A Study of Speed Control of PMDC Motor Using Auto-tuning of PID Controller through LabVIEW

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Abstract -- **This paper presents a method of controlling the speed of PMDC motor with the auto tuning of parameters of the PID controller for the purpose of on-line speed control and also presents a model of the closed loop system through LabVIEW. Currently, the Proportional-Integral-Derivative (PID) algorithm is the most common control algorithm used in industry. To achieve this objective, an auto tuning PID is used in three steps. In the first step, the PMDC motor-generator set is interfaced to Laptop using NI USB-6008 DAQ card. In the second step, the closed loop system is extracted through the LabVIEW system identification toolkit. In the third step, auto tuning procedure is used to obtain PID parameters and controlling of speed is done. The designed auto tuning PID controller provides minimum steady state error and give better performance compared to the manual tuning PID controller.**

Keywords: PMDC motor, Auto tune PID, LabVIEW, System identification, State-space model.

I. INTRODUCTION

DC motors provide excellent control of speed for acceleration and deceleration. The function of a DC motor speed controller is to take as input a signal representing the demanded speed and to drive a motor at that speed. The controller may or may not measure the speed of the motor to use it as a feedback for the purpose of error reduction. If it does so, it is called a closed loop system else an open loop system. Here the closed loop system is considered. Large experiences have been gained in designing trajectory controllers based on self tuning and Proportional Integral Derivative (PID) control. In order to adjust the speed of the system PID controller is widely used. The PID based speed control has many advantages like fast control, low cost and simplified structure. This paper mainly deals with closed loop controlling of DC motor speed using auto tuning PID as speed and current controller with Labview.

II. THEORY

Closed Loop Control Systems: In a closed-loop system the control input is affected by the system output. In this the signal is fed back from the system output to system input and comparison with a reference input signal is performed, then the result of this comparison is used to obtain the control or actuating system input[6]. Error of such a closed-loop system can be calculated as:

Error = Reference input - System output.
Mainly there are three types of controllers P, PI and PID. In this paper the PID controller is used to achieve the desired speed.

PID Controller: A (PID controller) proportional-integral-derivative is a control loop feedback mechanism which is widely used in industrial control systems. A PID controller compares the measured process variable with a desired setpoint and calculate the error. The controller adjust the process through use of a manipulated variable to minimize the error.

The PID controller also called three-term-control algorithm because involves three separate constant parameters: the proportional, the integral and derivative values, denoted by *P, I,* and *D.* Where *P* depends on the present error, *I* depends on the accumulation of past errors, and *D* is a prediction of future errors, based on current value of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve etc.

The PID control has three correcting terms, whose sum constitutes the manipulated variable (MV). These three terms (proportional, integral, and derivative) terms are summed to calculate the output of the PID controller[5]. Defining u(t) as the controller output, the final form of the PID algorithm is:

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{\tau d}{d} \quad (1)$$

where:
K_p: Proportional gain, a tuning parameter
K_i: Integral gain, a tuning parameter

k_d: Derivative gain, a tuning parameter

e: Error = SP-PV

t: Time or instantaneous time (the present)

τ: Variable of integration; takes on values from time 0 to the present t.

The following formula represents the proportional action.

$$u_p(t) = K_p e(t) \qquad (2)$$

The following formula represents the integral action.

$$u_I(t) = K_i \int_0^t e(\tau)d\tau \qquad (3)$$

The following formula represents the derivative action.

$$u_D(t) = K_d \qquad (4)$$

PID controllers also have some drawbacks. One of the current difficulties with PID controllers is the gain tuning. When the process dynamics or disturbances are unknown PID controllers are difficult to tune[10]. In this paper, an auto tuning PID controller is presented so that the parameters of the PID controller are automatically tuned through LabVIEW.

The Auto Tuning Algorithm: Tuning means change in setpoint automatically, and calculation of the controller's parameters from the response. For auto tuning control loop must be stable initially (with P, PI or PID controller). When the system come in steady state the tuning process starts [2]. There is a limit cycle exists with the required number of cycles, and PID parameters are evaluated, hence parameters of PID controller are updated and the auto-tuning process is stopped.
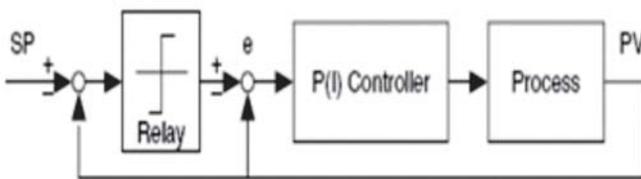
$$\frac{d}{dt}e(t)$$

Figure 1. Process Under P ID Control with Setpoint Relay.

