Design and Simulation of Armature Controlled DC Motor using MATLAB

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Abstract— In this paper, Technology at present needs faster and easier means of controlling equipment with few numbers of components. One of such equipment is the direct current (DC) motor, whose speed is directly proportional to the supply voltage. Using this established relationship between the speed and the supply voltage, this investigates the effects of different loads and inputs on the output response of the armature-controlled direct current motor. The aim is to establish relationship between the speed of DC motor and the load torque at different voltages as well as investigating the performance of closed-loop systems when different voltages are applied to the armature circuit of the motor when a constant voltage is supplied to the field circuit of the motor. The study was carried out in two stages. The first stage involved mathematical modeling of the system while the second stage centered on the simulation of an armature controlled direct current motor using Simulink environment in MATLAB. The performance analysis of the modeled system shows that usage of feedback enhances the performance of the transient response of the armature controlled DC motor. In addition, the result obtained shows that at different input voltages, the speed the DC motor is inversely proportional to the load torque. The performance analysis of the modeled system shows that usage of feedback enhances the performance of the transient response of the armature controlled DC motor. In addition, the result obtained shows that at different input voltages, the speed the DC motor is inversely proportional to the load torque. The steady state response shows that at different field current speed of the DC motor is directly proportional to the load torque. The transient response shows that without any feedback the performance of the response can be improved.

Keywords: MATLAB, DC motor, speed, voltage, feedback

I. INTRODUCTION

Matlab or Matrix laboratory is a high-level programming language consisting of interactive environment mainly used for numeric computation, programming, and visualization. MathWorks have developed it. The basic functions of Matlab are plotting of functions and data, the creation of user interfaces, matrix manipulations.

A model is simply a representation of the construction and working of some systems of interest. A model is similar to but simpler than the system it represents. The process of producing a model is known as modeling. which is the process of simulating the model under known input conditions and comparing model output with system output.

In order to enhance both the understanding and proper presentation of the study reported in this report, the remaining parts of this paper are organized as follows.

1) In depth information on DC motor such as its principle of operation, classification and different methods of controlling the speed of DC motors were presented.
2) The methodology used in carrying out the study reported in this report. The results obtained are presented, interpreted and discussed in report while the conclusions made are presented.

Hence, for this armature controlled DC motor modeling, the analysis was carried out using both the step and impulse responses.

II. REVIEW OF LITERATURE

1) A. Maria[1] introduced to modeling and simulation as her studies research interests include optimizing the performance of materials used in electronic packagin (including solder paste, conductive adhesives, and underfills), simulation optimization techniques, genetics based algorithms for optimization of problems with a large number of continuous variables, multi criteria optimization, simulation, and interior-point methods. Simulation models consist of the following components: system entities, input variables, performance measures, and functional relationships. According to her, simulation modeling and analysis is one of the most frequently used operations research techniques. Simulation can be a time consuming and complex exercise, Simulation languages, Application-Oriented Simulators from modeling through output analysis that necessitates the involvement of resident experts and decision makers in the entire process.
2) Jide Julius, P et.al [2] described that the simulation model of an armature controlled DC motor was developed using MATLAB/Simulink. The analysis and performance evaluation of the developed motor show that the simulated motor correctly predicts the effect of armature voltage on the armature voltage-speed characteristics and torque-speed characteristics of the armature controlled dc motor. Furthermore, the results of the study show that the speed of the DC motor is directly proportional to the armature voltage. Hence, a force is exerted on the coil because of the interaction of magnetic field and electric current. The force on the two sides of the coil is such that the coil starts to move in the direction of force. When an electric current pass through a coil that is in an electric field, then the magnetic force will produce a torque that will rotate the DC motor.
3) Devendra K. Chaturvedi [3] presented how to implement full-order and reduced-order observers using the software packages for computer aided control system design MATLAB. In fact, it has shown how to implement a dc motor state space model and its observer. Different observer gain(s) are determined by selecting different Eigen values for the observers. Observer estimation errors are presented by choosing the observer(s) initial conditions. Having full understanding of the observer implementation(s), students and engineers will fill confident to use this observers and

observer based controllers in numerous engineering and scientific applications. This paper will motivate undergraduate and graduate students to further study observers and use them as powerful tools for observing system dynamics and/or designing feedback control loops. It has shown in detail how to implement full-order and reduced-order observers in MATLAB environment and presented corresponding fundamental derivation and results with the help of dc motor state model.

