Simulation Approach for Torque Ripple Minimization of BLDC Motor

S.S. Sable, Shruti Kiran Perkar, Trupti Ramhari Jadhav, Krishna Ankush Giri, Sahas Bhagwan Wankar
DY Patil Institute of Engineering Ambi Pune

***Abstract* – This project presents the design and implementation of neural network controller for reducing torque ripples in permanent magnet brushless DC (PMBLDCM) motor drive with trapezoidal back-emf. The performances of the proposed neural network controller are compared with the corresponding fuzzy PI controller and conventional PI controller. Simulation results are used to show the abilities and shortcomings of the proposed speed regulation scheme for brushless dc motor which is considered as a highly nonlinear dynamic complex system. Matlab/Simulink software was used to simulate the proposed model. Buck-boost converter connected in between the input DC source and three phase bridge inverter, used for minimizing the commutation torque ripples in Permanent Magnet Brushless DC Motor is presented in this paper. Torque during the commutation period depends on phase current which is not undergoing commutation, so by controlling it, torque ripple can be minimized. Moreover, a greater DC link voltage is needed during the commutation time period in comparison to the normal conduction period. The Buck-boost converter operates in boost mode in commutation period for stepping up the DC voltage to the inverter. A simple mode switching circuit is employed to amend the output modes of the Buck-boost converter in normal and commutation time intervals. Simulation studies of this topology are carried out in MATLAB/Simulink environment.**

Index Terms* – *Permanent Magnet Brushless DC Motor (PMBLDCM), Buck-boost Converter, Commutation Time period,PI Controller.

I. Introduction

A brushless DC motor is one of a small-scale motor used in small electric devices such as CD players, hard disk drives, or even small electric cars. Its rotor is mounted with permanent magnet. There is no need for extra field excitation. This motor is well-known and popular for position and speed control drive applications. The key advantage of this motor over other types in the same rating is higher ratio of produced torque per weight, faster response, accurate position control, lower moment of inertia, less maintenance, etc. The construction of modern brushless motors is very similar to the ac motor, known as the permanent magnet synchronous motor. This project presents an implementation of neural network controller for improving the transient responses to torque disturbance and speed reference following of the BLDC motor drive. Simulation results are used to show the abilities and shortcomings of the proposed method as compared with the conventional PI and ANN controllers. Permanent magnet brushless DC motors (PMBLDC) find wide applications in industries due to their high-power density and ease of control. These motors are generally controlled using a three-phase power semiconductor bridge. For starting and the providing proper commutation sequence to turn on the power devices in the inverter bridge the rotor position sensors required. Based on the rotor position, the power devices are commutated sequentially every 60 degrees. To achieve desired level of performance the motor requires suitable speed controllers. In case of permanent magnet motors, usually speed control is achieved by using proportional-integral (PI) controller. Although conventional PI controllers are widely used in the industry due to their simple control structure and ease of implementation, these controllers pose difficulties where there is some control complexity such as nonlinearity, load disturbances and parametric variations. Moreover, PI controllers require precise linear mathematical models. This project presents the design and implementation of neural network controller for reducing torque ripples in brushless DC (BLDC) motor drive with trapezoidal back-emf. The performances of the proposed neural network controller are compared with the corresponding fuzzy PI controller and conventional PI controller. Simulation results are used to show the abilities and shortcomings of the proposed speed regulation scheme for brushless dc motor which is considered as a highly nonlinear dynamic complex system. MATLAB/Simulink software was used to simulate the proposed model. Buck-boost converter connected in between the input DC source and three phase bridge inverter, used for minimizing the commutation torque ripples in Permanent Magnet Brushless DC Motor is presented in this paper. Torque during the commutation period depends on phase current which is not undergoing commutation, so by controlling it, torque ripple can be minimized. Moreover, a greater DC link voltage is needed during the commutation time period in comparison to the normal conduction period. The Buckboost converter operates in boost mode in commutation period for stepping up the DC voltage to the inverter. A simple mode switching circuit is employed to amend the output modes of the Buck-boost converter in normal and commutation time intervals. Simulation studies of this topology are carried out in MATLAB/Simulink environment.

