Simulation of Pulse Amplitude Modulation based Voltage Control Technique for the Speed Control of BLDC Motor using Class-E Load Resonant Converter

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***Abstract*— Efficient power conversion systems are the major concerns of any industry. Thus BLDC motors gained higher priority in wide range of applications. Speed control of BLDC motors are very crucial in this attire .Many of the power electronic circuits used for this are subjected to very high switching losses ending up with reduced overall system efficiency. In this paper speed control of BLDC motor is achieved using a Class-E load resonant converter as the front end converter. Simulation of the proposed model was done in MATLAB/SIMULINK.**

Keywords—BLDC motor,Class E load resonant converter, Converter topologies.

I. Introduction

Permanent magnet brushless DC motors gained its full fledged acceptance in many research fields such as aerospace, traction, instrumentation etc due to key advantages like high torque, powerfactor, efficiency, simple control technique, low cost of maintenance. The elimination of brushes as well as the connection of windings to the control circuits makes it more suitable for high reliable, robust operations. Unlike a brushed DC motor, the commutation is controlled electronically. Hall effect sensors embedded into the stator provides exact rotor positions at every instant. The hall effect[3] signals provide switching pulses to the inverter providing ac signal to drive the motor.

DC-DC converters are used in a wide range as the front end converter to obtain a regulated dc output voltage. Even though the high rate of switching losses and the increased device stress urged the need of a high power density high efficient converter which can only be achieved using soft switching techniques. A resonant converter is the most suited choice. Phase shift modulated and load resonant types are the major categories of conventional resonant converters. Load resonant converters can be further divided into series, parallel, series-parallel resonant converters. Among which the series-parallel converter, LLC resonant converter[1]can be used for constant output voltage power supplies and is a good choice for high switching frequency applications without the effect of generated electromagnetic interferences.

In this paper, the speed control of BLDC motor fed by a LLC resonant converter is and its mode of operation is explained and simulated using MATLAB/SIMULINK.

II. Speed Control of BLDC Motor

There are three types of speed drives for a BLDC motor. Constant speed drive where the driving motor runs more or less the fixed speed. Discrete speed settings can be obtained using Multi speed drives. Step less change in speed and multi speed ranges can be together performed with Variable speed drives depending on the application.

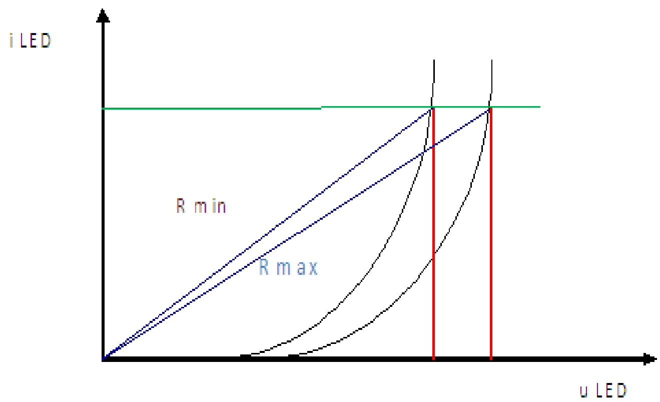

Fig. 1. Speed torque characteristic of BLDC motor

The motor speed can be varied up to 150 % of rated speed with a penalty on torque value. The motor can deliver a high torque maximum upto peak torque as long as the speed torque curve is followed, mainly during the applications that require frequent starts and stops and frequent reversals with load on the motor. Hall sensors are used to provide the exact switching pulses to the inverter thereby controlling the motor speed.

III. PROPOSED CONTROL SCHEME

Figure 2 shows the proposed scheme for a BLDC motor drive. The drive consists of a diode bridge rectifier, LLC resonant converter, MOSFET based voltage source inverter, PWM controller, and switching logic from the hall effect signals.

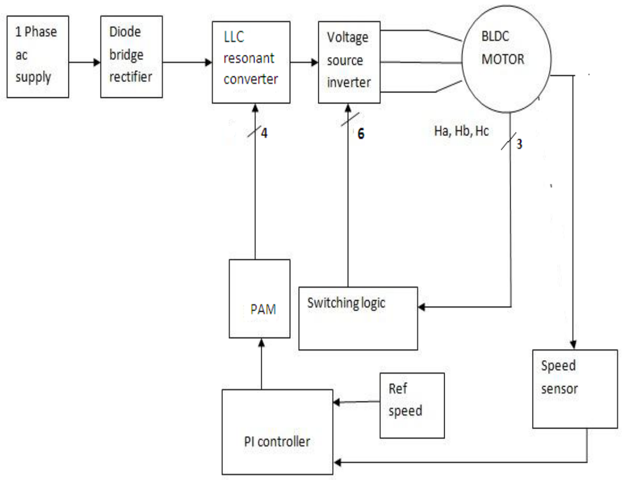

Fig 2.Proposed scheme

A. LLC resonant converter

Among the classifications of resonant converters LLC resonant converter has the most potential since it can achieve zero voltage switching in operating load range and zero current switching for rectifier diodes under some desired conditions.