4) L.Y. Hui, and K.H. Seok.[4] described that Optimization of PID Controller with Metaheuristic Algorithms for DC Motor Drives, Direct Current (DC) motors are broadly used in various industrial applications such as robotics, automobiles, toys and for many other motoring purposes. This is attributable to their extraordinary flexibility, durability and low implementation cost. It is essential to control the speed, position, torque and other variables of the DC motor to achieve the needed performance depending on the area of application. Many classical techniques have been used in the past to control the DC motor; however, such methods typically take a long time, particularly when used for complex nonlinear systems. The application of metaheuristic algorithms as a means of implementing Artificial Intelligence (AI) in this area has proven to be highly effective in overcoming these shortcomings. This review, therefore, presents the optimization of the PID controller with metaheuristic algorithms for controlling the DC motor drives. Finally, the paper presents some open issues and future directions for research.

5) T. Kailath, Prentice Hall.[5] described that the methods for filtering and smoothing data from dynamic models. For many applications, the relevant problems smoothing a nonlinear dynamic model that involves two point boundary data (or multipoint data).Well-posed boundary value linear models driven lead to reciprocal processes. A combination of boundary information and nonlinearities rule out a stochastic formulation of the smoothing problem. A deter-monistic (least squares) formulation leads to a two-point boundary problem that is well posed for controllable and observable linear models and algorithm for solving linear and nonlinear problems. It will converge for linear models. Its convergence for nonlinear models. Simulation models consist of the following components: system entities, input variables, performance measures, and functional relationships. For instance in a simulation model of an M/M/1 queue.

S. No.	Author	Software/ Equipment used	Application	Observation
1.	A.Maria (1997)	Matlab and Simulink. Simulation languages, Application-Oriented Simulators	Identify the problem, Formulate the problem, Collecting and process real system data and Formulate and develop a model.	Her research interests include optimizing the performance of materials used in electronic packaging (including solder paste, conductive adhesives, and under fills), simulation optimization techniques, genetics based algorithms for optimization of problems with a large number of continuous variables, multi criteria optimization, simulation, and interior-point methods.
2.	Jide Julius, P., Oladele Joshua, O., & Charity Segun, O. (2015)	Matlab and Simulink, DC Motor	Modelling and simulation of armature controlled direct current motor using MATLAB	The simulation model of an armature controlled DC motor was developed using MATLAB/Simulink using real time data and Simulation of DC Motor Speed Regulation by Field Current Control Using MATLAB
3.	Devendra K. Chaturvedi (2010)	DC Motor, Matlab and Simulink, Motor Parameters	Design and Implementation for DC Motor, State space, DC Motor, Reduced-Order Observer, Implementation in Matlab.	This paper presents how to implement full-order and reduced-order observers using the software packages for computer aided control system design in Matlab. It has shown how to implement a dc motor state space model and its observer. Different observer gain(s) are determined by selecting different eigen values for the observers. Observer stimation errors are presented by choosing the observer(s) initial conditions
4.	L.Y. Hui, and K.H. Seok (2004)	PID Controller; Metaheuristic, Algorithm, Computational Intelligence, Optimizing	The application of metaheuristic algorithms as a means of implementing Artificial Intelligence (AI) in this area has proven to be highly valuable, as their	Optimization of PID Controller with metaheuristic algorithms for DC motor drives. This review, therefore, presents the optimization of the PID controller with metaheuristic algorithms for controlling the DC motor drives. A short

		Parameters, Classical Techniques, DC motor drives.	tremendous success in addressing number real-world optimization pharmaceutical and industrial applications to intellectual applications.	description for each algorithm is presented along with papers published in various renowned journals. For a robust review, the application of various forms of PID controller, as well as different types of DC motors are examined. Finally, the paper presents some open issues and future directions for research.
5.	T. Kailath, (1980.)	Design of a nonlinear and linear Algorithm, A third order system.	The author interest lies in Computer Control Theory and Design, Adaptive Filtering, Prediction and Control, Linear Systems, Medical Imaging Systems.	This paper review, The Model Based Smoothing of Linear and Nonlinear Processes Conclusions that we have briefly-surveyed methods for filtering and smoothing datafrom dynamic models. For many applications, the relevant problem is smoothing a nonlinear dynamic model that involves two pointboundary data. Well-posed boundary value linear models driven by reciprocal processes.A combination of boundary information and nonlinearities rule out a stochastic formulation of the smoothing problem.