Figure 1 illustrates the auto tuning procedure. A relay and an extra feedback signal is connected with the set point, a loop is created. The existing controller remains in this the loop.

Mostly the nonlinear relay characteristic generates a limiting cycle, from which the auto tuning algorithm identifies the relevant information needed for PID tuning.

To determine the parameters of a PID controller, given auto tuning PID uses Ziegler and Nichols' heuristic methods.

TABLE 1 - TUNING FORMULA UNDER AUTO TUNE PID CONTROL

Controller	K_c	T_d	T_i
P	$0.26T_p/\tau$	-	-
PI	$0.24T_p/\tau$	5.33τ	-
PID	$0.32T_p/\tau$	4τ	0.8τ

An auto tuning wizard opens as shown in Figure 2, when the auto tuning procedure runs. A local variable updates the PID gains control. After the completion of control loop, the VI writes the current PID gains.
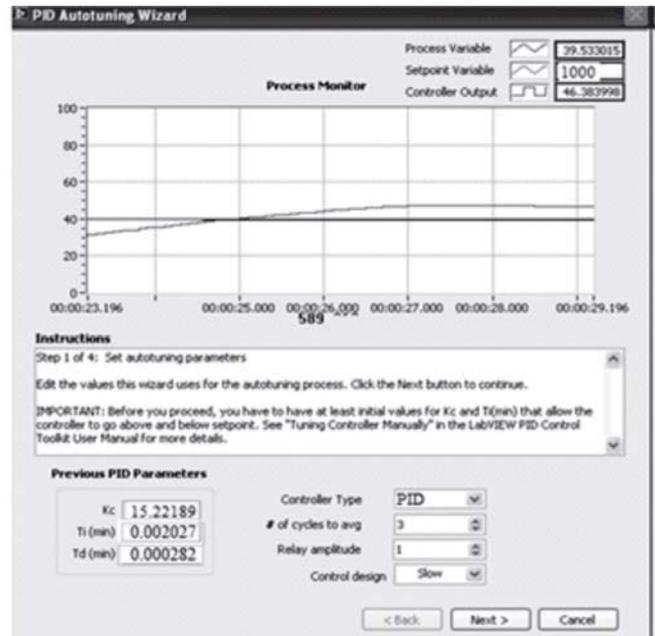

Figure 2. Autotuning Wizard.

III. EXPERIMENTAL SETUP

A. Hardware

Optical switch arrangement: MOC7811 is a slotted Opto isolator module, with an IR transmitter and a photodiode mounted on it. This is normally used as a Position Encoder
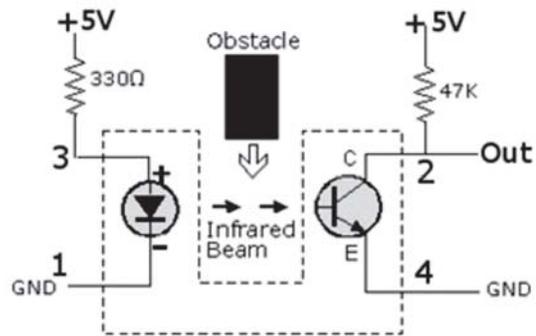

Figure 3. Optical Switch Circuit.

sensor which is used to find position of the shaft. LED and Photodiode mounted facing each other. Logic level of the photo diode changes when light emitted by the IR LED is blocked because of alternating slots of the encoder disc.

Microcontroller is used to sense this change in logic level [3]. The optical switch for speed measurement is shown in Figure. 3.

Motor driver circuit: Motor driving circuitry for driving the motor consists of 2 stages [3].

• Voltage amplification
• Current amplification

To meet the voltage specification of the motor, the output voltage from the DAQ [5] needs to be amplified, which is in the range of 0-5V to 0-12V. This is done by using IC 741. Since the output current of the IC 741 is in the range of milli Amperes, therefore amplification of the current is also needed for driving the motor.

