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ANN BASED ADAPTIVE TORQUE CONTROL OF BLDC MOTOR

Dr. E. Naveen Kumar
Assistant Professor
Department of EEE
Sri Venkateswara College of Engineering

Mohamed Harris R
Department of EEE
Sri Venkateswara College of Engineering

Siranjeevi M
Department of EEE
Sri Venkateswara College of Engineering

Shri Niranjan Kumar V
Department of EEE
Sri Venkateswara College of Engineering

Abstract-**Artificial Neural Network (ANN) is the simple network that has input, output, and hidden layers with a set of nodes. Implementation of ANN algorithms in electrical, and electronics engineering always satisfies with the expected results as ANN handles binary data more accurately. Brushless Direct Current motor (BLDC motor) uses electronic closed-loop controllers to the switch DC current to the motor windings and produces the magnetic fields. The BLDC motor finds more applications because of its high speed, less maintenance and adequate torque capability. This motor is preferred to other motors due to its better performance and it is very easy to control its speed by Power Converters. This article presents a method of speed control of BLDC motor where speed is controlled by changing the DC input voltage of the bridge converter that feeds the motor winding. The control is done by using a PI based speed controller. The motor is modeled in the MATLAB/Simulink and the speed control is obtained with a PI controller. EMF signals, rotor speed, electromagnetic torque, Hall Effect signals, PWM and EMF signals simulations are obtained. The obtained data is fed into binary artificial neural networks and as a result, the ANN model predicts the corresponding parameters close to the simulation results. Both the mathematical based simulation and data-based prediction gives satisfactory results.**

1. Introduction

The Electric and autonomous vehicles are impactful technologies in the global climate change and the conservation of fossil fuels. Brushless DCmotors are the primary motors that are employed in electric vehicles. Electric vehicles generally employ more than two motors for propulsion. BLDC motor is basically a synchronous motor that uses direct current supply. In BLDC motors the mechanical commutator is replaced by electronic servo system making it reliable to detect the angle of rotor and to control the switches. And, electronic closed loop controllers are employed to switch Direct Current to motor windings to produce magnetic fields. The controller modifies the amplitude and phase of DC pulses to control the torque and speed of the motors. Bridge Converter is basically a DC-to- DC converter topology that employs four active switching components in a bridge configuration across a power transformer. A full bridge converter is a popular configuration that gives isolation as well as stepping up or down the input voltage. Reversing the polarity and providing multiple output voltages simultaneously are the additional functions provided with bridge converters. Speed control in BLDC motor has a significant role in the modern control systems. Open-loop and closed- loop methods are the two major types of control system. Dual closed-loop control is a popular term where the torque or current loop forms the inner control loop, and the voltage or speed loop forms the outer control loop. When the motor runs less than the rated speed, the input voltage of the motor is varied through Pulse Width Modulation strategy. When the motor runs beyond the rated speed, the flux is weakened as exciting current or auxiliary flux is advanced. Several methodologies are proposed to the speed-control of BLDC motors.

Commonly PID control is preferred as it is one of the most popular methods for many years and still employed in several applications. Moreover, PID controller are employed extensively due to its robust property and more reliable. Generally, PID controllers satisfy the necessities of speed-regulation. Since BLDC motor is a non-linear system with multivariable, many challenges are to be considered for solving. At present, for speed control almost all BLDC motors Artificial Neural Networks Based Control and Analysis of BLDC

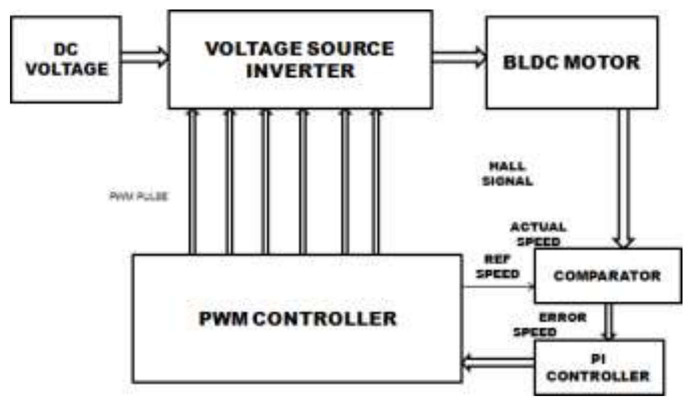
Motors employ PID controller for PWM.