Table 1: Literature survey

III. RESEARCH METHODOLOGY

In modeling the armature controlled DC motor for this study, simple electrical circuit of armature controlled DC motor diagram as shown in Figure 3 was employed while the activities involved were broken down into four stages. The four stages involved are presented in the following sub-sections as follows.

A. Armature Controlled DC Motor Circuit Diagram Representation

This stage focus was on development of an armature controlled DC motor as shown in Figure with torque and rotor angle.

B. Field Flux Control Method of DC Motor

Flux is produced by the field current, thus, the speed control by this method is achieved by control of the field current as shown in figure 1.

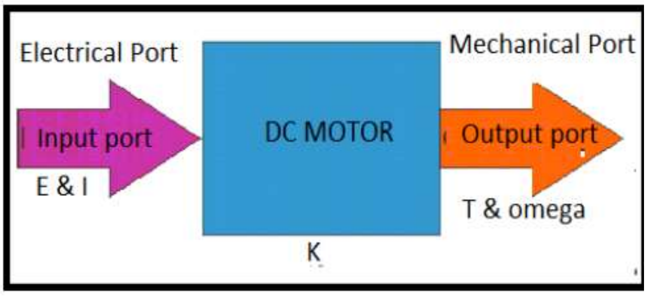

Fig. 1: Block diagram representation of I/O module of DC motor

Here in a DC motor, the supply voltage E and current I is given to the electrical port or the input port and we derive the mechanical output i.e. torque T and speed ω from the mechanical port or output port.

C. ShuntMotor

In a Shunt Motor, the variable resistor $R_C$is connected in series with the shunt field windings. This resistor $R_C$is known as a Shunt Field Regulator.

D. SeriesMotor

In a series motor, the variation in field current is done by any one method, i.e. either by a diverter or by a tapped field control.

E. By Using aDiverter

A variable resistance $R_d$is connected in parallel with the series field The parallel resistor is called a Diverter. A portion of the main current is diverted through a variable resistance R_d. Thus, the function of a diverter is to reduce the current flowing through the field winding. The reduction in field current reduces the amount of flux and as a result the speed of the motor increases.

IV. PROBLEM FORMULATION

In armature-controlled DC motors, the applied voltage Va controls the angular velocity w of the shaft.

A simplified model of the DC motor is shown above. The torque Td models load disturbances. You must minimize the speed variations induced by such disturbances.

DC motor fault zone analysis is a vital plan of any DC motor maintenance program. Several troubles may arise in a DC motor.

A few of them are discussed below:

1) Failure to start
2) Sparking at brushes
3) Vibrations and pounding noises
4) Overheating of DC Motor

Brush troubles may arise due to the insufficient contact surface, too short brush, too little spring tension or wrong brush setting.

Commutator troubles may be due to dirt on the commutator, high mica, rough surface or eccentricity.

Armature troubles may be due to an open armature coil. An open armature coil will cause sparking each time the open coil passes the brush. The location of this open coil is noticeable by a burnt line between segments connecting the coil.

V. RESULTS AND DISCUSSIONS

The simulation lasts from 0 to 14 seconds. A mechanical load is applied at constant. White noise is added to the mechanical and to the electrical portions of the model, in order to test its stability. The gain of the resulting mechanical and electrical disturbances can be modified, to test its effect on the model. The armature controlled DC motor is inherently stable, the back emf, which is proportional to the angular speed of the rotor. No control has been added to the model. The objective for a Control System could be to add a controller, in order to improve the response of the DC motor. In order to add a controller, it would be necessary to add a feedback loop, which physically would have to be a rotational encoder or a resolver attached to the shaft of the servomotor. The output signal would be compared with the input signal of the system. The simulation was done as well as analyzed based on its steady state responses.

The motor specifications are: 5 hp, 1750 rpm and 240 armature voltage, 150 field voltage. As, for this analysis all the initial conditions are assumed to be zero. Therefore, at the time of starting, there is no current flowing through the motor. Below sub-sections, represent the results under steady state and transient conditions, assuming the above values as inputs.

