A Speed Control of BLDC Motor by Using Model Reference Neural Network Adaptive Controller

[1]Shital B. Bhadade, [2]Suyog Hirve

Department of Electrical Engineering, Bharati Vidyapeeth Deemed to be University College of Engineering, Pune, Maharashtra, India

Abstract: This paper presents the design and performance analysis of Model Reference Neural Network Adaptive (MRNNA) controller for the speed control of Brushless Direct Current motor (BLDC). The behavior of BLDC motor drive is nonlinear so it is complex to handle by using conventional controller such as proportional-integral (PI), proportional-integral-derivative (PID) controller. The interest in emerging Artificial Intelligent (AI) controller for speed control of BLDC motor has been increased. In ANN (Artificial Neural Network) controlling method available data is the result of measuring the dynamic behavior of the system. To solve problem of nonlinearity and parameter variations caused by load and obtain the control scheme that have good dynamic responses model reference neural network adaptive control concept is applied. The controller is intended to track the variations of speed references and stabilizes the output speed during variations in the load. The effectiveness of this proposed method is established by developing simulation model in MATLAB/simulation.

***Keywords* – BLDC motor, Artificial Neural Network, Model Reference Adaptive Control, MATLAB simulation model.**

I. INTRODUCTION

In the conventional DC (i.e. brushed) motor commutator brushes are used to maintain contact with the power supply. The control of brushed motor is simple and does not require complex hardware structure. But DC motor have main disadvantage that brushes wear out with the time may cause sparking so lifetime of these motor is limited.

BLDC motor has several advantages such as simple structure, compact size, high dynamic response, high efficiency, noiseless operation, large speed ranges. BLDC operates without brushes due to this lifetime span can be increased as well as maintenance can also avoid. BLDC motor has significant application in electric train, electric automotive, robotic and home appliance.

The conventional controllers such as PI, PID are applied for control action. These are constant gain controllers also require precise process model for their design. The BLDC motor is nonlinear motor and often it is difficult to ensure exact mathematical model. The internal parameter such as resistance and inertia of the motor depart from its true value due to variation in ambient temperature condition and increase in the load.

Artificial Neural Networks have a tremendous scope in control system applications. ANN has advantages such as learning ability, massive parallelism, fast adaption, approximation capability, high degree of tolerance. Its high learning ability and non-linear mapping features offer a desired nonlinear mapping for an electric motor drive without going into the system complexity. MRAC is used to design a close loop controller with adjustable parameters so that behavior of the plant to be controlled to follows the behavior of a reference model.

In this paper, BLDC motor speed controlled by using model reference neural network adaptive controller. In order to obtain control schemes that have good dynamic responses, MRNNAC was applied.

II. RELATED WORK

The authors, Maloth Purnalal, Sunil kumar etc. in [1] describes mathematical model of BLDC motor and speed controlled by close loop control. PI controller is used to minimize the error between actual speed and reference speed. The studies are conducted at different load torques and the corresponding speed to highlight effectiveness of BLDC motor speed control by close loop control. The authors, Seng-Chi Chen, Chun-Yi Kuo etc. in [2] Describes PID neural network controller based on recurrent radial basis function neural network for BLDC motor. The designed controller based on NN is more effective in improving the control performance and faster in response than conventional PID controller. The authors, Qing KU, Gengguo CHENG, Yun WANG etc. in [3] describes neural network MRAC control for rotor slip gain adjust of asynchronous motor. Author also discussed about direct vector control and indirect vector control for the motor. The authors, Vishnu Vidya, Meher Madhu Dharmana in etc. [4] Describes how MRAC based on NN can give better performance for Active Suspension System for Vehicles, by reducing the vertical acceleration of chassis and enhance the comfort of ride& safety. The authors, Missula Jagath Vallabhai, Pankaj Swarnkar, D.M. Deshpande etc. in [5] gives explanation, how MRAC controller is used to improve the performance of Induction motor than PI controller. Simulation results of rotor speed, rotor torque and flux with Pi Control, Model Reference Adaptive Control and without any control at no load, constant load, varying load condition were given. The authors, Whei-Min Lin, Chih-Ming Hong, Ting-Chia Ou and Fu-Sheng Cheng etc.in [6] Describes a sensorless vector-control strategy for an Induction Generator in a variable-speed Wind energy conversion system using a model reference adaptive system combined with of RFNN to estimate the rotational speed of the IG.