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II. METHODOLOGY

1. Artificial Neural Network: - The Artificial Neural Network Controller Model The controller is represented as a nonlinear map between the inputs and outputs. Depending on a specific plant, the map (in the form of a network) can be trained to implement any kind of control strategy. A neuro-controller (neural networks-based control system) performs a specific form of the adaptive control with the controller taking the form of a multi-layer network and the adaptable parameters being defined as the adjustable weights. The main advantages are:
(1) Parallel architecture
(2) Any kind of nonlinear mapping is possible
(3) Training is possible for various operating conditions, so, it can be adapted to any desired situation.

Artificial neural networks (ANNs), usually simply called neural networks (NNs) or neural nets, are computing systems inspired by the biological neural networks that constitute animal brains.
An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal to other neurons. An artificial neuron receives signals then processes them and can signal neurons connected to it. The "signal" at a connection is a real number, and the output of each neuron is computed by some non-linear function of the sum of its inputs. The connections are called edges. Neurons and edges typically have a weight that adjusts as learning proceeds. The weight increases or decreases the strength of the signal at a connection. Neurons may have a threshold such that a signal is sent only if the aggregate signal crosses that threshold.
Typically, neurons are aggregated into layers. Different layers may perform different transformations on their inputs. Signals travel from the first layer (the input layer), to the last layer (the output layer), possibly after traversing the layers multiple times.

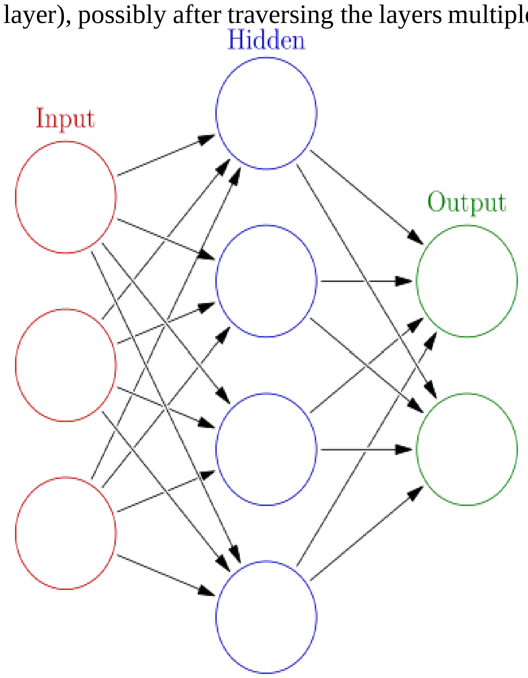


Fig.1 Artificial Neural Network

2. Buck-Boost Converter: - The configuration comprises of a Buck-boost converter and a mode selection circuit. During commutation period a higher DC voltage is required compared to the normal conduction period. A Buck-boost converter is inserted between DC source and inverter to control the DC link voltage. Mode switching circuit effectively handles the operating approach of the converter in the commutation interval to boost the input of the inverter.
The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer.