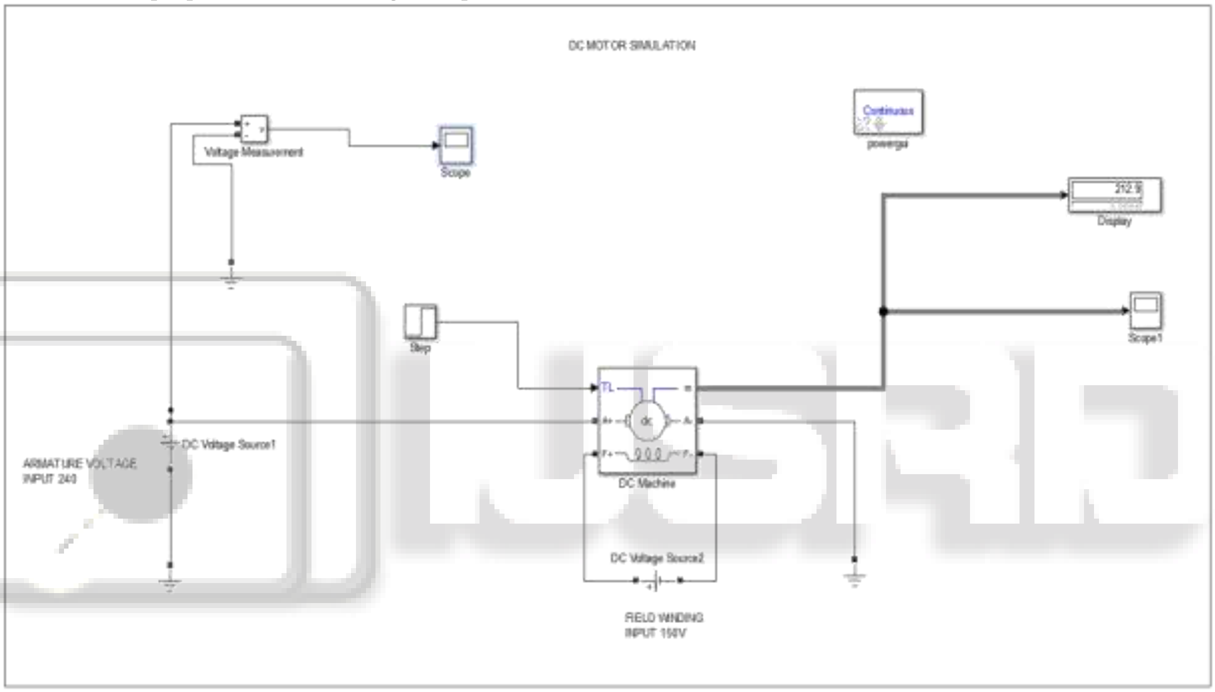

Fig. 2: Model created in SIMULINK toolbox of MATLAB

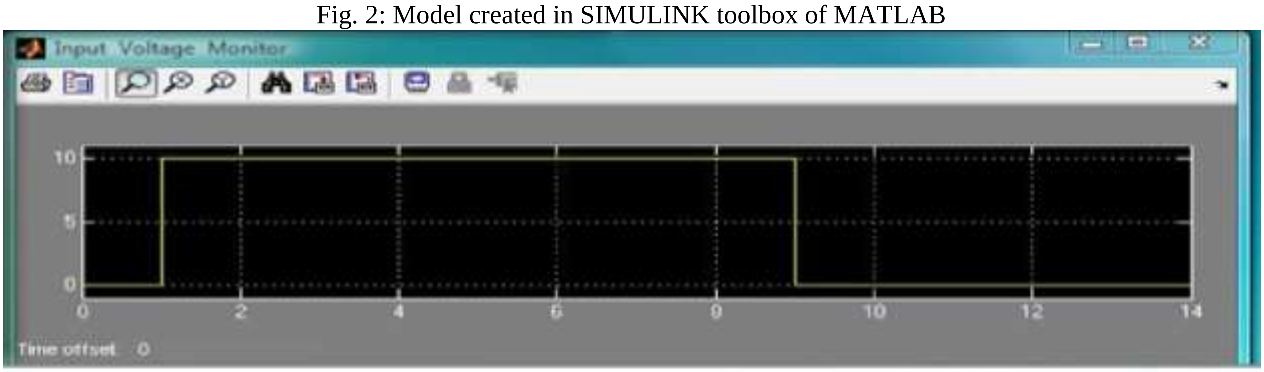