2. TECHNICAL BACKGROUND

The Brushless Direct Current motors are applied everywhere from an electric vehicle to an electric fan. The higher starting torque is the main reason for its wider usage. The speed control of BLDC motors is becoming very important to suit its need for various applications. The use of fuzzy controllers to control the speed of the motors have been popularly in practice. The proper selection of fuzzy logic algorithm is also very important for efficient speed control. There use of microcontroller hardware with fuzzy logic controller eliminates complex delay circuits. This reduces the overall cost of the system. In this method, the sensor-based fuzzy logic approach is not used to increase the robustness of the system. In a paper, the speed of the motor is using inverter via controlled voltage. This method dynamically controls the speed of the BLDC motor. There have been a series of experiments being carried out for closed-loop speed control of BLDC motor. The experiments have shown better performance for very low speed to higher speeds by the rapid control prototyping method. The performance of three-phase BLDC motor speed control using Fuzzy and PID controllers have been studied on various control system parameters like steady-state error, peak overshoot, rise, recovery and settling time. His research output stated that the Particle Swarm optimization method can improve the dynamic performance of the system. There have been a series of experiments conducted for speed control of BLDC motors. Through his experiments, results stated that the fuzzy PID controller with fuzzy control and PID small overshoot and small steady-state error has performed better in contrast to others. The manual tuning of the PID controller is also being implemented in a three- phase BLDC motor with a six-step inverter. Without PID controller, the maximum overshoot observed is 25% and with PID controller it is nearer to zero. Mahmud in his paper designed different control scheme with PID and fuzzy controller. The experimental results of his paper proved that the PID controller provides better performance out of the PI controller and fuzzy logic

In recent years, the use of ANN controllers increased exponentially. The ANN controller has a lesser settling time in contrast to another controller

3. EXISTING SYSTEM WITH BLOCK DIAGRAM



The traditional BLDC motor is working based on the Hall sensor feedback signals. A Sensor less method for six-space four switch three phase BLDC motor driver is described. Due to the nature of low resolution of position sensing. BLDC motor the speed feedback is variable sampling. and induction motors. A few of these are:

(1) Better speed versus torque characteristics
(2) High dynamic response
(3) High efficiency
(4) Long operating life

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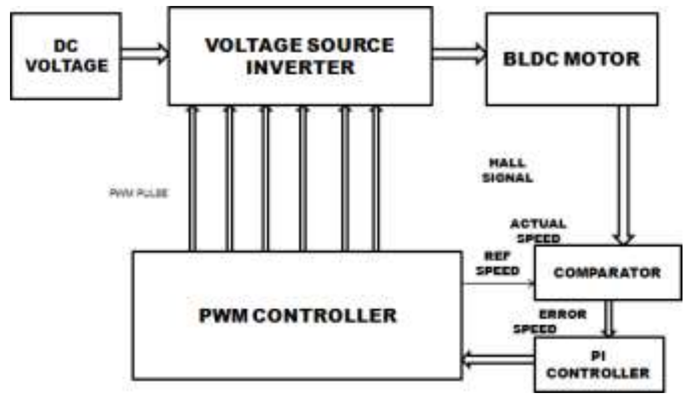

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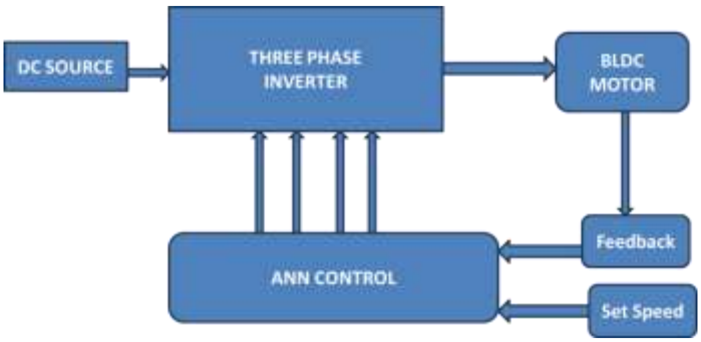
(7) Better speed versus torque characteristics
(8) High dynamic response
(9) High efficiency
(10) Long operating life (11)Noiseless operation
(12)Higher speed range

6. PROPOSED SYSTEM



The DC voltage is given to the voltage source inverter. The voltage source inverter is three phase voltage source inverters with 120^0 mode of operation it having 3 legs each legs consists of 2 MOSFET. So, totally six MOSFET are used in the voltage source inverter. By varying modulation induce the inverter will supplies the voltage to the BLDC motor. The objective of this work is to run the BLDC motor with use of Hall sensor and reduce the manufacturing cost of the motor. To implement hysteresis comparator-based ANN based BLDC motor drive. To implement closed loop speed control algorithm using ANN controller.