This amplification is done by connecting the TIP122 NPN power transistor in common collector configuration. Therefore, the current amplified output is given to the motor from the emitter junction of the TIP122. Thus, the motor can be driven properly and circuit connection is made as shown in Figure 4.
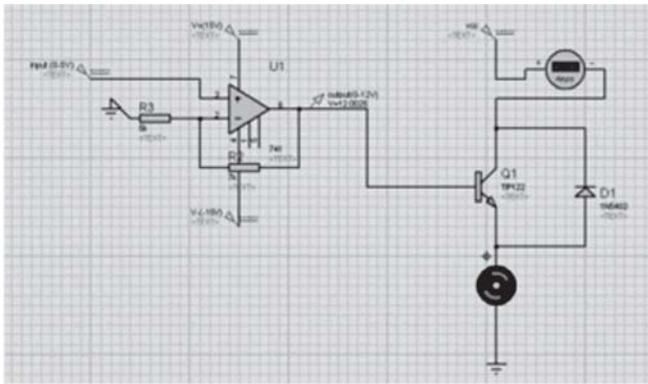

Figure 4. Voltage and Current Amplification Circuit.

Frequency to voltage converter: The frequency to voltage converter used in those application which requires measurement of a repeating event, such as a wheel making a complete rotation [3].

Here LM2907, frequency to voltage converter with a high gain op amp/comparator is used for measuring the speed of the motor. Optical switch produce pulses which are given as a input to voltage to frequency converter, as a result output is produced in the form of voltage proportional to input pulse frequency. Connection for 2907 is shown in figure 5.
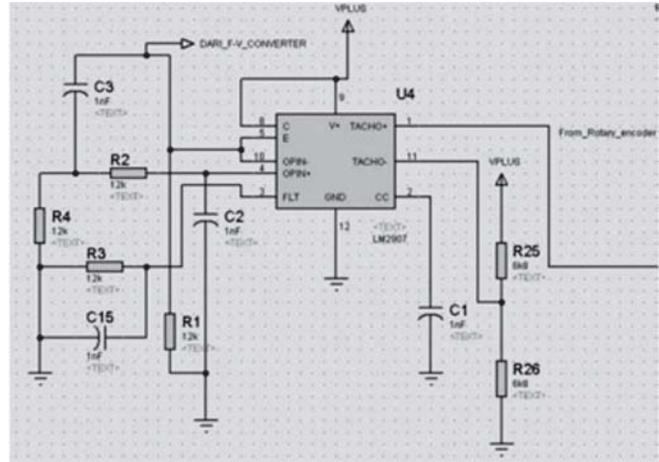

Figure 5. Frequency to Voltage Converter Circuit.

B. Software

A LabVIEW platform is used here to interface auto tuning PID controller with the DC motor for controlling the speed of the motor. Interfacing is provided through NI DAQ card USB-6008. LabVIEW by National Instrumentation (NI) USA, is used for development of virtual instrumentation system. It is a graphical programming language called G programming is performed using a graphical block diagram that compiles into machine code and eliminates a lot of syntactical details. Speed controlling of the PMDC motor and system identification are performed on the same platform With the use of the LabVIEW [1].

Closed loop PID speed control: Functional block diagram of closed loop system for controlling the speed of the motor is shown in Figure. 6.
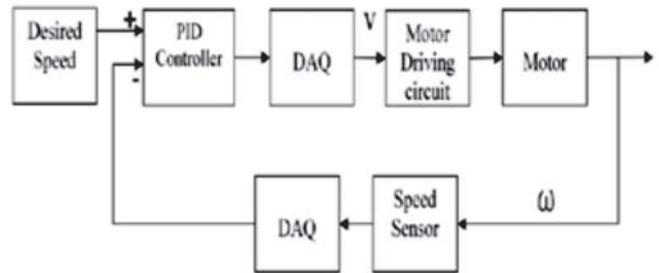

Fig. 6: Functional Block Diagram of Closed Loop Speed Control System of DC Motor

The desired speed is provided by the user and the actual speed of the motor is received through the DAQ card.

A ultimate gain method[8] is used to calculate desired speed, the actual speed and the PID gains which are given as inputs to the PID controller, as a result controller produces output in the range of 0- 5V through the DAQ card. High-frequency noise from measured values is filter out by the PID Control Input Filter[9].

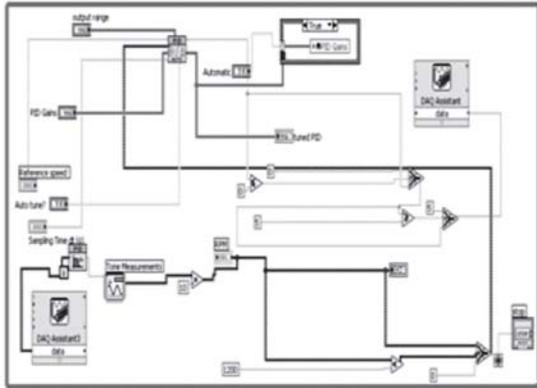The LabVIEW block diagram of closed loop speed control system is shown in Figure 7.

