IJARSCT

ISSN (Online) 2581-9429

Impact Factor: 6.252

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 2, Issue 1, August 2022

Advanced Drive System for DC Motor Usingmultilevel DC/DC Buck Converter Circuit

Mr. Bombarde Sudhanshu S.[1] **and Prof .Bagale L. V.**[2]
M.Tech, Student, College of Engineering Ambajogai, Beed, Maharashtra, India[1]
Professor, College of Engineering Ambajogai, Beed, Maharashtra, India[2]

Abstract: *This paper focuses on the design and analysis of a speed drive for a Permanent Magnet DC (PMDC) Machine using MATLAB/SIMULINK as a simulation aid. The speed drive is designed for fast dynamic speed and current response in all four quadrant of the motor's torque- speed plane. The DC motor's mathematical model is used for characterizing the system, PID/PI controllers are designed and tuned with methods including (MATLAB tuning, particle swarm optimization (PSO) and Internal Model Control). Two control strategies, single loop PID and cascaded PI loops, were studied. The cascaded PI control was used for developing the speed drive of the PMDC machine which was tuned for a current loop bandwidth of 2π.600 rads/s and a current limiting logic was implemented in the current loop of the controller. The PMDC machine's speed was controlled using voltage control method with the use of Full bridge DC-DC power converter. Metal–oxide–semiconductor field-effect transistor (MOSFET) was used as the switch. The switching was done using Unipolar Pulse Width Modulation technique due to its positive effect on the motor's current ripples. The use of active damping and active resistance in the speed and current loop respectively was done to improve the drive performance.*

Keywords: Multilevel DC/DC converter, traditional DC/DC converter, and DC drive systems

I. INTRODUCTION

Process control industry has seen many advances in the past two decades in terms of controller design and its implementation. The need for automatic controllers that are responsive and accurate in carrying out precision tasks in the industry is of great demand. (Ali A. Hassan, 2018). For achieving the desired performance in the control of most systems, the feedback loop is an indispensable tool in the control of systems. In order to get fast dynamic response of the system, many control strategies have been devised in various feedback control systems. The importance of controls in a drive system includes precise and quick tracking for reference speed with minimum overshoot or undershoot and having little or no steady-state error. Muhammad Rafay Khan, (2015)

Proportional Integral and Derivative (PID) controller is one of the earliest and best understood controllers which is integrated into almost every industrial control application due to its efficiency, high reliability, good robustness, easy to operate stabilization and elimination of steady-state error. Sabir & Khan, (2014)

The PID controller has optimum control dynamics including zero steady state error, fast response (rise time), little or no oscillation and higher stability. The purpose of using the derivative gain component in addition to the Proportional-Integral (PI) controller is to eliminate the overshoot and the oscillation occurring in the output response of the system. A key advantage of the PID controller is that it can be used in the control of higher order processes including more than one energy storage element. Rao, (2013)

PID type controllers are used to attain the speed-torque control of a DC motor. However, the optimization and tuning task of these controllers is very difficult and time consuming, mainly under the varying load conditions, parameter variations in abnormal operating modes etc. Muhammad Raday Khan, (2015)

This thesis discusses the use of PID Controllers in achieving stable speed control of a Permanent Magnet DC (PMDC) Machine at a specified value. The DC motor model is developed by using the dynamic equation of the system and MATLAB/SIMULINK is used for simulating and analysing the response of the system, the PID tuning and analysis is done on the Simulink platform. The operation and tuning rules of the PID controller is also discussed. At the end, experimental results are presented and discussed.

DOI: 10.48175/568

II. DC MACHINE

For many decades (since 1980), the Brushed DC machine has been the automatic choice where speed torque control was very necessary. Figure 1 shows a schematic of a brushed DC motor showing all its important part consisting of the Commutator, Brushes, Armature conductor, and the Field windings. The applications of a DC motor ranges from steel rolling mills, electric traction, center winders to a very wide range of industrial drives, robotics printers and precision servos. The range of power outputs is wide, which varies from several mega-watts to a few watt of power. Also the speed of DC machines can be easily varied and controlled which makes them very suitable for precision industrial activities. (Hughes, 2006). Their speed-torque characteristics also makes them very useful in various applications. A few major components of a DC motor are described in turn. These parts provide a major contribution in the operation of a DC machine. They are also used to determine the kind of DC machine in use.

