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Modelling and Analysis of MLI fed Brushless Motor Drive

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Abstract
This paper presents the design and control of multilevel inverter fed brushless dc (BLDC) motor drive. Diode clamped multilevel inverter is designed and verified with BLDC motor at different speeds. The multicarrier PWM technique can be implemented for producing low harmonic contents in the output, hence the high-quality output voltage was obtained in the proposed system. The validation of the neutral clamped multilevel inverter-based BLDC motor drive system is verified in the MATLAB/Simulink software environment.

Keywords: *pulse width modulation (PWM), speed control, multilevel inverter, brushless dc motor (BLDCM).*

1. Introduction

Brushless dc (BLDC) motors are nowadays widely used in high power high voltage application because of good performance, higher in efficiency, simple construction, low cost, less maintenance required, no loss of rotor copper, no commutation problems, higher power density than induction motor and high torque. The structure of BLDC motor is compact in size and robust in construction, which contributes to the popularity of BLDC motors in efficiency-critical applications or where commutation-induced spikes (which are unwanted) exist. Commutation necessitates using an inverter and a rotor position sensor. Good armature current response is also necessary to drive a BLDC motor satisfactorily. Inverters are suitable for driving the BLDC motor systems. Pulse width modulation (PWM) inverters one of the best performance inverters. Generally, in case of two-level inverters, there will be a problem with harmonics distortions. The conventional method produces high switching losses, results in poor drive performance. One of the solutions for the reduction of harmonics distortion in the output of two-level inverter is the increment of the number of steps of the voltage and the same concept is associated with the inverters are known as multi- level inverters [1]- [6].
The Multilevel inverter (MLI) topologies have been widely used in the industry application of motor drive systems. The various MLIs such as neutral-point clamped (NPC) MLI, flying-capacitor (FC) MLI, and cascaded H-bridge (CHB) MLIs are being used for wide range of power and variety of applications [5]-[8].

In BLDC Machine, the windings of the stator are in the form of distributed concentrated and each occupying one third of the pole pitch. The flux density on the surface of the magnet and in the air-gap is also concentrated distributed over the magnet but almost uniform in the air gap. The development of torque is by the interaction of magnets with the stator current. For the same direction of flux, results opposite forces from opposite current directions. Therefore, it results in reduction in total torque. This in turn makes it necessary that all the current in the stator above the rotor is in the same direction. The formulae for the developed torque of BLDC are given by equation.1, from which it's clear that the developed torque is directly proposal to the stator current [4], [5].

$$T = K.\varphi.I_s \quad (1)$$

The arrangement of this paper is as follows. A brief introduction to the BLDC motor drive, importance of multilevel inverters is given in the Introduction section. Schematics and operating principle of presenting multilevel inverter fed BLDC motor drive system is given in the section II. Validation of MATLAB/Simulink based results of proposed system is discussed in the section III. Finally, conclusion is given in the section IV.

2. Modelling and Control of MLI fed BLDC motor drive

This sections deal the block diagram of MLI fed BLDC motor drive system and its operating principles and simulation ratings. Figure 1 shows the block diagram of MLI fed BLDC motor drive system. For the proposed MLI fed BLDC motor drive a 3-phase a.c voltage is the source supply, the same will be rectified by a 3-phase diode rectifier and then the rectified output voltage is given to the multilevel inverter as an input. Finally, the BLDC is driven by the output from the MLI, which is free-from harmonic distortion. The controlling pulses to MLI is taken from the responses from the BLDC as a feed-back [4], [5].

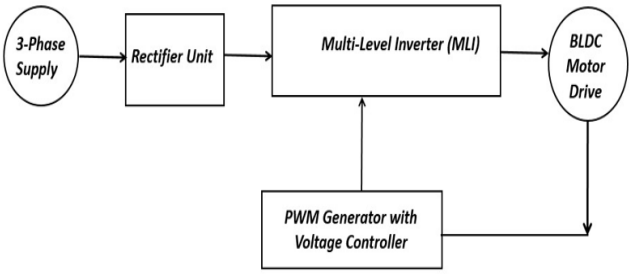


Fig. 1 Block diagram of MLI fed BLDC motor drive system

MATLAB/Simulation diagram of MLI is given by Fig. 2. The [A] to [L] are the gate pulses for the MOSFET switches of the MLI unit. While the BLDC model connected with the demux which gives the ouput like stator current, rotor speed, electromagnetic torque and dc bus voltage is illustrated in Fig. 3 The complete MATLAB/Simulink based MLI fed BLDC motor drive system with many masked blocks is given by Fig.4. All the simulation parameters of the system are given by Table.1

