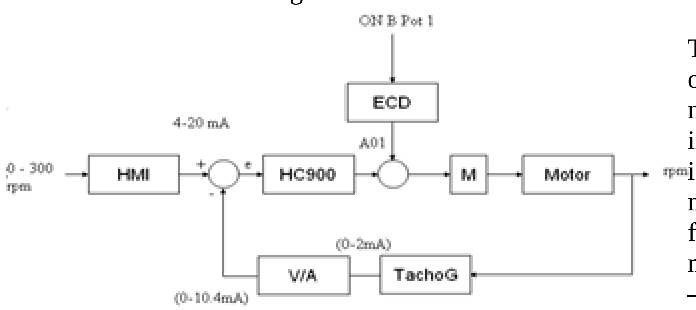

Figure 9: The Block Diagram of operation for speed control system.

18. Interfacing of Components

The experiment lay out is discussed. Now the interfacing of the various components used is addressed. The eddy current dynamometer, v/i converter, etc, components are so selected to suffice the purpose. The basic theory of control systems was to be proved hence instead of discussing the components with respect to construction and working, the interfacing is addressed for specifications and interfacing. The corresponding HC900 port allocation is automatically addressed.

19. HMI Interface: Analog Input 2 (AI2)

The PID block of HC900 controller works on two types of set points. The one is working set point (WSP) and second is remote set point (RSP). The remote set point means, the pin gets the set point value from a sensor or transducer at remote place. And the working set point facilitates to change the set point from the point of control itself.

In case WSP is selected, then there is no need to give the RSP, and for the sake of experimentation RSP is introduced here. The analog variable is selected from Function block diagrams, and assigned a value of set point. This is connected to WSP pin of PID function block.

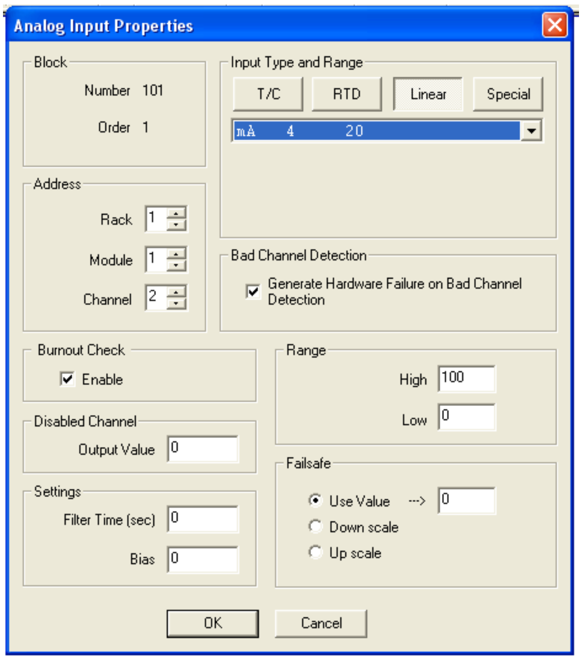

Figure 10: Analog input 2 Properties Dialogue Box

The rack indicates where HC900 is mounted. There may be other controllers in some other racks. Such racks are numbered as rack 2, 3, etc. In HC900, first module is analog input module, second module is analog output module, third is digital input module, and fourth module is digital output module. Hence for analog input module 1 is selected. The first channel is reserved for rheostatic input, hence channel no 2 is selected. The input type and range is selected to be 4 – 20 mA linear input. Burnout check is enabled by default. Other settings are accepted as it is.

The output of HMI is internally connected to channel no 2, by the manufacturer itself. Hence no wiring is required to be done from outside. The Analog input ranges from 4 mA (corresponding to 0 rpm) to 20 mA corresponding to 300 rpm. The set point is selected to be 50% of full range i.e. 12 mA. The HMI reads 150 for this setting.