III. ORGANIZATION OF PAPER

Organization of paper as fallows, section A discusses the BLDC motor mathematical equation. Section B discusses neural network. Section C discusses Model reference adaptive control. Section 4 discusses simulation diagram and simulation result

A. BRUSHLESS DC MOTOR

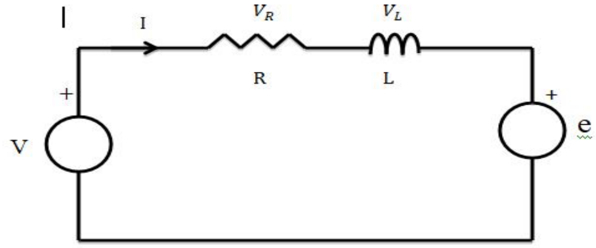

Fig. 1. Shows electromechanical model of BLDC motor

$$\omega \ \alpha \ \frac{(V_a - I_a R_a)}{\phi} \qquad (1)$$

$$\omega \ \alpha \ \frac{(V_a - I_a R_a)}{K_a \phi} \qquad (2)$$

where,
ω = angular speed (rad/sec)
Va = armature voltage
Ia = armature current
Ra = armature resistance
ϕ = field flux per pole
Ka = armature constant
Ka = $\frac{PZ}{2\pi a}$
P = no of poles
Z = total no of armature conductor
a = number of parallel paths

From (2), BLDC motor speed can be controlled by three techniques. They are:

- Controlling armature resistance
- Controlling field flux
- Controlling armature terminal voltage.

In this paper speed of BLDC motor is controlled by the control of armature terminal voltage.
The dynamics equations of Brushless DC motor using assumption can be expressed by,

$$V_a = RI_a + (L - M)\frac{di_a}{dt} + e_a \qquad (3)$$

$$V_b = RI_b + (L - M)\frac{di_b}{dt} + e_b \qquad (4)$$

$$V_c = RI_c + (L - M)\frac{di_c}{dt} + e_c \qquad (5)$$

Where,
V_a, V_b, V_c = Stator phase voltage
I_a, I_b, I_c = Stator phase current
L = Stator inductance
M = Mutual inductance
R = Phase resistance

B. ARTIFICIAL NEURAL NETWORK CONTROLLER

Neural network has high learning capability. Therefore, ANN is used for the identification and control of nonlinear systems. Structure of ANN has three layers 1. Input layer, 2. hidden layer, 3. Output layer.

1 Input layer: This layer provides information or input signal from the outside world to the network and just pass on the information to the hidden node.
2. Hidden layer: This layer is an intermediate layer found between input layer and output layer also perform actual computation and extract the required features from the input data set.
3. Output layer: This is the last layer in the neural network architecture, which transfer the information from network to the outside world.

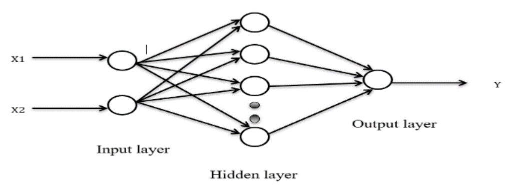

Fig2. The Architecture of ANN

The function of network is determined by relationship between elements and it is trained to build particular function. Feed forward neural networks are widely used to solve complex problem in pattern classification, system identification and modeling, nonlinear system. The classical method for learning feed forward network is back-propagation (BP) algorithm. BP is based on the gradient descent optimization technique. The algorithm tracks the weighted value to minimize total error through training sets.

Iteration in the back-propagation algorithm expressed as:

$$w_{k+1} = w_k + \triangle w_k \triangle w_k = -\propto \frac{\partial E}{\partial w_k} \qquad (6)$$

Where,
$\triangle w_k$ = update weighted of w_k
$\propto$ = learning rate

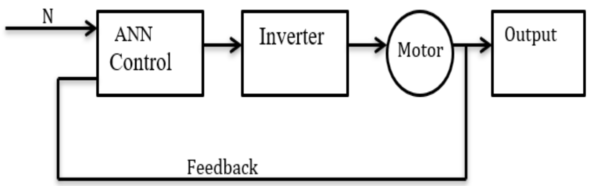

Fig.3 Block diagram of BLDC motor control by ANN

C. MODEL REFERENCE ADAPTIVE CONTROLLER (MRAC)

Model Reference Adaptive Control provides promising solution when variation in process parameter. In this systems, the desired performance specifications of plant are expressed in terms of reference model which gives the ideal response to the control signal.