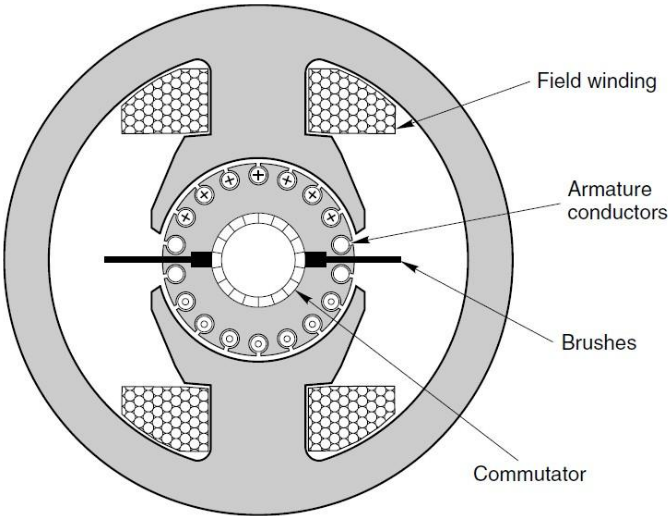

Figure 1: Conventional Brushed DC Motor (Austin Hughes, 2006)

III. CONTROL SCHEMES

3.1 Single Loop Feedback Control

A control system using a feedback mechanism maintains a prescriptive relationship between the process output and the set point by constantly comparing them using the error signal as a means of control. Feedback control is the simplest form of closed loop control scheme. Feedback control system has many daily routine application e.g. Automobile speed control or air conditioner temperature control system which uses the difference between the actual and the desired speed or temperature to change the manipulated variable. A system in which the output is used to regulate the output is called a Closed-loop system. The block diagram is shown in Figure 2 represents a simple feedback control system. S.K. Singla, (2013)

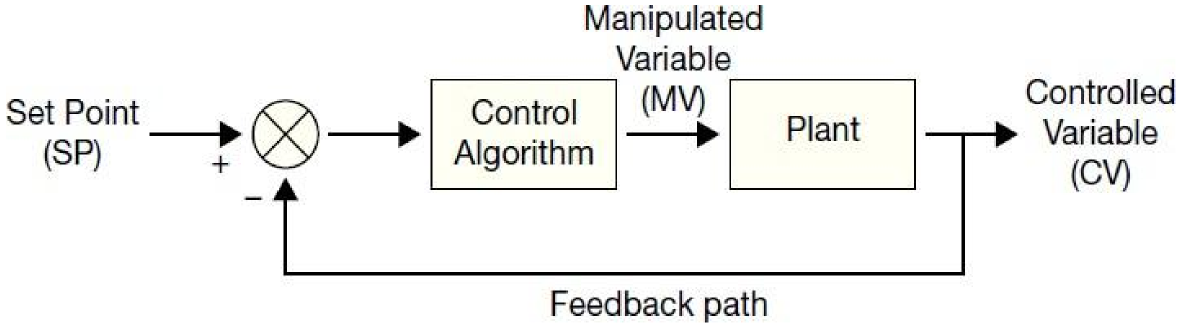

Figure 2 : Feedback Control System (S.K. Singla et al.)

Different variation of a feedback loop are used in the design of speed control of DC motor, due to its simple and robust structure

3.2 Cascade Feedback Control

This is the most commonly used variation in Speed control drives and steam process industry. A cascade control comprise of two loops an inner loop and an outer loop. Optimal performanceof a cascade control scheme is achieved when the inner loop has a faster dynamics as comparesto the outer loop. Figure 3 Shows the structure of a cascade scheme. The inner loop controlsthe secondary process e.g. armature terminal voltage of a DC motor. While the outer loop controls the primary process e.g. the angular displacement of a DC motor. Initially the inner loop is tuned first while keeping the outer loop controller in manual mode. The methods for tuning the inner loop includes the direct synthesis, Ziegler-Nichols, RA methods, metaheuristictechniques (PSO, GA etc.). Thereafter the outer loop controller is tuned to complete the tuningprocess. A variation to the cascade feedback system is the Cascade plus Feed-Forward Scheme. S.K. Singla, (2013)