Fig. 3: Responses of the motor to a unit step input

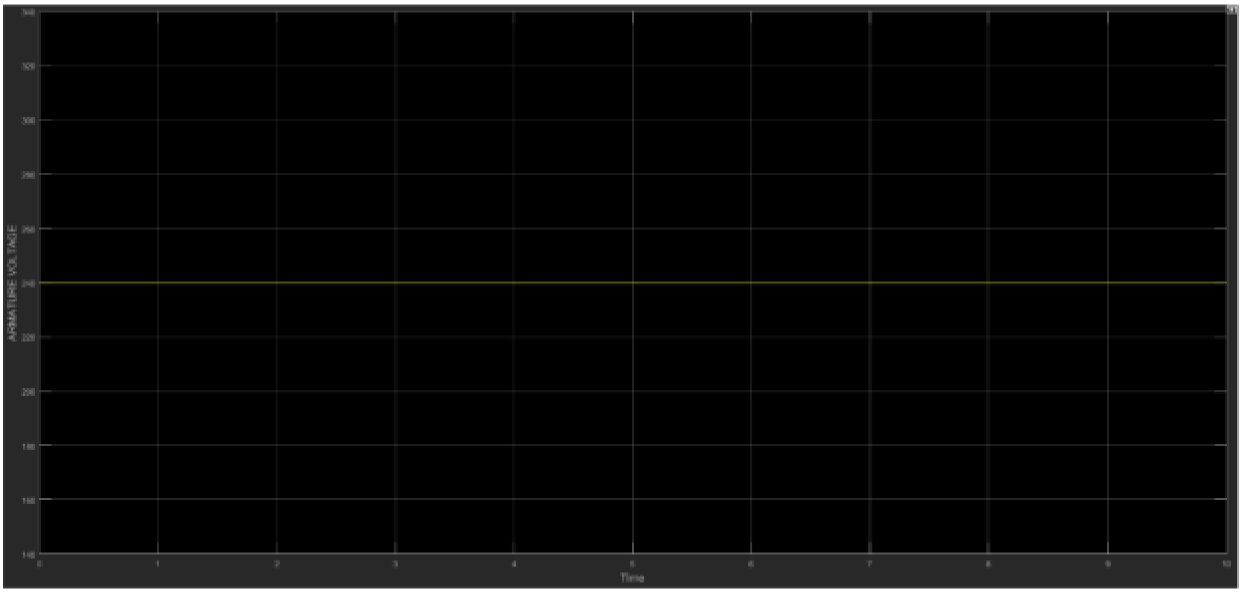

Fig. 4: Torque–speed characteristic for different field current.