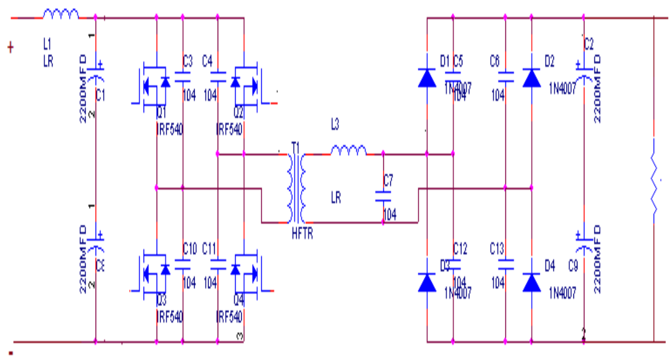

Fig 3.Full bridge LLC converter with full bridge rectifier.

The LLC resonant tank is excited using the square wave generated from the switching circuit. Transformer and rectifier circuit scales and rectifies the resonant sinusoidal current which is filtered by the output capacitors and dc voltage is obtained.

Depending on the load current conditions and the applied voltage, LLC resonant converters can operate in three modes

- At resonant frequency where fs= fr
- Above resonant frequency where fs>fr
- Below resonant frequency where fs<fr

But of all above mentioned modes, converter has only two operations within a switching cycle.

Power delivery operation, occurring twice in a switching cycle when the resonant tank is excited by positive and negative voltages during the first and second half of the switching cycle respectively. The difference in the resonant and magnetizing currents flows through transformer rectifier assembly delivering power to the load.

Freewheeling operation, occurs only when the resonant current reaches magnetizing transformer current, following a power delivery operation. The transformer secondary current reaches zero thereby disconnecting the secondary side rectifier hence the magnetizing inductor is made free to enter the resonance with the resonant inductor and capacitor.

B. BLDC motor drive

A voltage source inverter is used to fed a BLDC motor. The exact position of rotor at every instant is obtained with the help of hall sensors mounted on stator. From the hall signals the switching logic is determined to provide triggering pulses to the inverter switches.

The actual and reference is compared to produce an error signal, which is then fed to the PI controller, generated control signal will then modify the speed accordingly. The switching pulses for the LLC resonant converter are obtained using pulse amplitude modulation method.

IV. SIMULATION

Figure 3 depicts the simulation circuit for the LLC resonant converter fed BLDC motor drive .The total simulation time was 1.2 seconds and the input supply was a dc source of 24 V.

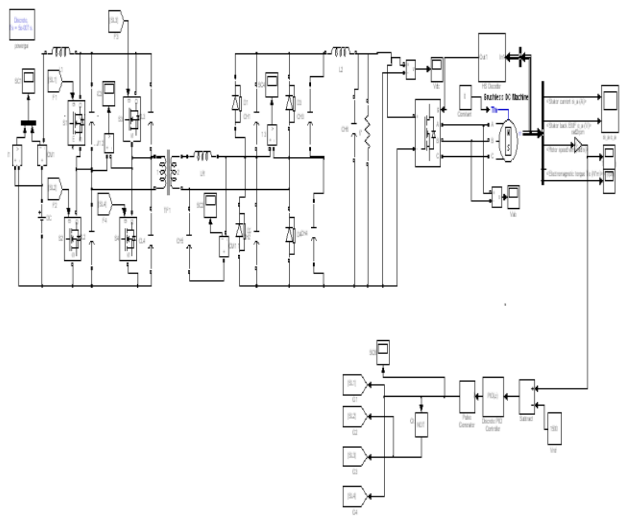

Fig 4.Simulation diagram of speed control of BLDC motor fed by a LLC resonant converter

V. RESULTS

The results obtained on performing the simulation are as shown. The stator current waveform and the generated back emf waveforms are as shown below

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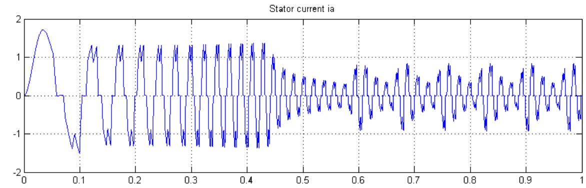