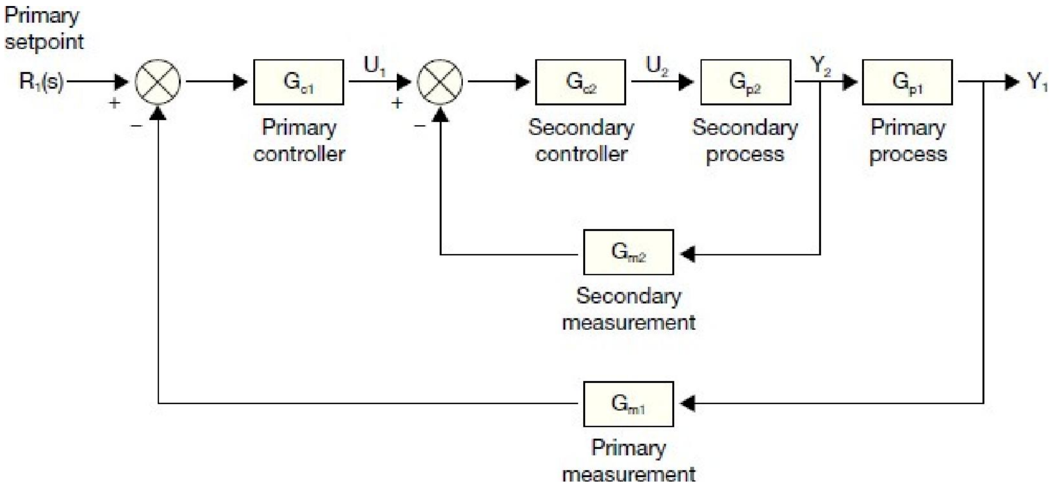

Figure 3: Cascade Control System (S.K. Singla et al.)

Most literature look into the speed control of a DC motor as a feedback control loop otherwiseknown as a closed loop control system. The research activities carried out on these areas showsthe need for continuous improvements on the simple feedback loop in controlling the speed ofindustrial actuators (DC motors). Literature based on various kinds of controllers used for DCmotor speed control are presented and discussed.

IV. DC MOTOR SPEED CONTROL USING PID ALGORITHM

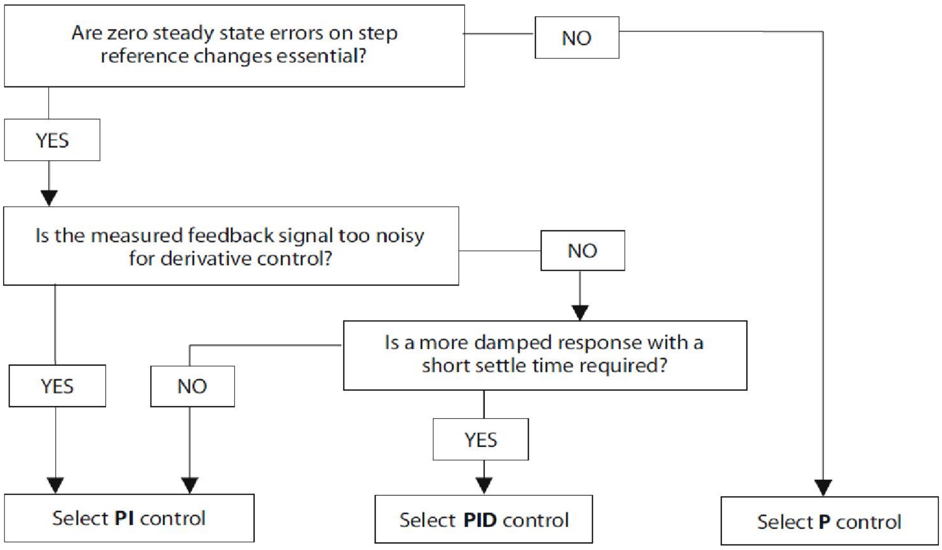

Figure 4 : PID Term Selection Flowchart. Johnson & Moradi, (2005)

The need for accurate speed control of a DC motor is very important and that leads to the use of accurate control techniques. PID controllers are one of the most popular controls used in industries nowadays, due to its accuracy and robustness in achieving precision speed control. The performance of a PID controller depends heavily on the gain parameters for the proportional, integral and derivative term. Various tuning methods have been devised and will be analysed and discussed in this section. Due to the difficulty involved in the tuning process of a PID controller, there has been considerably lot of effort done in researching on ways to make these controller even more accurate and easy to use. The first step of parameter tuning for the PID controller was done using Ziegler-Nichols tuning method which overcomes the overshoot problem of reference speed and actual speed under no-load condition and also eliminates steady-state error. The next step was to use manual tuning to overcome the undershoot problem of the motor speed under the loading effect. The PID controller is applied as an input voltage to the armature terminals of the DC motor. The ultimateparameters for the gain values were found and simulated.

