control voltage required is 2 V DC. Figure 8 shows the block diagram of operation.

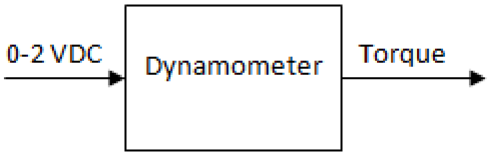

Figure 8: Block Diagram of Dynamometer

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.

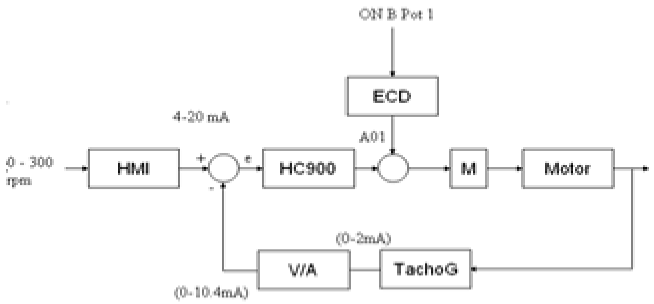

Figure 9: The Block Diagram of operation for speed control system.

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.

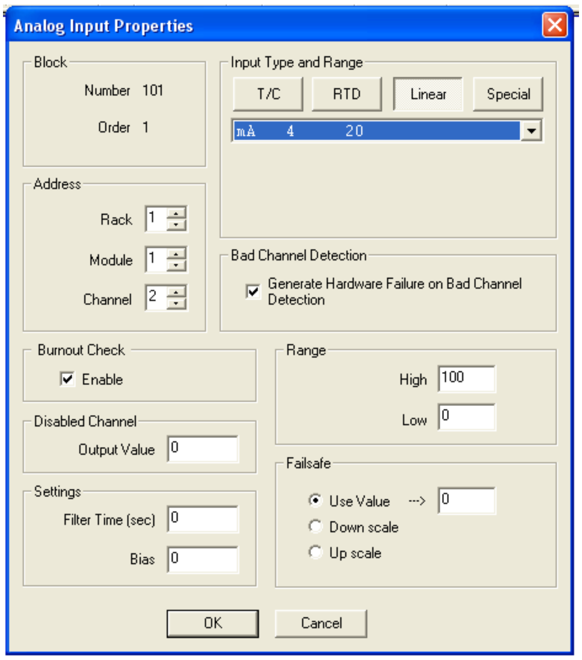

Figure 10: Analog input 2 Properties Dialogue Box

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.

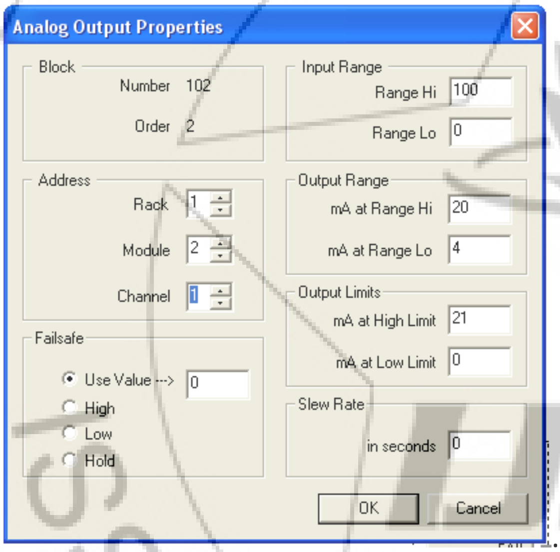

Figure 11: Analog Output AO1 Function Block Properties.

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

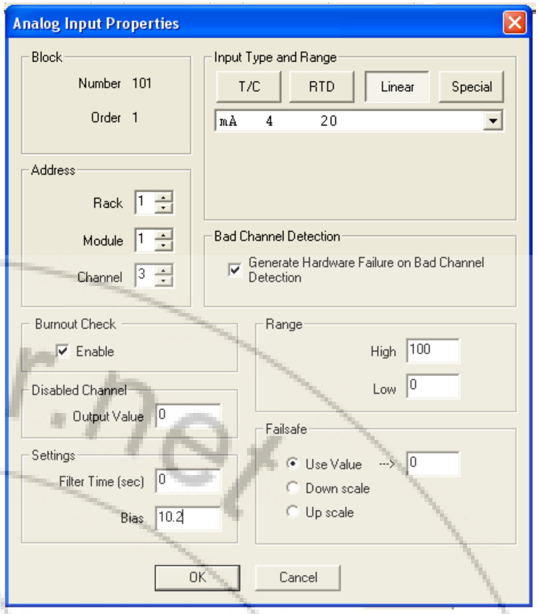

Figure 12: Analog input 2 Function Block Properties.

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)

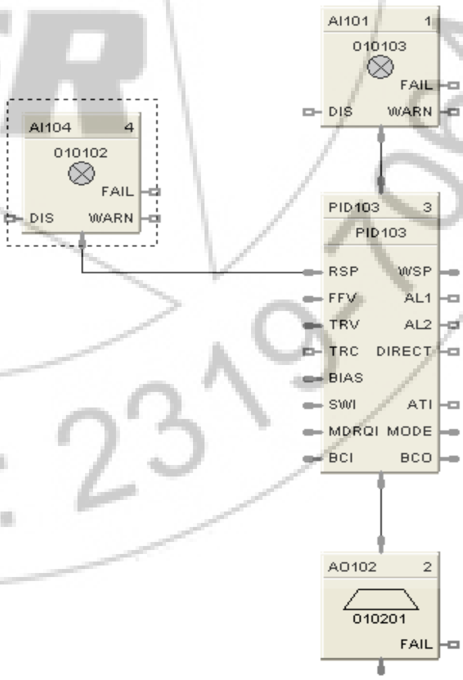

Figure13: The Basic PID Function Block Defined.

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.

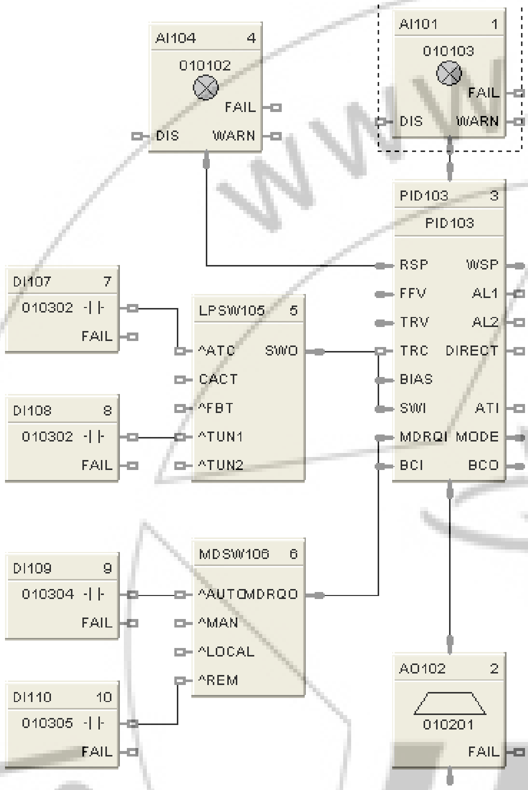

Figure 14: The Complete PID Function Block Defined.

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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