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Design of Control Scheme and Performance Improvement for Multilevel Dc Link Inverter Fed PMLDCL Motor Drive

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Abstract - PMLDCL motors are gaining a lot of popularity due to their high efficiency as the Permanent Magnets do not carry current which results in negligible copper losses as compared to asynchronous motors. This paper introduces a design for speed control of the PMLDCL motor using multilevel dc link inverter fed by a Boost Converter. The multilevel dc link inverter consist of five level voltage sources, which are controlled by switches. The motor can be driven at different speed level as per its load requirement by making use of five level MLDC Link Inverter. In case of traditional inverter which is only a one level inverter the speed cannot be controlled as per the load requirement. The MLDC link inverter provides the output voltage waveform in step shape form. Thus as the number of cells (n) increases output voltage touches the fundamental component. The input voltage is low, thus to increase the input voltage given to the MLDC link inverter the (Boost Converter) has been designed. The Boost Converter is placed in between (DBR)Diode Bridge Rectifier and (MLDCLI). Both the design and results of Single level inverter and Multilevel Dc Link Inverter are obtained and compared by using the MATLAB Software along with the use of Simulink and Simpower system Tools.

Keywords - Component; PMLDCL motor, MLDCLI, BOOST Converter.

I. INTRODUCTION

For widespread industrial applications, such as high performance motor drives, accurate motor speed control is required in which regardless of sudden load changes and parameter variations [7]. Hence, the control system must be design very carefully as it required to ensure the optimum speed operation under the environmental variations, load variations and structural perturbations. Alternative control strategies have been studied extensively in attempts to provide accurate control capability. Among many kinds of control schemes MLDCL control scheme is one of the scheme designed for varying the speed as per the load requirement of the plant. In permanent magnet (PM) motors, the main flux is produced by the magnets either mounted on the surface of or buried inside the rotor. Because the magnets do not carry current, copper loss is eliminated from the rotor. Further, PMLDCL motors can operate at nearly unity power factor. Hence, PM motors have higher efficiency compared to asynchronous motors. Moreover, it is easier to achieve high-performance torque control with PM motors, in particular, brushless direct current (BLDC) motors or brushless PM motors. Owing to these advantages, PM motors have been widely used in a variety of applications in industrial

automation and domestic appliances with power levels up to 30 kW[1][2]. The PMLDCL motor comes under the family of Three Phase Synchronous motors. The PMLDCL motors uses regular position feedback from the rotor position and given to the 3 phase inverter[3]. The 3 phase PMLDCL motor is given supply from 3 phase rectangular current blocks. The Back EMF is Trapezoidal. The (MLDC)link inverter consists of five voltage cells. The number of cells is denoted by n. As the number of cells that is the value of n increases the output voltage value touches the fundamental value of ac voltage waveform. If the number of cells decreases such as (n-1) (n-2) (n-3) (n-4) (n-5) then the speed also reduces from the highest point to the lowest point.

II. MLDC LINK INVERTER

In this paper the MLDC link inverter consist of 5 level voltage source. Each voltage source consist of 2 switches, one switch in parallel with the voltage source and another switch in series with the voltage source. When the voltage source is to be connected in the circuit series switch is used and when the voltage source is to be bypassed make use of parallel switch. Thus it can be said that if all the series switches are on the motor will run at full load speed and when all the parallel switches

are on the motor will stop. Thus when the full load requirement is there all the series switches are closed, thereby fulfilling the load requirement of the projected plant. This can be more clearly understood from the figure given below.

Fig. a : 5 Level MLDC Link Inverter, n=5

The above fig shows the multilevel dc link inverter with five voltage sources. It can be seen from the fig that each voltage source consist of parallel and series switches.

III. BOOST CONVERTER

The input voltage to the MLDC link inverter should be high so that it should be distributed equally into 5 numbers of cells. But only 230 volt is available at the source. When the motor will be on full load the voltage required will be 430 v which is the full load requirement of the motor used in this paper. Therefore in any case we will have to design BOOST CONVERTER which will increase the voltage level to the required value.

Fig. b : Boosted Voltage supplied to MLDCLI.