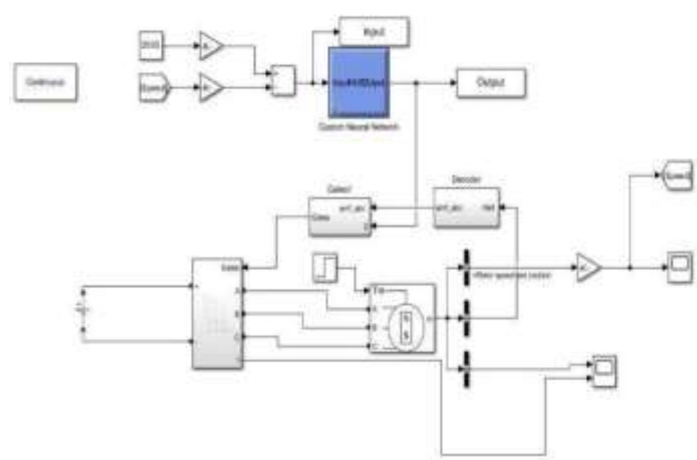
7. THEORY OF OPERATION

Each commutation sequence has one of the windings energized to positive power (current enters into the winding), the second winding is negative (current exits the winding) and the third is in a non-energized condition. Torque is produced because of the interaction between the magnetic field generated by the stator coils and the permanent magnets. Ideally, the peak torque occurs when these two fields are at 90° to each other and falls off as the fields move together. In order to keep the motor running, the magnetic field produced by the windings should shift position, as the rotor moves to catch up with the stator field.

"Six-Step Commutation" defines the sequence of energizing the windings. Every 60 electrical degrees of rotation, one of the Hall sensors changes the state. Given this, it takes six steps to complete an electrical cycle. In synchronous, with every 60 electrical degrees, the phase current switching should be updated. However, one electrical cycle may not correspond to a complete mechanical revolution of the rotor. The number of electrical cycles to be repeated to complete a mechanical rotation is determined by the rotor pole pairs. For each rotor pole pairs, one electrical cycle is completed. So, the number of electrical cycles/rotations equals the rotor pole pairs.

8.SIMULATION

Simulink is a graphical extension to MATLAB for the modeling and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Simulink is integrated with MATLAB and data can be easily transferred between the programs. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.



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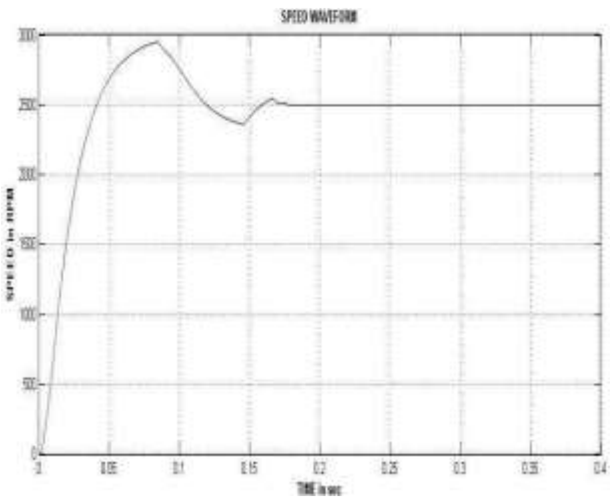
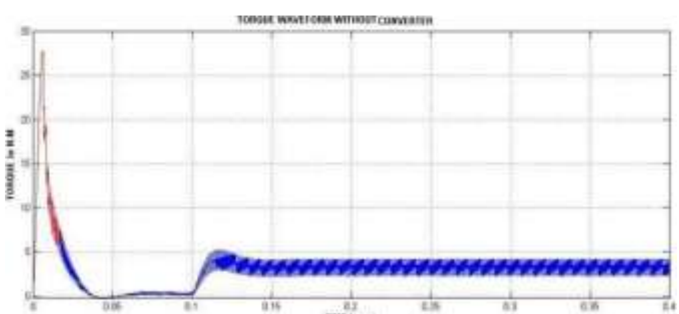
9. SIMULATION RESULTS

Simulation graphs were obtained from the Simulink model and we can infere various data from it.