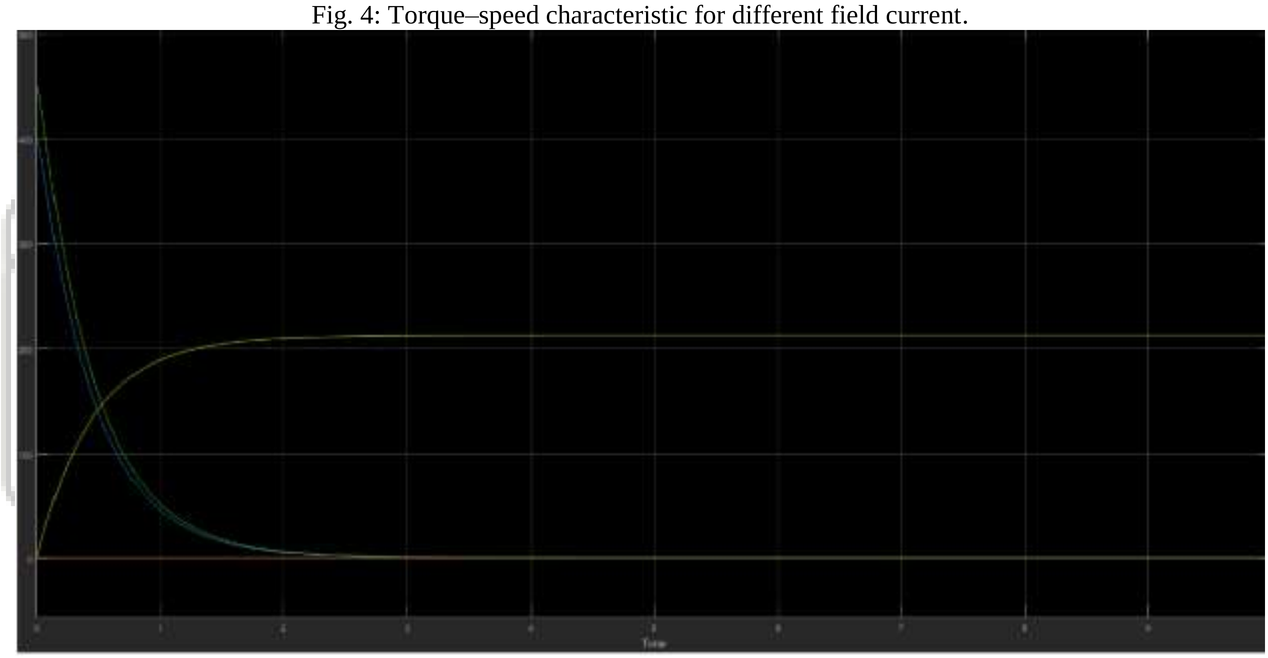

Fig. 5: Plot of the field current against motor speed

A. Steady State Response

The steady state responses of this field controlled DC motor show the operating characteristics of the motor under different conditions. The steady state responses under consideration are: field current speed characteristics and torque speed characteristic for different field current.

B. Transient Response

In a similar way, the transient response of the modeled field controlled DC motor was examined. In the proposed model, as there is no feedback loop, so variation of kk_f remains ineffective on the stability or performance of the motor, except the amplitude of the output increases. However, one important thing is that, as the value of kk_f increases, the amplitude of the speed curve decreases, and it reaches to steady state stability more quickly

VI. CONCLUSION AND RECOMMENDATIONS

Dc motor, armature-controlled simulation has been carried out for all the proposed systems. Using MATLAB and the initial response of all the systems have been plotted.. If substantial unknowns are involved, the feedback signal given to the matrix should be relatively large. Further, as we examine the performance of the various systems found, we see that each system has a different output feedback response and not every system at the desired poles can be stabilized to a particular value. However, the stabilizable ones provide satisfactory estimates even in the presence of external noise input, or torque disturbances and with varied initial conditions.

The discussion has made in this paper about field controlled Dc Motor in MATLAB-SIMULATION. The various graphical analytical results shows that the motor accurately defining the effect of change in filed current in the field current vs. speed characteristics curve as well as torque vs. speed curve of the designed field controlled DC motor. Also, it can be said in addition to that is the steady state response shows that at different field current speed of the DC motor is directly proportional to the load torque. The transient response shows that without any feedback the performance of the response can also be improved.