The selection flowchart shown in Figure 4 shows that a PID controller is consists of a familyof controller with labels (P, PI, PD, and PID). The flowchart gives a guide to selecting an optimal controller strategy for various application that requires accurate control

V. SIMULINK MODEL

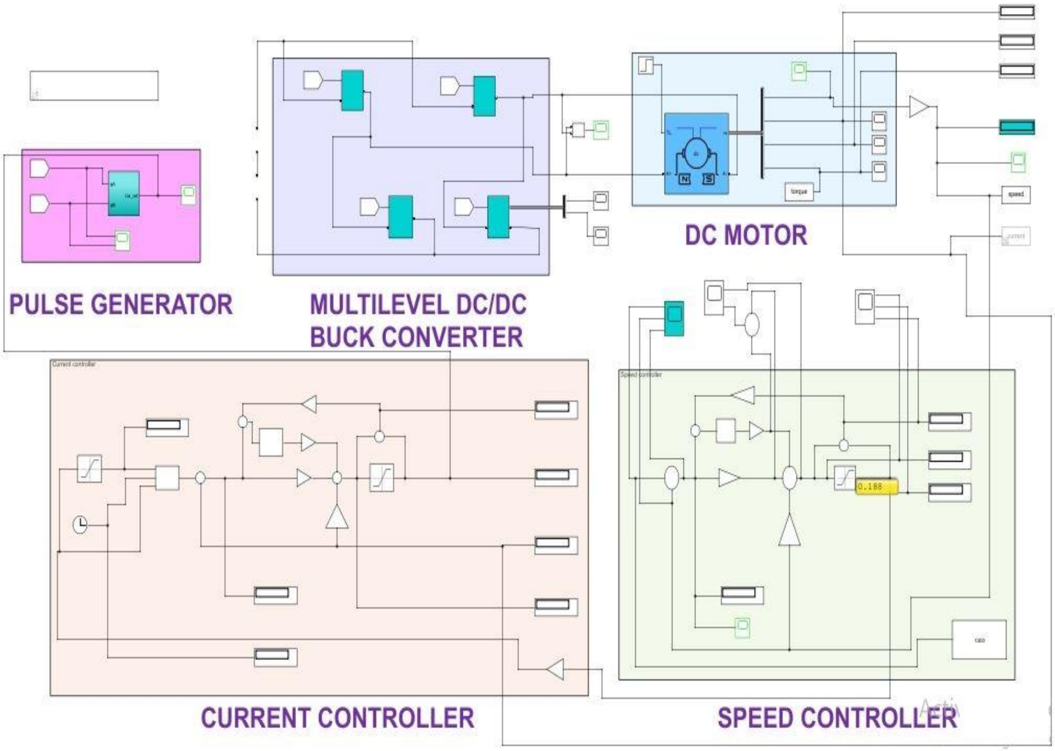

Figure 5: Simulink model for solar powered system

Based on the modelling of the Controller and MLCC discussed in this Chapter MATLAB Simulink Models have been built of the Proposed Controller which controls the PMDC Motor based on the reference Speed and at required Load Torque.