20. Interfacing Controller Output: Analog Output AO1

When 150 rpm i.e. 12 mA is configured as set point, and it is connected to WSP pin of PID function block, depending on the process variable PV, the PID function block outputs a analog value between 4 – 20 mA on percent scale. That is 4 mA corresponds to 0 % and 20 mA corresponds to 100 %. This output is given to input of M Controller. The M Controller is controller of DC motor. The motor \outputs 0 rpm for 4 mA input and 300 rpm for 20 mA input. When process variable is 12 mA, WSP is 12 mA, the PID block outputs 50% that is 12 mA. This 12 mA of PID, is input to M Controller. Hence DC motor outputs 150 rpm at corresponding torque. The HC900 details are as given below. The rack selected is 1, module 2 and channel no 1. Other parameters like range Hi, range Low are accepted to default settings.

21. Configuring Feedback: Analog input AI2

The tacho-generator built in the eddy current dynamometer, is used as feedback as discussed. The eddy current dynamometer is specified for 1440 rpm at 47.088 N.m (4.8 kg.m). The corresponding tacho-generator output is 0 VDC (0 rpm) to 10 VDC (1440 rpm.) The present application of speed control system works only on range 0 to 300 rpm.

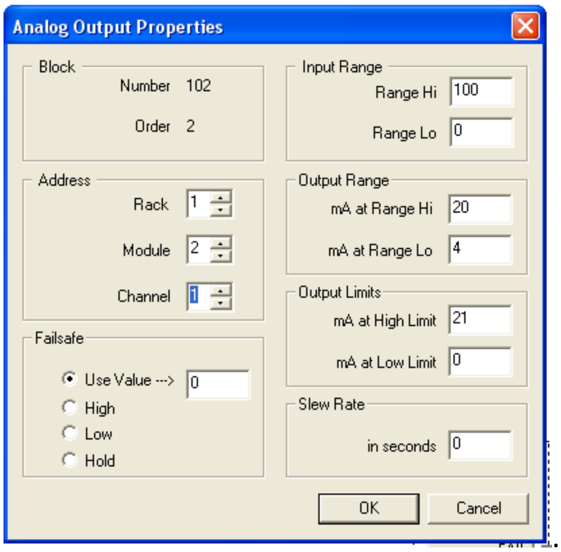

Figure 11: Analog Output AO1 Function Block Properties.

Hence maximum tacho-generator voltage shall be 2.08 VDC approximately 2 VDC. The voltage interfacing with HC900 requires additional signal conditioning. Hence a voltage to current converter is employed. The v/i converter accepts 0 – 10 VDC to convert it to 4 – 20 mA DC. The 2 V DC input to this v/i converter amounts to 3.6 mA corresponding to 300 rpm. Hence for 150 rpm, the converter output is 1.8 mA. This is 50% of full range. Therefore to shift this to 12 mA, as it is required to indicate 50% of full range, 10.2 constant analog value is added permanently. This is called as bias value and is entered in analog input property box as shown in figure 11.

22. The PID Block Configuration: Basic

Figure shows the basic definition of PID function block. The analog input AI2 is configured to RSP pin, the analog input AI3 is interfaced With PV, and the output of PID block is connected to analog output AO2. The actual working of PID block requires few more pins to be connected. The quick mention about the vary required pin configuration is addressed herewith

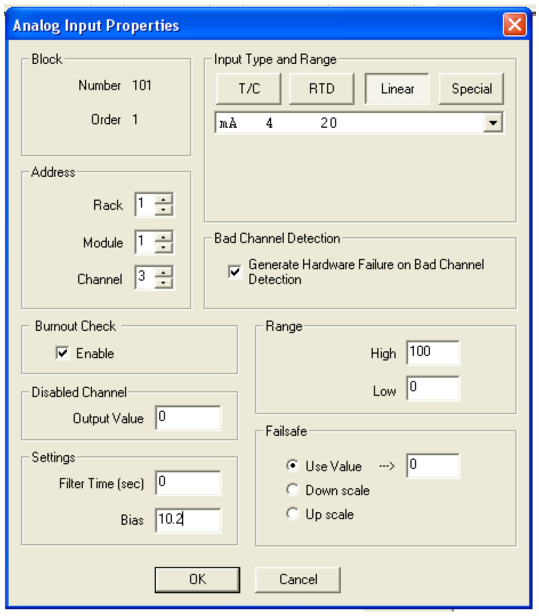

Figure 12: Analog input 2 Function Block Properties.