REFERENCES

[1] Jide Julius, P., Oladele Joshua, O., & Charity Segun, O. (2015). Modelling and simulation of armature controlled direct current motor using MATLAB. SSRG International Journal of Electrical and Electronics Engineering (SSRG-IJEEE), 2(3), 19-25.
[2] Bansal, D., Evans, D. J., & Jones, B. (2004). A realtime predictive maintenance system for machine systems. International Journal of Machine Tools & Manufacture, 44, 759-766.
[3] Nandam, P. K., & Sen, P. C. (1986). A comparative study of proportional-integral (P-I) and integralproportional (I-P) controllers for dc motor drives. Int. Jour. Of Control, 44, 283-297.
[4] George, M., Basu, K. P., &Chiat, A. T. W. (2010). Model reference controlled separately excited DC motor. Neural Computing and Applications, 19, 343-351.
[5] Gaurav Kumar, M., Pandey, A. K., &Avinash, M. (2014). Combined armature and field speed control of DC motor for efficiency enhancement. SSRG International Journal of Electrical and Electronics Engineering (SSRG-IJEEE), 1(6).
[6] Anurag, D. (2013). Speed control of Dc shunt motor with field and armature rheostat control simultaneously. Advance in Electronic and Electric Engineering, 3(1), 77-80.
[7] Moleykutty, G. Speed control of separately excited DC motor. American Journal of Applied Sciences, 5(3), 227-233.
[8] Monaaf, D. A. A. Speed control of a separately-excited DC motor. International Journal of Research in Aeronautical and Mechanical Engineering.
[9] Kosow. Electric Machinery and Transformers. Pearson Education India.
[10] Krisnan, R. (2011). Electric Motor Drives: Modeling, Analysis, and Control. New York: Prentice Hall.
[11] Hasan Saeed, S. Automatic Control Systems. S. K Kataria& Sons.
[12] Roy Choudhury, D. Modern Control System. PHI Publications.
[13] DC motor or direct current motor. Electrical4u. Retrieved from http://www.electrical4u.com/dcmotor-or-direct-current-motor/
[14] Speed control of DC motor: Armature resistance control and field flux control. Circuitglobe. Retrieved from http://circuitglobe.com/speed-control-of-dc-motor-armature-resistance-control-and-field-fluxcontrol.html
[15] Rajeshkanna, G. (2013). Modern speed control of separately excited DC motor by boost converter fed field control method. Proceedings of 2013 International Conference on Computer Communication and Informatics (ICCCI).
[16] Devendra K. Chaturvedi, Modeling and simulation of system using MATLAB and Simulink, CRC Press Taylor and Francis group Boca Raton London New York 2010.
[17] M. S. RUSU, and L. Grama, The Design of a DC Motor Speed Controller, Fascicle of Management and Tech. Eng., Vol. VII (XVII), 2008, pp. 1055-1060.
[18] Debabrata Pal, "Modeling, analysis and design of a dc motor based on state space approach" IJERT, volume 5 Issue 2, February 2016, pp293-296.
[19] Debabrata Pal, "Full order observer controller design for dc motor based on state space approach", International Journal of science and research (IJSR), volume 5 Issue 2, February 2016, pp1752-1756.
[20] A. Maria, Introduction to modeling and simulation studies, Proc. of the 1997 Winter Simulation Conf. Atlanta, GA, Dec. 7-10, 1997, pp. 7-13. Online [Available]: http://imap.acqnotes.com/Attachments/White%20Paper%20Introduction%20to%20Modeling%20and%20Simulation%20by%20Anu%20Maria.pdf. Accessed on 6 th February, 2015.
[21] K.B.T.M. Khalil, PI control of DC motor drive, B.Sc. diss. UniversitiTeknikal, Melaka,Malaysia,2007.Online[Available]:http://library.utem.edu.my/index2.php?option=com_docman &task=doc_view&gid=5008&Itemid=208. Accessed on 5th February, 2015.
[22] L.Y. Hui, and K.H. Seok, Digital controller design to control the direct current motor system, International Journal of Control and Automation, Vol.7, No. 9, 2004, pp. 283-288.
[23] D. Bansal, D.J. Evans, and B. Jones, A real-time predictive maintenance system for machine systems, International Journal of Machine Tools & Manufacture, Vol. 44, 2004, pp. 759-766.
[24] M. Abdus Salam, Fundamentals of electrical machines, Narosa Publishing House, New Delhi, 2005.
[25] B.M. Chen, Personal Course Website EG1108 Electrical Engineering Part 2- Chapter 4: DC Motors, 2011, pp. 1-19. Online [Available]: http://vlab.ee.nus.edu.sg/~bmchen/courses/EG1108_DC moto rs.pdf. Accessed on 23rd March, 2015.
[26] S.L. Alerich, and W.N. Herman, Industrial motor control, Delmar Publishers, Fourth Edition, 1999.
[27] H.A. Toliyat, and G.B. Kliman, Handbook of Electric Motors, CRC Press, USA, 2004.
[28] B.L. Theraja, and A.K. Theraja, A Textbook of Electrical Technology, S. Chand and Company Ltd, Twenty-Third Edition, 2012.
[29] I.J. Nagrath, and M. Gopal, Control Systems Engineering, New Age International Publisher, New Delhi, Fifth Edition, 2011.
[30] Luenberger D. G., "An introduction to observers," IEEE Transaction on Automatic Control, 1971; AC-16: 596-602.
[31] Katsuhiko Ogata, "Modern Control Engineering", Pearson Publishers.
[32] NagoorKani, "Advanced Control Theory", RBA Publications.
[33] T. Kailath, Linear Systems, Prentice Hall, 1980.