5.1 Speed Controller Block

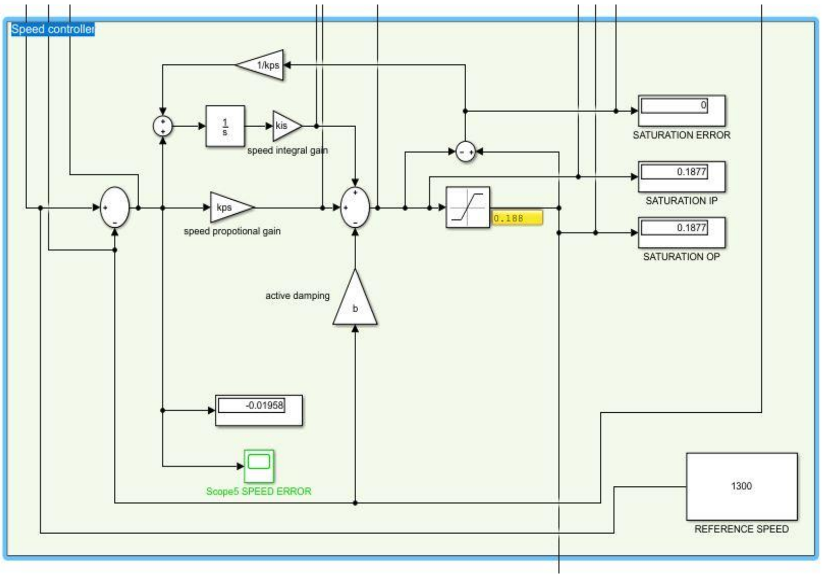

Figure 6: Speed Controller Block

5.2 Current Controller Block

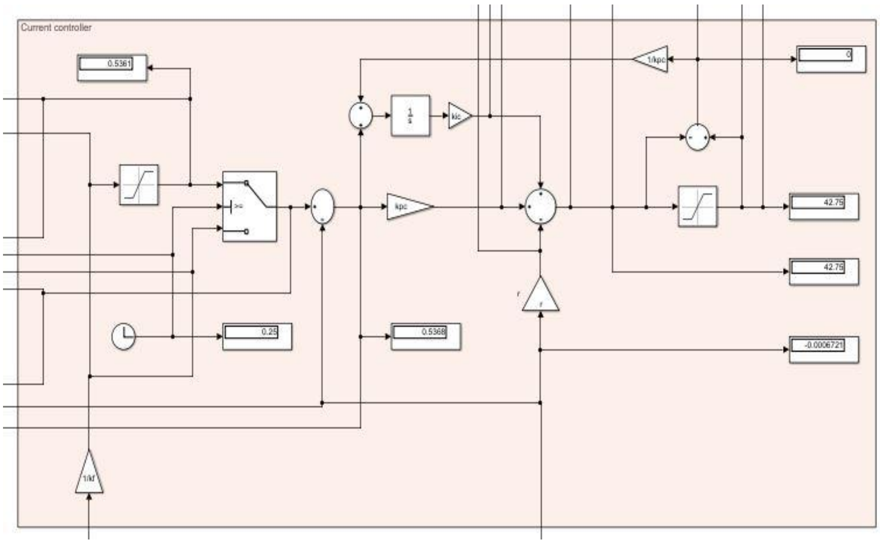

Figure 7: Current Controller Block

This section presents the response of the controllers designed in the previous chapter. Two controllers were realized, Single loop PID controller (tuned with MATLAB and PSO) and a Cascaded loop PI controller (tuned with a Model-Based method). The PID Single loop controller was done as preliminary step in showing the effectiveness of the tuning methods used (MATLAB automatic tuning and particle swarm optimization). The cascaded PI controller was then used for the proper DC Machine drive simulation using PWM on Simulink software. The cascaded PI controller was tuned using a model based method which offers quick determination of the PI controller gain with respect to the desired bandwidth of the system.

5.3 Matlab Tuned Pid (Single Loop Pid Controller)

The speed response of the single loop PID controller tuned using MATLAB is shown in figure 8 The figure shows the response to a set reference of 24 rads/s