Fig 5.Stator current for phase a

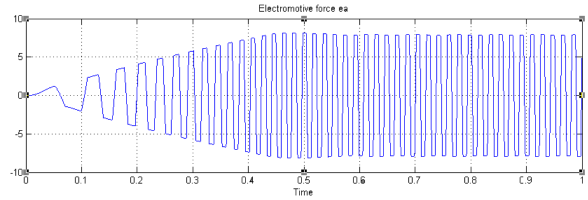

Fig 6.Back emf waveform of phase a

Converter output when the reference speed is set at 800 rpm

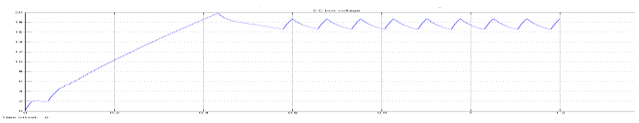

Fig 7.DC bus voltage at 800 rpm

Speed characteristics at set speed of 800 rpm

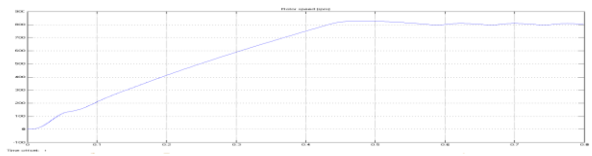

Fig 8.Speed curve at 800 rpm

Converter output when the reference speed is set at 1000 rpm

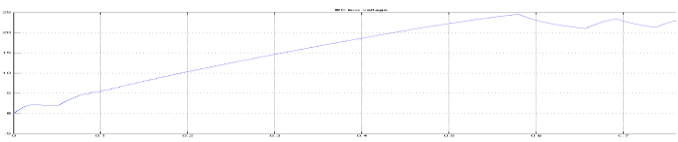

Fig 9.DC bus voltage at 1000 rpm

Speed characteristic at set speed of 1000 rpm

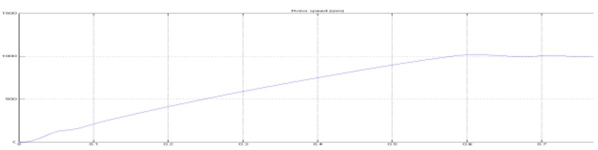

Fig 10.Speed curve at 1000 rpm

Converter output when the reference speed is set at 1500 rpm

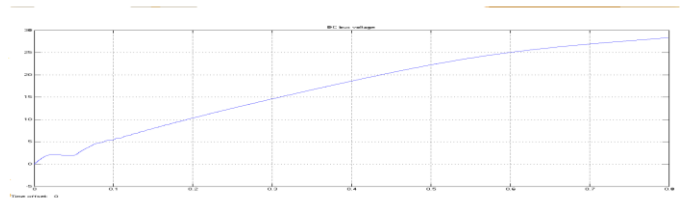

Fig 11.DC bus voltage at 1500 rpm

Speed characteristics at set speed of 1500 rpm

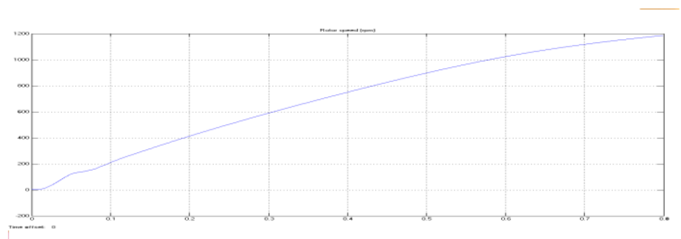

Fig 21.Speed curve at 1500 rpm

VI. CONCLUSION

The speed control of a BLDC motor fed by a LLC resonant converter was modeled using MATLAB/SIMULINK. It can be concluded that use of LLC resonant converter as the front end dc-dc converter is the most suited choice since it reduces the switching losses and device stress to a great extent. High power density and high efficiency can hence be achieved without fearing the effect of electromagnetic interference/ noices. Thus LLC resonant converters are widely used in battery chargers, renewable energy and transportation systems. Since the back emf of the motor is directly proportional to rotor speed and field strength of the motor, any change in one of the parameter cause the other to modify accordingly.

REFERENCES

[1] Fang Z, Duan S, Chen C, Zhang J “Optimal Design Method for LLC Resonant Converter with Wide Range Output Voltage” IEEE transactions on applied power electronics Conference and Exposition (2013). (APEC), Twenty-Eighth Annual IEEE,pp. 2106-2111.

[2] Alin Stirban, Ion Boldea, Gheorghe-Daniel Andreescu,”Motion-Sensorless Control of BLDC-PM Motor With Off line FEM-Information-Assisted Position and Speed Observer", IEEE transactions on industrial and applied electronics.vol 48, no.6,pages1950-1958, Nov/Dec.

[3] Si Young, Ho Joon Lee, Position control of low cost Brushless DC motor using hall sensor Dept of Electrical Engineering Hanyang University,Korea

[4] Haiyan Pan, Chao He,” Pulse-width modulation control strategy for high efficiency LLC resonant converter with light load applications”College of Electrical Engineering, Zhejiang University, Hangzhou 310027, People? Republic of China IET Power Electronics received on 12th November 2013 ,accepted on 7th June 2014.

[5] Yeh Ting, Sjoerd de Haan, Jan A. Ferreira” A DC-DC Full-Bridge Hybrid Series Resonant Converter enabling constant switching frequency across wide load range “IEEE 7th International Power Electronics and Motion Control Conference – ECCE Asia June 2-5, 2012, Harbin, China