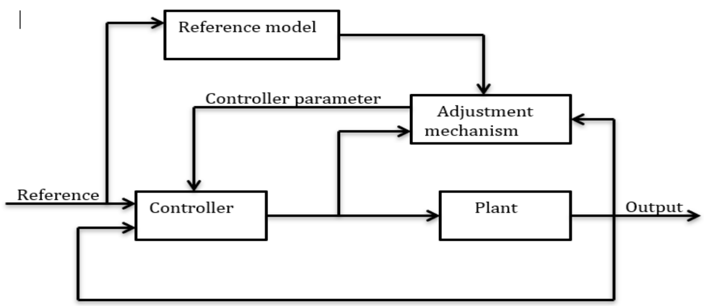

Fig.4 Block diagram of MRAC

The controller consists of two loops. The inner loop is an ordinary feedback loop composed of the plant and controller as shown in diagram. The outer loop tracks the error e and adjust controller parameter, the error is the difference between plant output Y and model output.

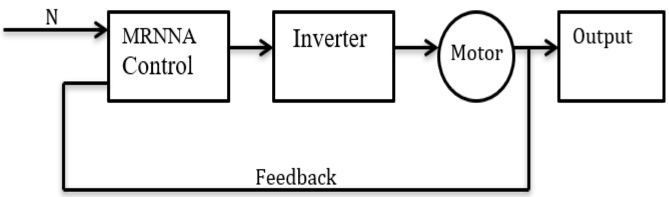

Fig.5 Block diagram of BLDC motor control by MRNNA

IV SIMULATION DIAGRAM AND RESULTS DISCUSSION

A. SIMULATION DIAGRAM

Fig.6 shows the MATLAB model for speed control of BLDC motor using ANN and MRNNA control. Here, DC voltage is used as supply input and given to the inverter as shown in Fig.6, after the conversion of DC-AC, torque of 0.8 is externally connected to the motor. Motor is having 4 poles with 2.68 mH of stator inductance and 18.7 ohm of stator resistance. Motor terminal voltage is 300V. The Hall effect sensor is used to give the information about position of the rotor.

Rotor speed is used in the feedback loop. In first part ANN and in second part MRNNA control is used as a controller then output response of both controllers are compared. Levenberg-Marquardt algorithm adopted for the training of neural network. Output of the controller is modified and fed up to the inverter as gate pulses, which in turn control the voltage of the motor to control the speed.

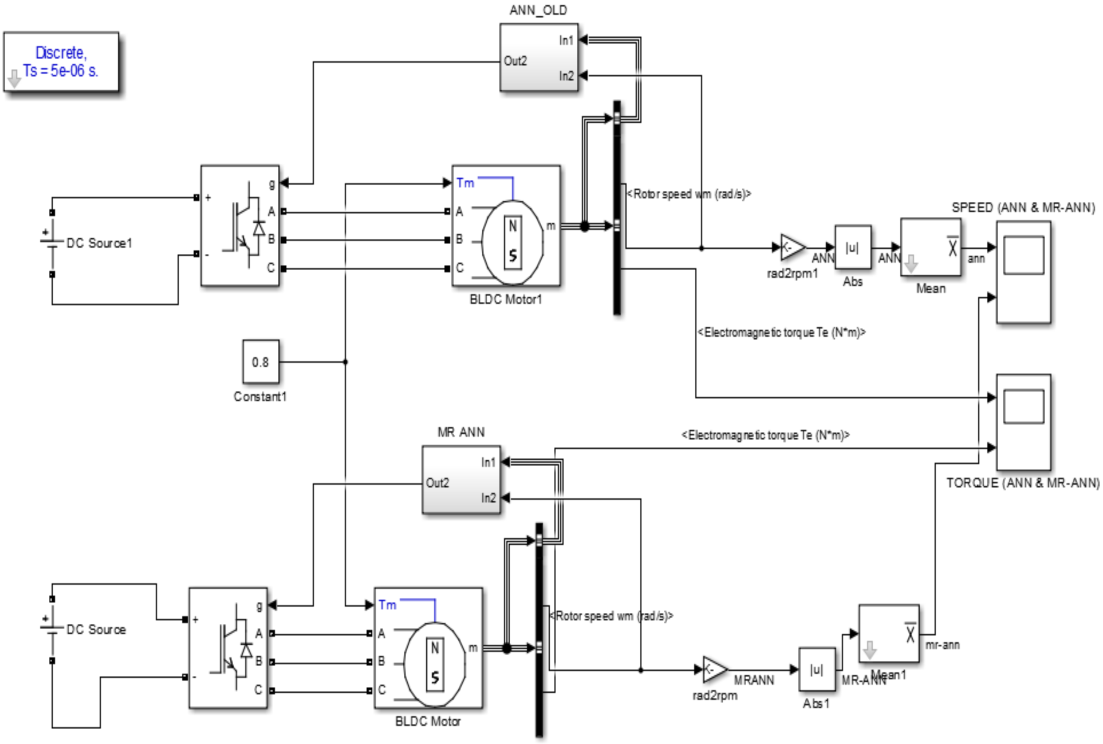

Fig.6 Simulink model for Neural Network Control and Model Reference Neural Network Adaptive Control