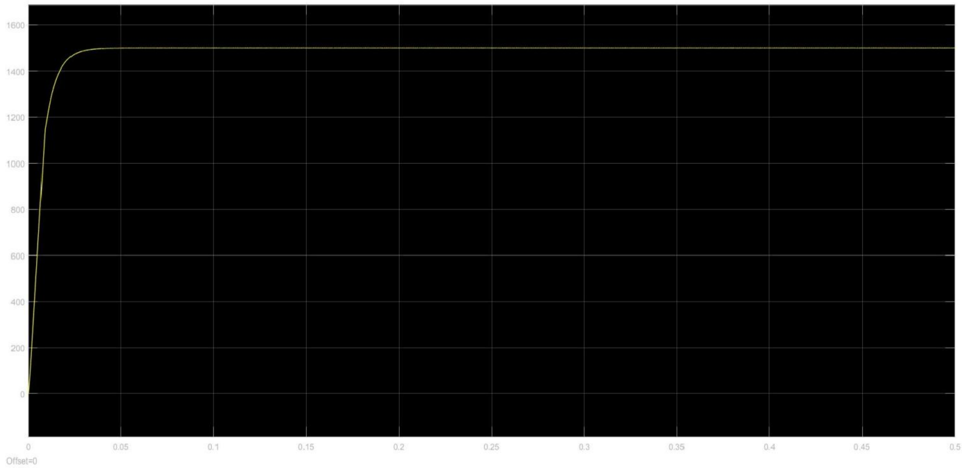

Figure 8 : Speed Response of MATLAB Tuned PID

5.4 Reference Speed is Constant, Input Load Torque is Varied < T rated.

According to the motor datasheet, the continuous stall torque is given as 0.28 Nm. To study the load disturbance rejection capacity of the DC motor speed drive, a load torque of 0.25 Nm is introduced to the DC motor at time 0.1s when motor speed is 1000RPM, the speed response is shown in figure 9 and the graph is zoomed in to show the impact of the load toque on the motor speed

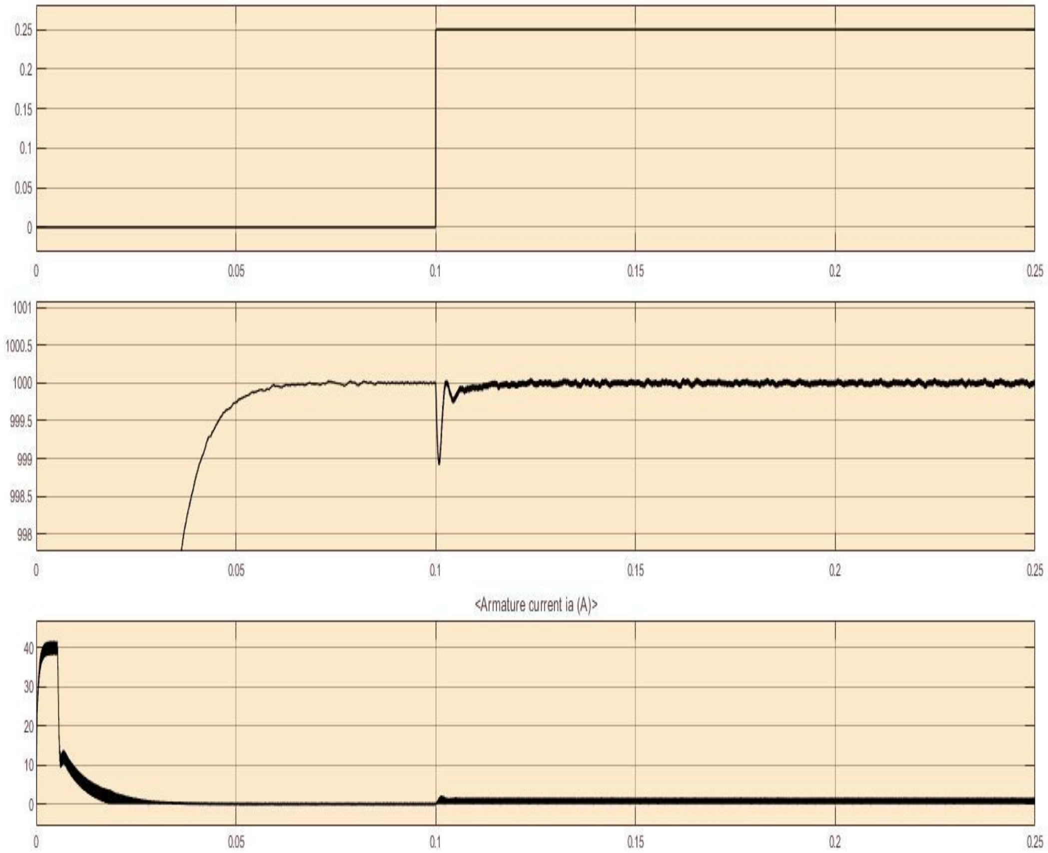

Figure 9: Load Rejection Capacity of Speed Drive to Load Torque of 0.25 Nm fromSimulink Scope Output (a) Input Load Torque (b) Actual Motor Speed (c) Armature Current

The load causes the motor shaft speed to drop to approximately 994 RPM, then the speed drive ensures the motor regains its reference set speed of 999 RPM in 0.001 seconds. The motor supplies more current to compensate for the additional demanded shaft torque imposed on it by load disturbance. The graph showing the motor input and output parameters of torque and speed during this phase is shown in figure.