Figure 7. LabVIEW Block Diagram of Closed Loop Speed Control System.

The parameters of tuned PID gains obtained are as follows:

Kp=15.2289 ;
Ti=0.002027 s ;
Td=0.000282 s;
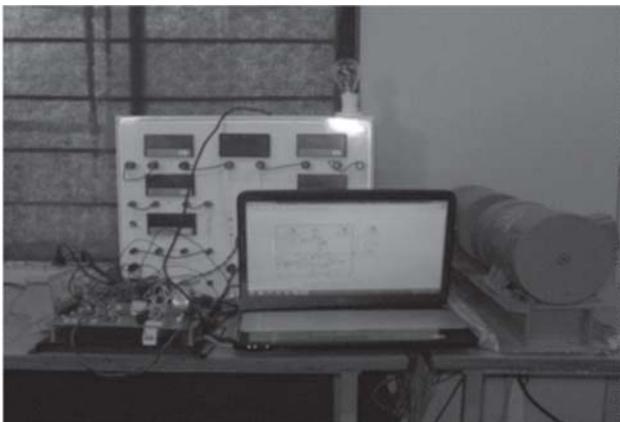
The hardware setup is shown in Figure 8.

Figure 8. Hardware Setup.

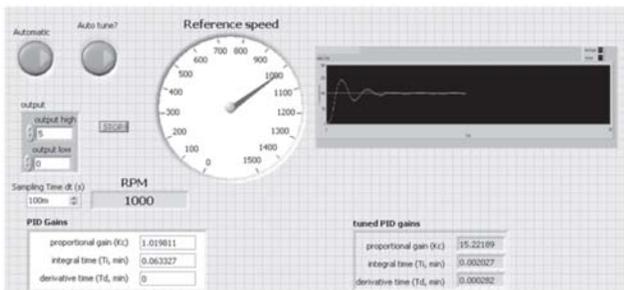The result front panel is with the as shown in Fig. 10

Figure 10. Output Shown in LabVIEW Front Panel.

System identification: Since the parameters of the PMDC motor and the system is unknown, we perform the subspace system identification method[8]. This procedure includes 3 steps. They are-

• Data logging
• Model estimation
• Model validation

Procedure is as follows [4]:
i. The actual speed (input) and the desired speed (output) are logged into the measurement file.
ii. The first proportion of data is given to the state space estimation VI and the output will be the state space model of the system. This completes the model estimation stage.
iii. The optimum model can be obtained by changing the user defined order and thus model validation is done.

System identification block diagram is shown in Figure 11.

The comparison is made between the desired speed and output speed. The simulation output is as shown in Figure 12.
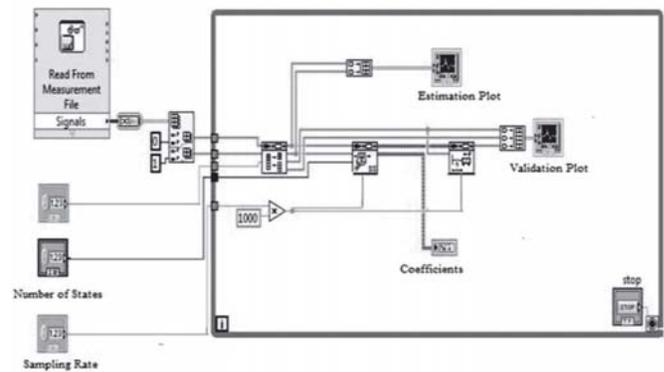

Figure 11. LabVIEW Block Diagram of System Identification.

Figure 12. Model Simulation Output.

IV. CONCLUSION

The virtual instruments makes data analyzing more accurate by decreasing the measuring time significantly. In this paper an auto tuning PID controller is presented for controlling the speed of the PMDC motor using LabVIEW. Here a closed loop system is used to identify the initial parameters of the PID which controls the speed to a more precise value and error can be easily reduced by giving feedback signal from the sensor to the controller using the DAQ card. Simulation result with LabVIEW shows that PID controller can be the best option for both command following control and disturbance rejection controll. The response of the System shows the fast rise time, fast setting time as well as fast recovering time.

V. ACKNOWLEDGEMENT

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