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An Analysis of Simulation of Neural Network Controlled BLDC Drive

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ABSTRACT

A new BLDC motor drive with improved performance characteristics is proposed. Solar energy is used at the supply end and an interleaved boost converter is added to improve the power supply. The proposed model shows the sensored control of BLDC motor and hall sensors are integrated in the circuitry for this purpose. ANN provides the control circuitry and the whole set up is developed in MATLAB/SIMULINK.

Keywords: Brushless Direct Current (BLDC), Artificial Neural Networks (ANN), Interleaved Boost Converter (IBC).

I. INTRODUCTION

Researchers try to improve power generation schemes from the power grid in order to meet the constantly increasing electricity demands. As a result of global and local pollution, use of fossil fuels is a black mark on our society. In addition to that, the fossil fuels, which we are depending tremendously, are depleting on a constantly increasing high rate. Thus, the power generation schemes employing renewable energy sources are a great relief and will reduce power drawn from the grid. The energy cost needed to be paid by the consumers will reduce by using renewable energy sources. In this paper, solar energy is used as a supply source.

A converter section is used at the supply end to improve power supply and thus to reduce output power ripples. An IBC is employed and its output voltage drives the inverter section of the circuit. It consists of two parallel connected boost converter units are controlled by phase shifted switching function.

PI (Proportional Integrator) controlled systems are less responsive to relatively fast alterations in state. The system will be slower to reach set point and hence, slower to respond to perturbations. In order to increase the response towards perturbations and to reduce the settling time, a new control method called NN (Neural Network) is proposed. NN is a technology built on the simplified imitation of computing by neurons. The proposed model is simulated in MATLAB and verified.

II.PROPOSED SYSTEM

A solar supply is provided for IBC. The Interleaved Boost DC-DC converter provides a boosted output voltage on the supply side. The boosted voltage drives the inverter section of the motor. Hall sensors are placed to obtain different rotor positions. The gating signals for the inverter switches are provided on basis of hall sensor signals.Figure1 shows the block diagram of the proposed system for a neural network controlled BLDC motor.

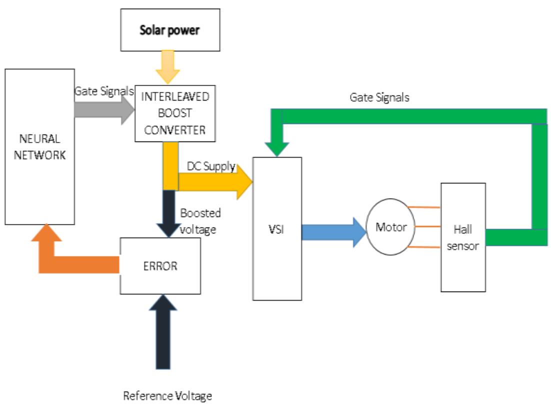

Figure 1. Block diagram of the proposed configuration.

Neural Network is a data processing system consisting of large number of highly interconnected processing elements in an architecture inspired by the cerebral cortex of the brain. NN provides the gating signals for the switches of the Interleaved Boost Converter. The input to the Neural Network is the summation of the reference speed and the boosted voltage of the Interleaved Boost DC-DC Converter. The major section of the drive are the converter, control section and BLDC motor. Each section of the proposed drive is explained in following sub-sections: A, B and C.

A. INTERLEAVED BOOST DC-DC CONVERTER

The Interleaved Boost DC-DC converter has two parallel connected boost converters. Phase shift is implemented between the timing signals of the first and the second switch. The phase shift value is 180°.

- Q_1 closed and Q_2 open: The current starts rising in inductor L_1. At the same time current in inductor L_2 continues to discharge. The rate of change of $i_{l1} = \frac{di_{l1}}{dt} = \frac{V_i}{L}$ and the rate of change of $i_{l2} = \frac{di_{l2}}{dt} = \frac{V_i - V_{out}}{L}$.

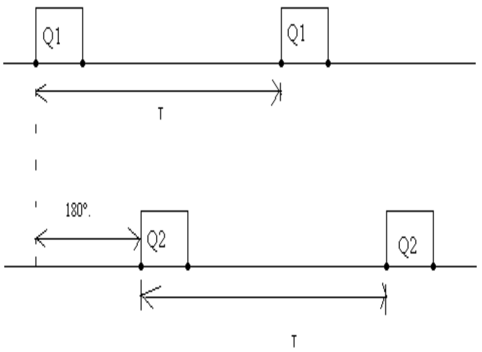

Figure 2. Timing diagram of control signals.