The load torque of 0.25 Nm is below the continuous stall torque of the dc motor given in its datasheet. This means load torque of 0.25 Nm is within the safe operating range of the motor. The high current drawn by the motor at starting period are possible and are allowed. The current spike is due to the inherent nature of the dc motor at stall condition i.e. speed = 0. At this point the largest current flows through the motor, which is necessary for acceleration purposes during starting. It is also due to the torque-speed characteristics of dc motors. It is possible to significantly exceed the current and torque limits on a short term basis, but at steady state operation i.e. during normal ON time of the dc motor, the current and torque is expected to stay within the rated limits, for safe continuous operation.

VI. CONCULSION

This research paper has shown that PID/PI controllers play a major role in the design of speed drives for DC machines. The PID control implemented helps in delivering effective control signals for fast and robust response to changing reference speed and improved load disturbance rejection in the DC motor.

Among the three PID tuning methods that were presented, Particle Swarm optimization (PSO) method of tuning has shown to be a useful method for finding optimal gains for the PID controller and requires less technical knowledge on the PID controller and the plant. However, a method requiring more technical knowledge of the control system namely Internal Model Control (IMC) principle was used to tune the gains of the PI cascade controller for a predetermined speed and current loop bandwidth which enabled accurate orchestration of the cascaded loops.

REFERENCES

[1]. Ali a. Hassan, n. K.-s. (2018). Comparative study for dc motor speed control using pidcontroller.
[2]. Arnisa myrtellari, p. M. (2016). Optimal control of dc motors using pso.
[3]. Ayasa, m. S., & sahinb, e. (2019). Parameter effect analysis of particle swarm optimization algorithm. *An international journal of optimization and control: theories & applications*.
[4]. Bista, d. (2016). Understanding and design of an arduino-based pid controller.
[5]. Dani, s., & ingole, d. (2017). Performance evaluation of pid, lqr and mpc for dc motorspeed control.
[6]. Engelbrecht, a. P. (2007). *Computational intelligence. An introduction.* South africa: johnwiley and sons, ltd.
[7]. Fatah, i. S. (2014). Pso-based tunning of pid controller for speedcontrol of dc motor.
[8]. G¨ucin, t. N., bibero˘glu, m., fincan, b., & g¨ulbahc¸e, m. O (2015). Tuning cascadepi(d) controllers in pmdc motor drives: a performance.
[9]. Gajanan, m. (2011) Design of pid controller for improved performance of higher ordersystems.
[10]. Getu, b. N. (2019). Tuning the parameters of the pid controller using matlab. *Journal ofengineering and applied sciences*.
[11]. Gucin, t. N., biberoglu, m., fincan, b., & gulbahce, m. O. (2015). Tuning cascade pi(d)controllers in pmdc motor drives: a performace comparison for different typesof tuning methods.
[12]. Hagglund, k. J. (1995). *Pid controllers, theory, design and tuning.* International societyfor measurement and control.
[13]. Harun yazgan, f. Y. (2018). Comparison performances of pso and ga to tuning pidcontroller for the dc motor.
[14]. Hinkkanen, m. (2017). *Control of a dc motor drive.*
[15]. Hinkkanen, m. (2017). *State feedback current control: continuous-time design.* Politecnico di torino.
[16]. Hughes, a. (2006). *Electric motors and drives fundamentals, types and applications.*
[17]. Johnson, m., & moradi, m. H. (n.d.). *Pid control new identification and designmethods.* 2005: springer.
[18]. Joshi, n. P., & thakare, a. P. (2012). Speed control of dc motor using analog pwm technique. *International journal of engineering research & technology (ijert)*.
[19]. K. Venkateswarlu, d. C. (2013). Comparative study on dc motor speed control usingvarious contorllers.
[20]. Karl johan astrom, t. H. (1995). *Pid controllers: theory, design and tunning.* International society for measurement and control.