B. SIMULATION RESULTS AND DISCUSSION

The fig.7 and 8 shows the output waveform of speed versus time and torque versus time, when BLDC motor is controlled with Artificial Neural Network

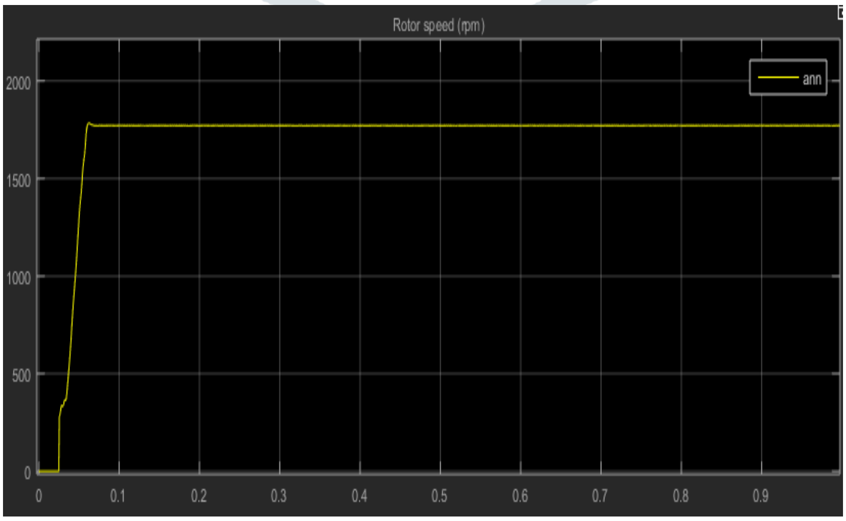

Fig.7 response speed output of Neural Network Control

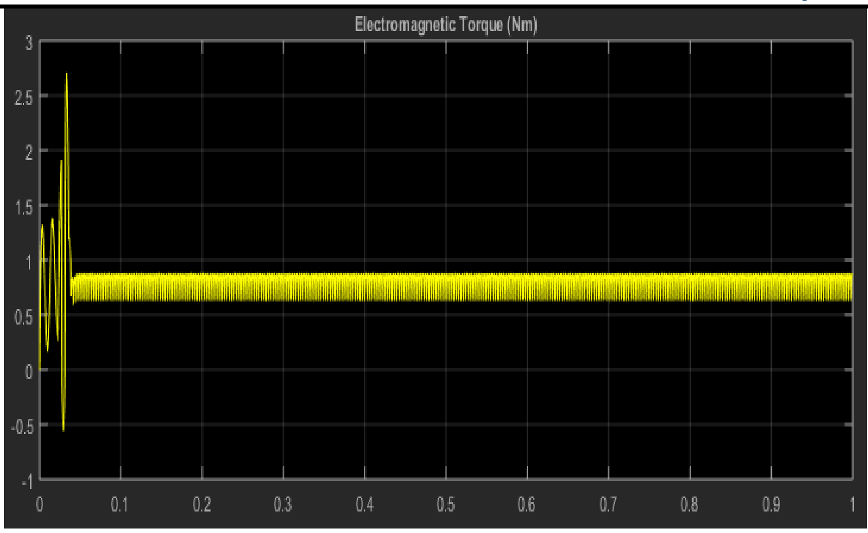

Fig.8 response torque output of Neural Network Control

The fig.9 and 10 shows the output waveform of speed versus time and torque versus time, when BLDC motor is controlled with Model Reference Neural Network Adaptive control