- Q_1 and Q_2 are opened: The inductors L_1 and L_2 discharges through the capacitor. The rate of change of i_{l1} and i_{l1} are $\frac{di_{l1}}{dt} = \frac{di_{l2}}{dt} = \frac{V_i - V_{out}}{L}$.
- Q_2 closed and Q_1 open: The current starts rising in inductor L_2. At the same time current in inductor L_1 continues to discharge. The rate of change of $i_{l2} = \frac{di_{l2}}{dt} = \frac{V_i}{L}$ and the rate of change of $i_{l1} = \frac{di_{l1}}{dt} = \frac{V_i - V_{out}}{L}$.

Figure 2 and Figure 3 shows the timing diagram of control signals and interleaved boost converter respectively.

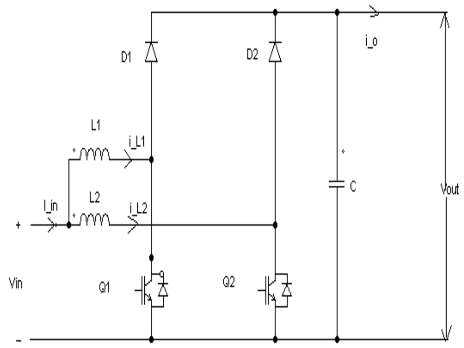

Figure 3. Interleaved boost DC-DC converter

B. NEURAL NETWORKS

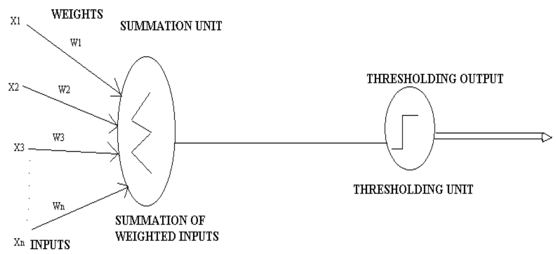

Figure 4. Simple model of an artificial neuron

Neural Networks are simplified models of the biological neuron system and are represented by highly interconnected neural computing elements. They have the ability to learn and acquire knowledge. They can also make it available for use.

Every component of the model in Figure4 bears an actual analogy to different constituents of the biological systems of neurons. X_1, X_2, X_3, ………. X_n are n inputs to artificial neurons and W_1, W_2, …….. W_n are the weights associated to the input links. Like the biological neuron system receives all inputs through dendrites and sums them and if the sum is greater than a threshold produces an output. The inputs are passed through synapse which may accelerate or decelerate an arriving signal. The acceleration and retardation of input signals is modelled by weights. Weights are multiplicative factors of the inputs on the basis of strengths of synapses. Thus, the total current received by an artificial neuron is

$$I = W_1X_1 + W_2X_2 + \dots\dots\dots + W_nX_n$$

Generally an ANN structure can be represented by a directed graph. Graph is represented as 2-tuple (V, E) where V is a set of vertices and E is a set of edges. Each edge is given an orientation, it is called a digraph.

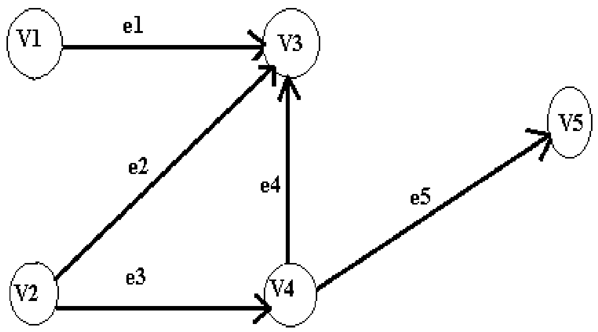

Figure 5. A simple representation of digraph

The vertices of the graph represent neurons and the edges represent synaptic links.
Vertices= V= { V_1 ,V_2 , V_3,V_4,V_5}
Edges= E = { e_1 ,e_2 , e_3,e_4,e_5}
Neural Network with two hidden layers is used in the proposed model.