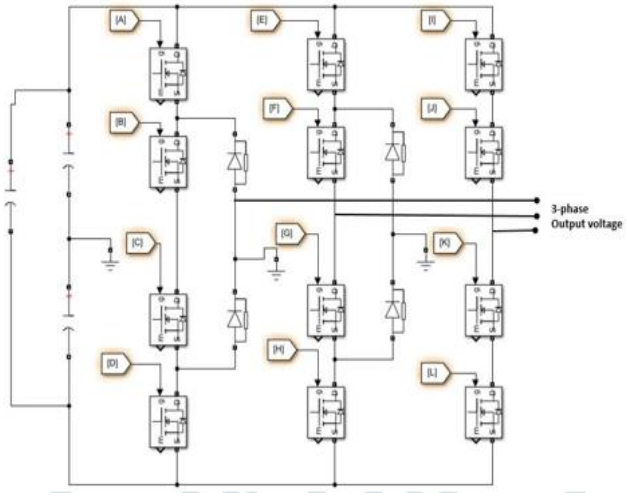


Fig 2 MATLAB/SIMULATION Model of Inverter

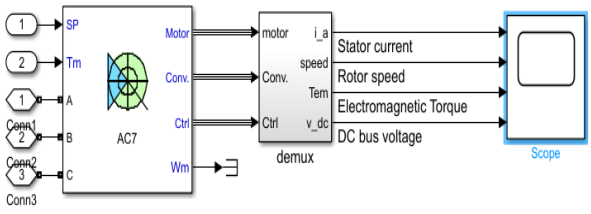


Fig 3 MATLAB/Simulink based different outcomes of the System

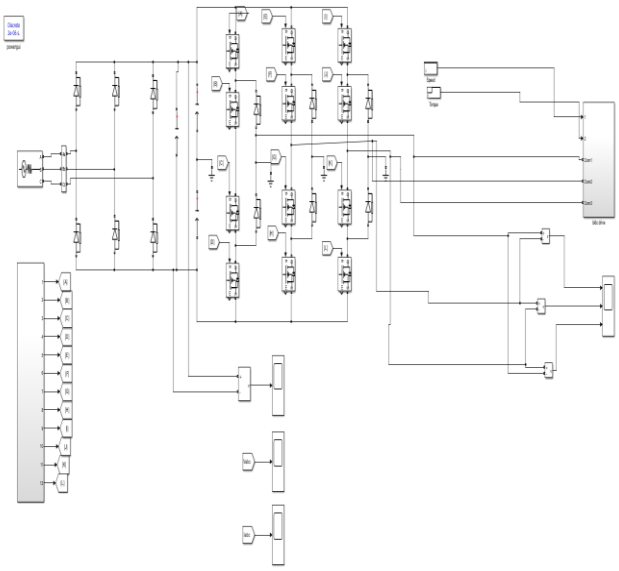


Fig 4 MATLAB/Simulink based MLI fed BLDC Motor drive with masked blocks

Table 1. Parameter value used for simulation

Parameters	Value
3-Phase AC Voltage source	50 Hz , Vrms 250 V
Diode rectifier	Forward voltage 0.8 V, Snubber resistance Rs -500 Ω Snubber capacitance Cs- 250e-9 F
MOSFET – Diode switch	Resistance Ron -0.1 Ω Internal diode resistance Rd- 0.01 Ω Snubber resistance Rs - 1e5 Ω
BLDC Motor	No. of poles- 4 Resistance – 0.2 Ω Inductance - 8.5e-3 H Back EMF flat area – 1200 Inertia - 0.089 k.g m^2 Friction factor- 0.005 N.m.s Proportional gain- 3.3 Integral gain- 300 Current controller hysteresis bandwidth- 0.01 A

3. RESULTS AND DISCUSSION

In this sections, MATLAB/Simulink based simulation results of MLI fed BLDC motor drive system is given. Figure 5 shows the simulated gate pulses of MLI which is used to drive the inverter. The 3-phase voltage and current of the proposed system input is illustrated in Figure 6 (a) and (b) respectively. And converter voltage in Figure 7.

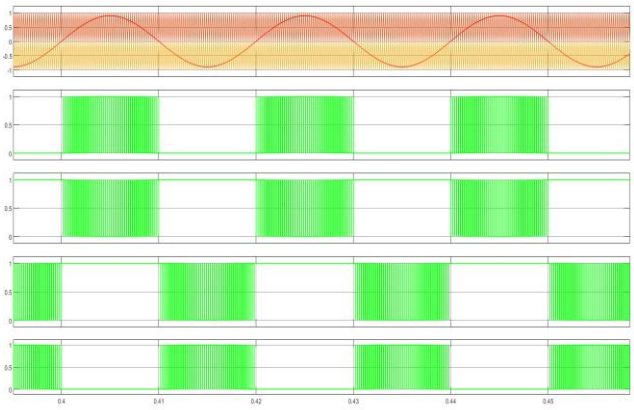
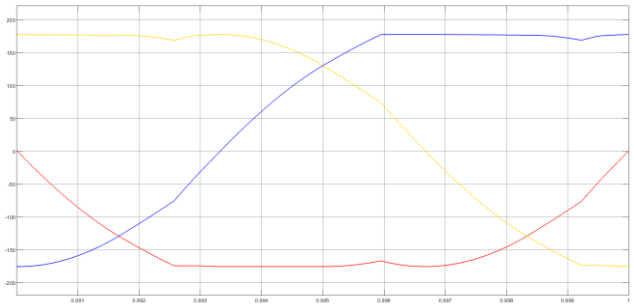
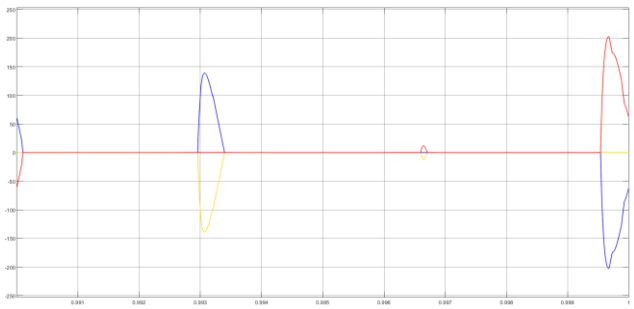