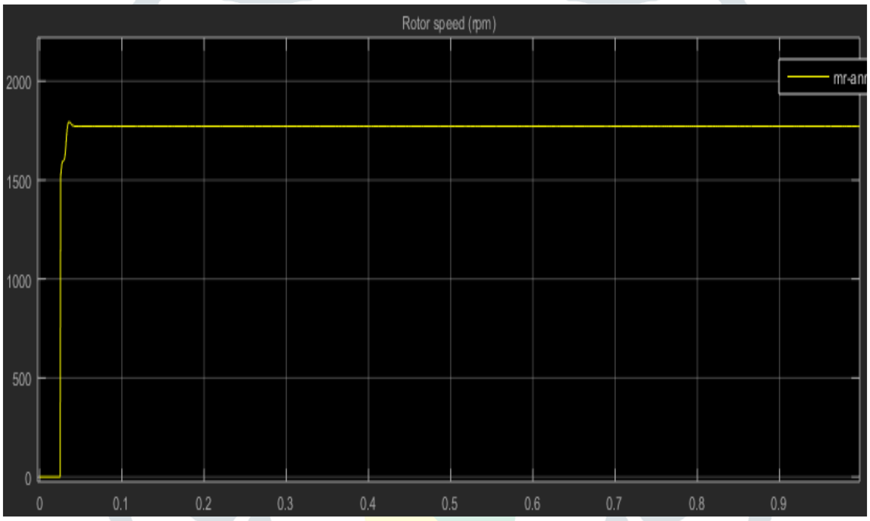

Fig.9 response speed output of Model Reference Neural Network Control

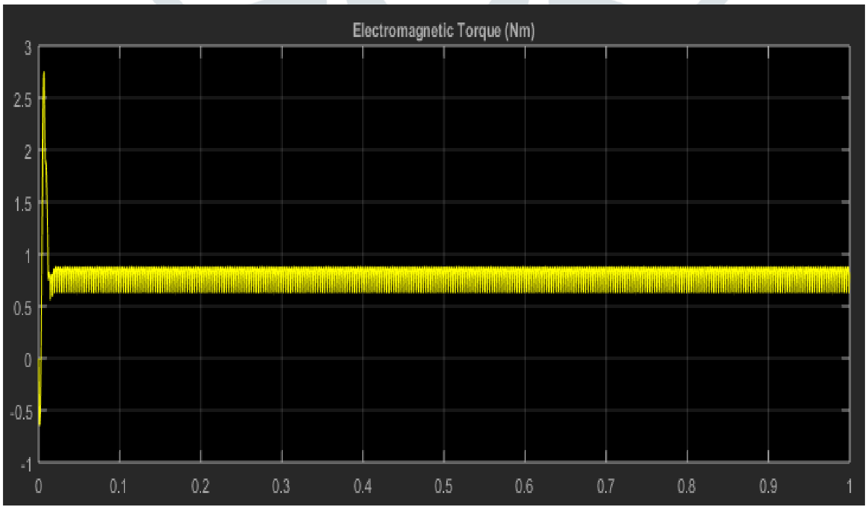

Fig.10 response torque output of Model Reference Neural Network Control

ACKNOWLEDGEMENT

This work is supported by the department of Electrical (Power System) from Bharati Vidhyapeeth Deemed to be university, College of Engineering, Pune.

CONCLUSION

This paper presents the new approach of an Artificial Intelligent for BLDC motor speed control by using a Model reference neural network adaptive control. To study dynamic performance of BLDC motor MATLAB Simulink toolbox is used. The simulation results for proposed NN controller and MRNNA controller are compared. For practical cases where BLDC motor parameters change frequently, MRNNA control provides efficient adaptability and better transient response. Simulation results showed that Model Reference Neural Network Adaptive Control can give better performance.

REFERENCES

[1] Maloth Purnalal, Sunil kumar "Development Of Mathematical Model And Speed Control Of BLDC Motor" 2015 International Journal of Electrical and Electronics Engineers

[2] Seng-Chi Chen, Chun-Yi Kuo " Design And Implement Of The Recurrent Radial Basis Function Neural Network Control For Brushless DC Motor" 2017 IEEE International conference on applied system innovation.

[3] Qing KU, Gengguo Cheng, Yun WANG "BP Neural Network MRAC Applied to Slip Gain Adjusting" June 8-12, 2015, The 5th Annual IEEE International Conference on Cyber Technology in Automation, Control and Intelligent Systems, Shenyang, China

[4] Vishnu Vidya, Meher Madhu Dharmana "Model Reference Based Intelligent Control of an Active Suspension System for Vehicles" 2017 IEEE, International Conference on circuits Power and Computing Technologies [ICCPCT]

[5] Missula Jagath Vallabhai, Pankaj Swarnkar, D.M. Deshpande "Comparative Analysis Of Pi Control And Model Reference Adaptive Control Based Vector Control Strategy For Induction Motor Drive" May-Jun 2012, Vol. 2, Issue 3, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622

[6] Whei-Min Lin, Chih-Ming Hong, Ting-Chia Ou and Fu-Sheng Cheng "MRAS-Based Sensorless Wind Energy Control for Wind Generation System using RFNN" 2010 5th IEEE Conference on Industrial Electronics and Applications.