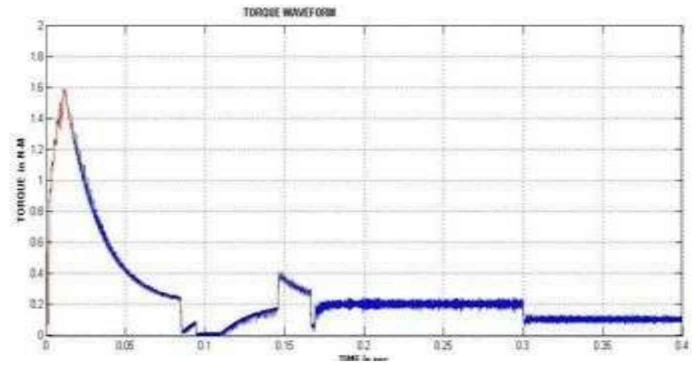
BLDC motor speed waveform using ANN controller

The BLDC motor speed waveform using ANN controller is shown in Fig 5.2. In this motor speed(rpm) is plotted was in y–axis and time(sec) in x-axis. This wave form represents the variation of speed wave form with respect to time. It also reveals that using ANN controller the speed variation has been damped at 2 second.



BLDC motor torque waveform using hall sensor

The variation of torque waveform of the brushless DC motor with respect to time is shown in above Fig . It reveals that harmonics are present in the torque waveform by using hall sensor which is to be reduced by the proposed methodology.



BLDC motor torque waveform without using hall sensor

The variation of torque waveform without using hall sensor is shown in above Fig. It also reveals that the harmonics has been reduced by discarding the usage of hall sensor the output torque waveform are smooth when compared to the waveform

10. HARDWARE COMPONENTS

10.1 Brush Less DC Motor

A brushless DC motor (BLDC), also known as an electronically commutated motor, is a synchronous motor using a DC power supply. It employs an electronic controller to switch DC currents to the motor windings, producing rotating magnetic fields that the permanent magnet rotor follows. The controller adjusts the phase and amplitude of current pulses to control motor speed and torque. BLDC motors resemble permanent magnet synchronous motors but can also be switched reluctance or induction motors. They may use neodymium magnets and come in outrunner, in-runner, or axial configurations. BLDC motors are popular in industries such as automotive, aerospace, consumer, and medical.

output will not be according to your requirement. Therefore, design of gate driver circuit is critically important in designing of power electronics converters.

BLDC motor

10.2 TRANSFORMER

Selecting a suitable transformer is crucial due to its impact on the current rating and secondary voltage. The current rating depends on the load's requirements, ensuring that the transformer can handle the necessary current. For the 7805 IC, the input voltage must be at least 2V greater than the 5V output, necessitating a minimum input voltage close to 7V. While any transformer supplying a secondary peak voltage up to 35V can be used, higher voltages increase the transformer's size and the power dissipation across the regulator. Therefore, balancing voltage and current requirements is essential for optimal transformer selection.

Transformer

10.3 TLP 250 M0SFET DRIVER

Gate driver circuit is circuit integral part of power electronics converters which is used to drive power semiconductor devices like BJT's, IGBT's and MOSFETs. Output of DC-DC converters mainly depend on behaviour of gate driver circuits. Its mean if gate driver circuit doesn't drive gate of MOSFET device properly, your designed DC-DC converter

The TOSHIBA TLP250 consists of a GaAlAs light emitting diode and a integrated photodetector. This unit is 8-lead DIP package. TLP250 is suitable for gate driving circuit of IGBT or power MOS FET.

- Input threshold current: 5mA(max)
- Supply current: 11mA(max)
- Supply voltage: 10-35V
- Output current: ±1.5A (max)
- Switching time (tpLH/tpHL): 0.5μs(max)
- Isolation voltage: 2500Vrms (min)

TLP 250 Mosfet Driver

10.4 DSPIC CONTROLLER

Microchip Technology's Motor Control & Power Conversion family of DSPIC Digital Signal Controllers provides an easy-to-use solution for applications requiring motor control. Microchip Technology introduced 20 16-bit Flash micro controllers that provide the industry's highest performance.

The DSPIC family of Digital Signal Controllers features a fully- implemented digital signal process or (DSP) engine, 30 MIPS non- pipelined performance, C compiler friendly design, and a familiar Microcontroller architecture and design environment. The 20 new dsPIC30F2010 devices form three product families targeting motor control and power conversion, sensor, and general- purpose applications. The DSPIC core is a 16-bit (data) non-pipelined modified Harvard machine that combines the control advantages of a high-performance 16-bit Microcontroller with the high computation speed of a fully implemented DSP to produce a tightly coupled, single-chip single-instruction stream solution for embedded systems designs. The initial 20- dsPIC30F2010devices feature 12 Kbytes to 144 Kbytes of on-chip secure Flash program memory space and up to eight Kbytes of data space Operating voltage appeals to many Microcontroller applications that remain at 5 volts, while many DSPs are restricted to 3.3-supply V maximum. Devices are planned in 40-pin package.