C. BLDC MOTOR DRIVE

The BLDC motor is fed from a three phase voltage source inverter (VSI). The DC link voltage to the inverter is taken from the output of the Interleaved Boost DC – DC Converter. The inverter switches are controlled based up on the hall sensor signals.Three hall sensors, a, b, and c are mounted on the stator at 120° intervals, while the three phase windings are in a star formation. For every 60° rotation, one of the hall sensors changes its state; it takes six steps to complete a whole electrical cycle. In synchronous mode, the phase current switching updates every 60°. For each step, there is one motor terminal driven high, another motor terminal driven low, with the third one left floating.

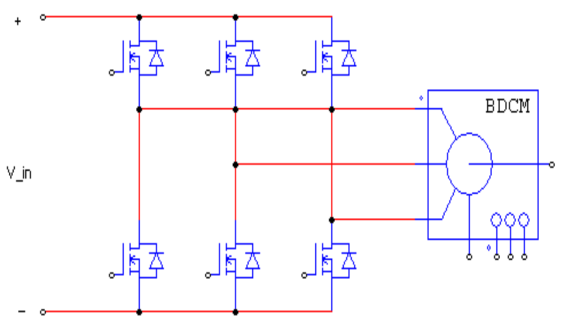

Figure 6. Model of BLDC drive.

III. SIMULATION MODEL AND RESULTS

The simulation model of the proposed system is shown in Figure7.The supply is provided from the solar PV cells and interleaved boost converter is designed which is driven by solar supply. Boosted output voltage drives the VSI of BLDC motor.

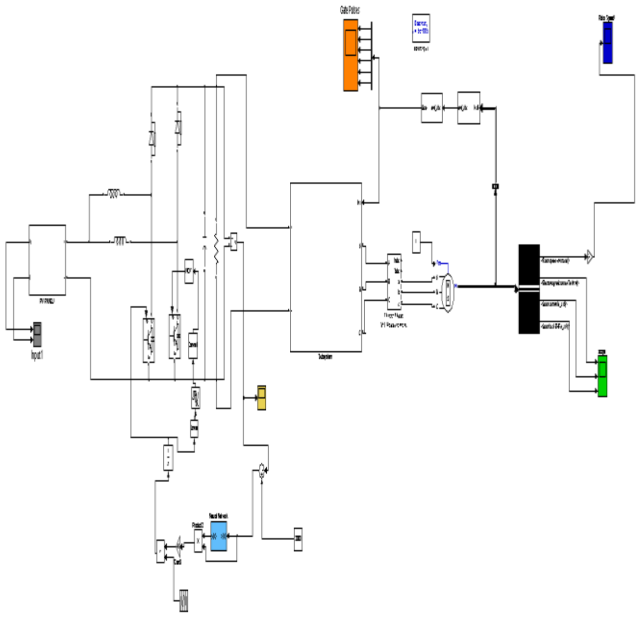

Figure 7. Simulation diagram of neural network controlled BLDC drive.

The simulations have been performed through MATLAB/SIMULINK and the system parameters are given as follows:

- Inductance of inductors L_1 and L_2 is,
  L_1=L_2=L=0.0534μH.
- Capacitance of capacitor, C=1100μH.
- Duty cycle, D=0.346.

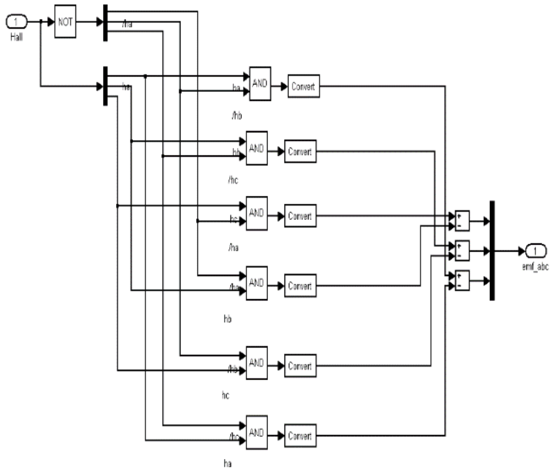

Figure 8. Simulation diagram of hall sensor circuit.

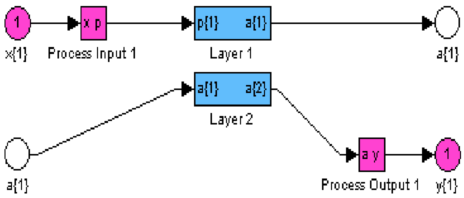

Figure 9. Simulation diagram of NN.