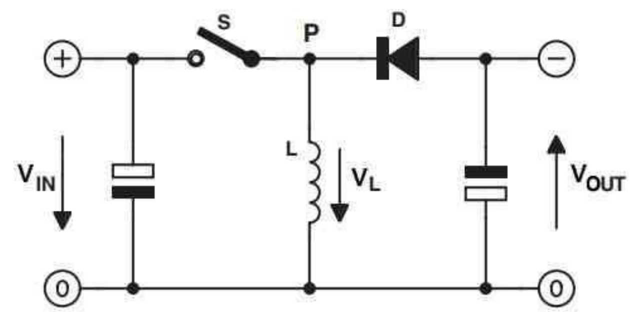


Fig.2 Buck-Boost Converter

3. PI Controller:

Proportional Integral controller sometimes also known as proportional plus integral (PI) controllers. It is a type of controller formed by combining proportional and integral control action. Thus, it is named as PI controller.
The first theoretical analysis and practical application of PID was in the field of automatic steering systems for ships, developed from the early 1920s onwards. It was then used for automatic process control in the manufacturing industry, where it was widely implemented in pneumatic and then electronic controllers. Today the PID concept is used universally in applications requiring accurate and optimized automatic control.
One combination is the PI-control, which lacks the D-control of the PID system. PI control is a form of feedback control. It provides a faster response time than I-only control due to the addition of the proportional action. PI control stops the system from fluctuating, and it is also able to return the system to its set point. Although the response time for PI-control is faster than I-only control, it is still up to 50% slower than P-only control. Therefore, in order to increase response time, PI control is often combined with D-only control.

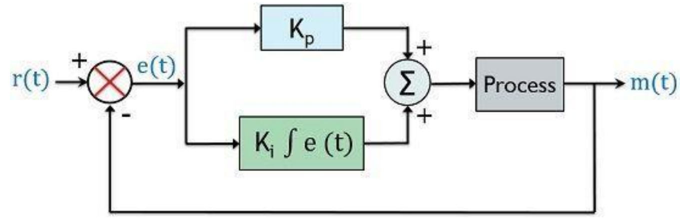


Fig.3 PI Controller

4. BLDC Motor:

The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. A Brushless DC Electric Motor (BLDC) is an electric motor powered by a direct current voltage supply and commutated electronically instead of by brushes like in conventional DC motors.

Brushless DC motors have some significant advantages over their competitors, such as brushed motors, largely because of the electronic commutation. It allows the controller to switch the current promptly and thus regulate the motor's characteristics effectively. In this article, we'll consider the peculiarities of a brushless DC motor controller. You will learn about its operating principles as well as the design features and challenges you should know about before building your own device.

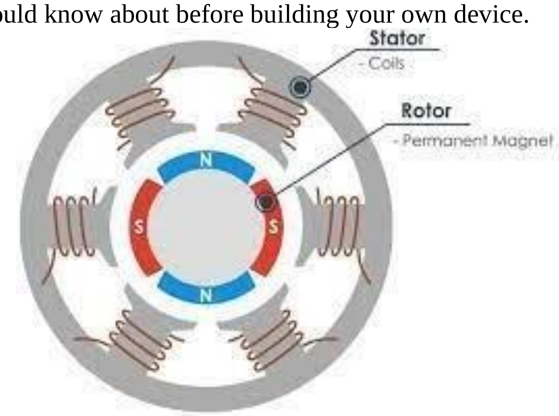
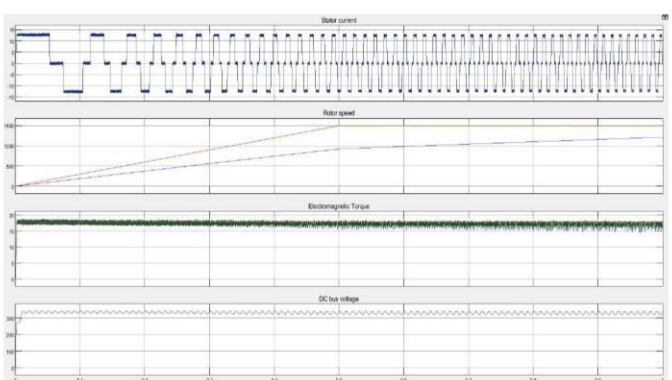


Fig.4 BLDC Motor

III. RESULT



III. CONCLUSION

On the control side of BLDC motors, this article shows control methodologies for decreasing torque ripples. It is either the motor's design or the power inverter supply that causes the pulse torque movements to deviate from ideal conditions, resulting in non-ideal current waveforms.

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