10.5 IRF840 MOSFET

IRF840 is rated for 8a, 500v, 0.850-ohm, n-channel power mosfet this n-channel enhancement mode silicon gate power field effect transistor is an advanced power mosfet designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation.

All of these power mosfet's are designed for applications such as switching regulators, switching converters, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. these types can be operated directly from integrated circuits. Formerly developmental type TA17425.

Features
• 8a, 500v
• rds (on) = 0.850Ω
• single pulse avalanche energy rated
• soa is power dissipation limited
• nanosecond switching speeds
• linear transfer characteristics
• high input impedance

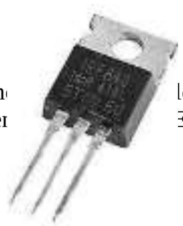
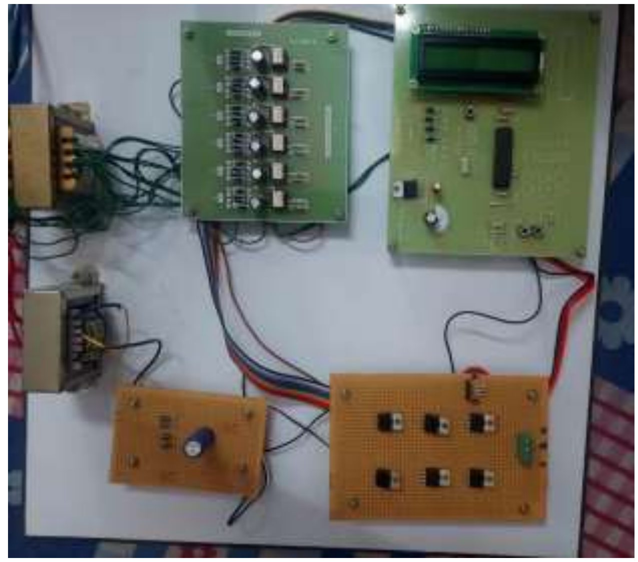


Figure 10.4 IRF840 MOSFET

11. H ARDWARE



This system drives a BLDC motor using several interconnected components. A 230/24V AC transformer steps down mains power, which is rectified and filtered to DC, then fed to a 3-phase inverter powering the BLDC motor. A separate 230/12V AC transformer supplies the TLP250 driver, which controls the inverter. The dSPIC30F4011 evaluation board, powered by a 9V adaptor, generates control signals for the TLP250 driver based on feedback from the BLDC motor, ensuring precise operation. This configuration enables efficient conversion and control of power to drive the motor effectively**.**

12. LOAD TEST OF BLDC MOTOR

We can calculate the torque produced by a brushless DC (BLDC) motor by Performing a load test on a BLDC (Brushless DC) motor. It involves applying a controlled load to the motor shaft and observing its performance under different conditions. This test helps in understanding the motor's behaviour, efficiency, torque-speed characteristics, and its ability to handle varying loads. Based on the test results, you may need to adjust motor parameters such as voltage, current limits, or control algorithms to optimize performance.

Power $=\tau\times\omega$

- T is the torque (in Newton-meters)
- ω is the angular velocity (in radians per second)

We need to convert speed from rpm to radians per second

$$\omega = \frac{2\pi \times \text{speed in rpm}}{60}$$

From rearranging the power formula, we can solve for torque

$$T = \frac{P \times 60}{2\pi \times \omega}$$

Now, we can calculate the torque constant (Kt) using the formula:

$$Kt = \frac{T}{I}$$

The general formula for torque (T) in a BLDC motor is given by:

$$T = Kt \times I$$

Where:

- T is the torque produced by the motor (in Nm)
- Kt is the torque constant of the motor (in Nm/A)
- I is the current flowing through the motor windings (in A)

13. Conclusion

The proposed method is based on controlling the input of DC voltage of bridge converter which feeds the motor windings. The input is controlled using PI controller. For the proposed system the data is fed into to a binary Artificial Neural Network for various parameters obtained from the simulation. The simulation results and prediction result so obtained are synonymous. The activation function and neuron for each layer is altered and studied with respect to the input data.

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