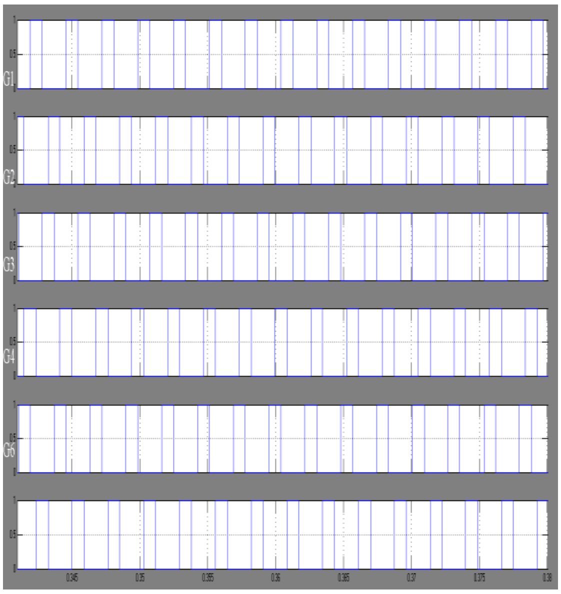

Figure 10. Gate pulses of the VSI.

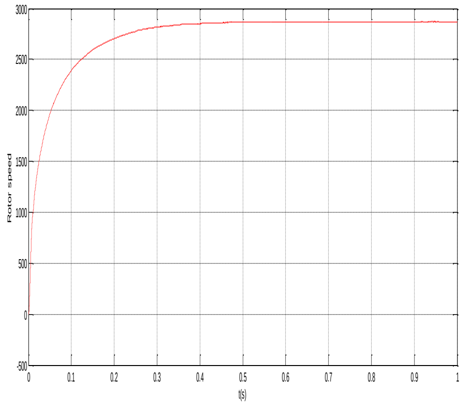

Figure 11. Rotor speed of BLDC drive.

The rotor speed is obtained as 2800 rpm.

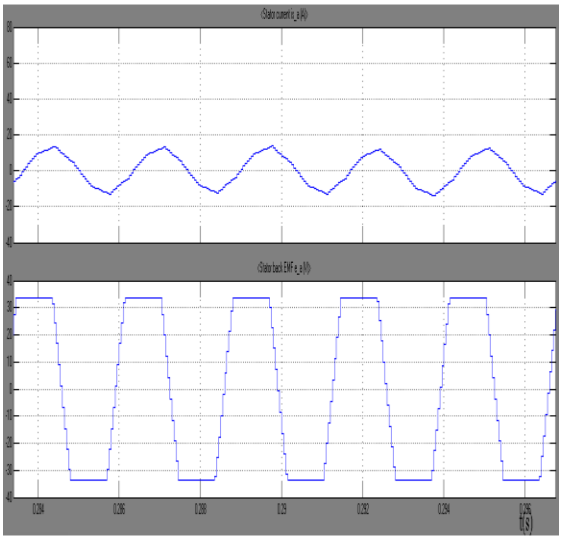

Figure 12. V_a and I_a of BLDC motor.

Voltage and current of phase A of BLDC motor are 31V and 15 A respectively.

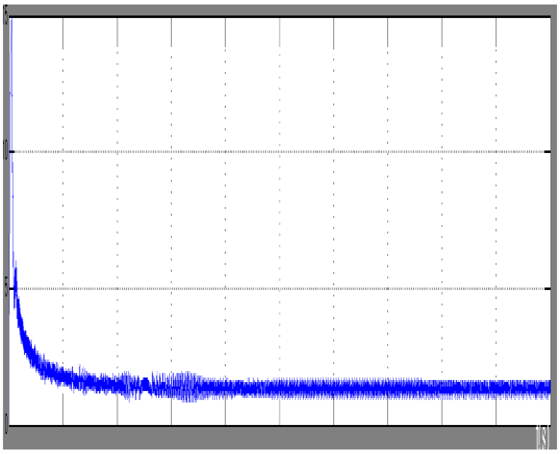

Figure 13. Electromagnetic torque

The electromagnetic torque is obtained at 15Nm and it settles at 0.2s. With the help of NN controller faster response is achieved with the reduced settling time.

III. CONCLUSION

BLDC motor drive run via NN control circuitry is simulated. The interleaved boost converter helps to reduce ripples of input current and exhibited input current sharing. With the help of NN ripples in torque is minimised. A more efficient and cost effective BLDC motor is developed and the efficiency is expected to improve. The circuit can be placed wherever BLDC motor is employed.

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