Fig. 5 Comparison of different WPT techniques



(a)



(b)

Fig. 6 (a) 3-phase voltages (b) 3-phase currents

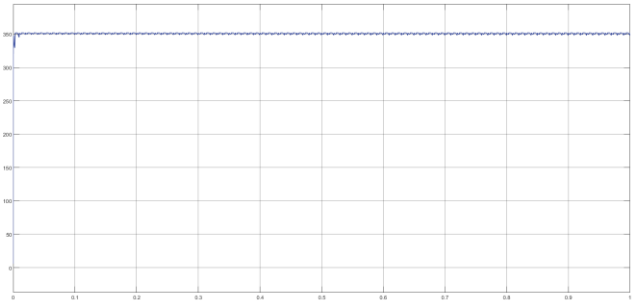


Fig. 7 Converter voltage

Fig.8 shows the output voltage from the MLI. The switching angles of the three phases of A, B and C with delaying 0,1 20 and 240 electrical degree for phase respectively. The output phase voltage is given by 2N+1, Here the term N is the number of cells or dc link voltages. The responses from the simulated MLI fed BLDC drive is shown in the figure. The stator current, rotor current electromagnetic torque and dc bus voltage of the proposed system is illustrated in Fig.9.

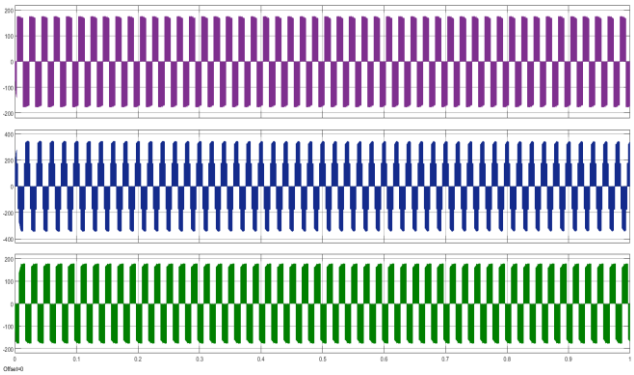


Fig. 8 Output voltage of the MLI

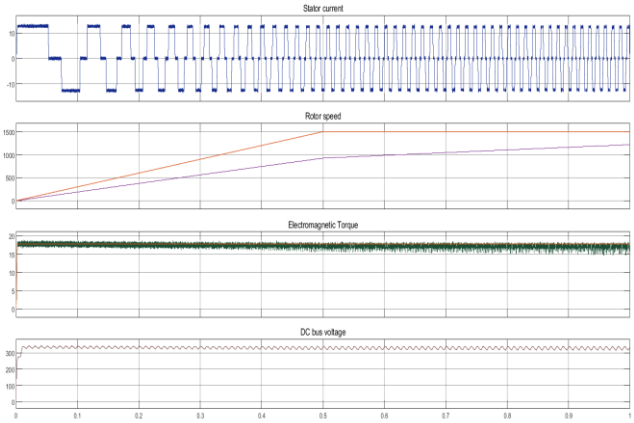


Fig. 9 Output of the proposed system

4. Conclusion

A multilevel inverter has been presented for BLDC motor drive applications. The multicarrier PWM technique can be implemented for producing low harmonic contents in the output, hence the high-quality output voltage was obtained. The modeling of three level BLDC motor drive was done and simulated using Simulink. The total harmonic distortion is very low compared to that of classical inverter. The different speeds obtained for BLDC motor were found to be in the range between 600 rpm and 900 rpm. The inverter system can be used for industries where the adjustable speed drives are required and significant amount of energy can be saved as the system has fewer harmonic losses. Also, the number of levels may be incremented so as to reduce the amount of harmonic distortion furthe Hence, in this work a four level multi-level inverter has designed and fed to the brushless (BLDC) dc motor. The output responses of each section have validated through the MATLAB/Simulink simulation results. Multicarrier PWM technique has been implemented for the firing pulses of MOSFET based MLI unit hence the low harmonic content and high-quality output voltage was obtained in the output.

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