23. Loop Switch: LPSW

The LPSW label stands for Loop Switch. This block is part of the Loop Blocks category. The function is described as follows. It is a digital interface to control loops to initiate autotuning, change control action, force bumpless transfer, and select tuning set. It connects to a PID, TPSC, or CARB function block. The various inputs to LPSW are

Input

^ATC Autotune Command (OFF to ON initiates Autotuning)

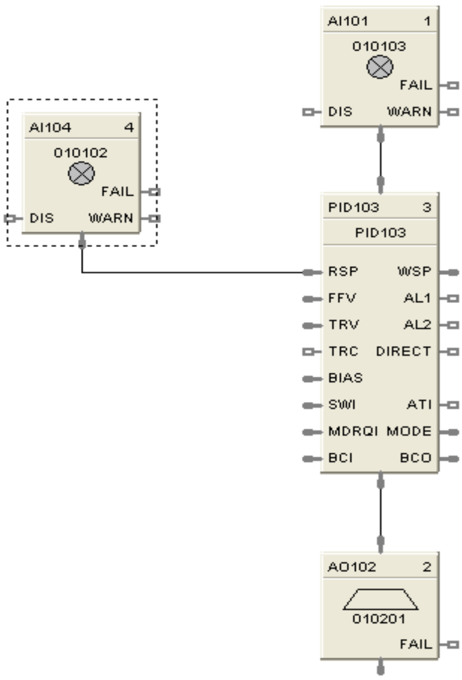

Figure13: The Basic PID Function Block Defined.

The only required inputs are ^ATC to turn on auto tuning. It is explained in results and discussion. And ^TUN1 to tune the controller to Tune Set 1. This is also explained in chapter results and discussions. For these two, digital input channel 2 and 3 are designated. The properties are set as rack 1, module 3, channel 2 and 3 respectively.

Similarly other function block required is Mode Switch. This is explained as follows. It is evident from the description that, only ^AUTO and ^REM pins are required to be configured. The digital input 4 and 5 are designated for these two input and output is configured to SW1 and MDRQI respectively on PID function block. The complete PID block definition now appears is shown in figure 14.

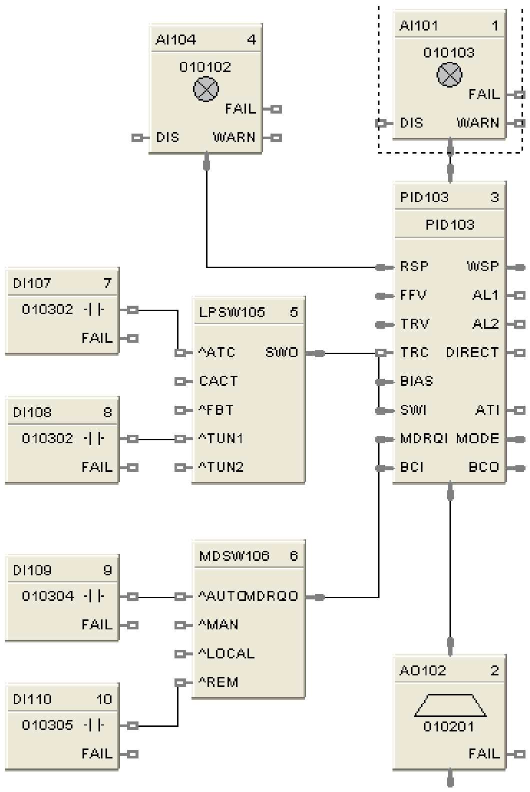

Figure 14: The Complete PID Function Block Defined.

24. Results and Discussion

24.1 Introduction

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.

24.2 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 16 mA 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 35.316 N.m (3.6 kg.m) to 41.202 N.m (4.2 kg.m) the speed droops down to 138 rpm as discussed.

24.3 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 is 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.

24.4 Conclusion

The experimentation has proved following results.

(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.

24.5 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.

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