BOOST EQUATIONS:

$$V_s = 220V$$

$$V_i = 175V$$

$$V_o = 430V$$

$$f = 25KHZ$$

$$L = ?$$

$$C = ?$$

$$(1 - K) = \frac{V_s}{V_a}$$

$$L = \frac{K(1 - K) \cdot R}{2f}$$

$$C = \frac{K}{2fR}$$

MATHEMATICAL EQUATIONS OF PMBLDC MOTOR:

The simulated machines are smooth air gap PMBLDC without any damping circuits in the rotor. The rotors field are constant and created by permanent magnets and the back e.m.f are considered as Trapezoidal. The simplified electric equations for motor can be presented as below.

$$v_1 = Ri_1 + L \frac{di_1}{dt} + jp\omega_{r,1}\psi_{r,1} \quad (1)$$

$$T_1 \quad T_{L,1} = J \frac{d\omega_{r,1}}{dt} \quad (2)$$

$$\text{with } T_1 = \frac{3}{2} p \Im m \{i_1 \psi_{r,1}\} \quad (3)$$

$$\omega_{r,1} = \frac{d\theta_1}{dt}$$

ω_r = Motor angular velocity

T = Electrical Torque

T_L = Load torque

J = Moment of Inertia

$$\left. \begin{aligned} i_a &= \frac{i_{ab} + i_{ac}}{3} \\ i_b &= \frac{i_{ab} - 2i_{ac}}{3} \\ i_c &= \frac{i_{ac} - 2i_{ab}}{3} \end{aligned} \right\}$$

MOTORS

TABLE I

No	Motor Specifications	Value
1	Rated Torque	6 Nm
2	Rated Speed	3000 rpm
3	Inertia	0.0006329 kgm ²
4	Resistance	0.26 Ω
5	Inductance	3.1 H
6	Magnet Flux	0.1173wb/m
7	DC link Voltage	430 v

MOTORS PARAMETERS

IV. TRADITIONAL INVERTER

Traditional inverter is a conventional inverter which is fed directly by a single voltage source or a single voltage cell. The single phase ac voltage is converted into dc voltage by making use of (DBR)Diode Bridge Rectifier. This dc voltage is converted into ac by means of the 3 phase inverter and fed to the PMBLDC motor.

Ff

Fig. c : PMBLDC motor fed by DBR

The above fig shows a single level inverter or a conventional inverter. The voltage required to run the motor at a rated speed is much higher as compared to a single phase supply which is only 230 v. Thus to increase the voltage upto the required value we will design a boost converter. This boost converter will increase the voltage level upto the required value .Thus it plays a very important role in this project. The output dc voltage equation obtained by making use of diode bridge rectifier is as follows.

$$V_{dc} = \frac{2Vm \cos \alpha}{\pi}$$

Fig. d : PMBLDC motor fed by Boost Converter.

The above fig shows the boost converter which increases the voltage level upto 430v.

Fig. e : Waveform of Boosted Dc voltage using Boost Converter

Thus from the above waveform it can be seen that voltage level is raised to the required value. Now this required voltage is given to the MLDC link inverter where it is distributed equally.

Fig. f : Simulation diagram of MLDC fed PMBLDC motor

- When all the 5 cells are activated at No load.

Fig. g : Waveforms at $n=5$ on No load condition.
Speed=3000rpm.

All the five voltage sources are on. At this time the full rated voltage is applied across the motor and thus the motor runs at its rated speed that is 3000 rpm.

- When 4 cells are activated, i.e. (n-1) condition

Fig. h : Waveforms at condition (n-1), at speed 2400 rpm

From the above fig it is seen that as soon as the voltage source is bypassed the speed reduces by 600 rpm

- When 3 cells are activated, i.e. at (n-2) condition.

Fig. i : Waveforms at (N-2) condition, speed 1800rpm.

Fig above shows that at (N-2) condition speed is again reduced by 600 rpm. Thus speed is reduced by 1200 rpm from the rated speed at n-2 condition.

4. When 2 cells are activated i.e at (n-3) condition.

Fig. j : Waveforms at(n-3) condition, speed is 1200 rpm

The above fig shows that speed has reduced to 1200 rpm at (n-3) condition .Where n is 5. Thus only two voltage sources are activated at a time. That why the speed is reduced by 1800rpm from its rated speed.

5. When one source is activated i.e at (n-4) condition

Fig. l : Speed on full load at rated torque 6 N-m.

Fig. m : Current on Full load at rated torque 6 N-m

From the above waveform it can be seen that as the full load is applied at 0.6 sec the speed gets reduced from 3000rpm to 2750 rpm. As soon as the load is applied the stator current increases to a certain value.

SPEED and CURRENT of MOTOR ON 75% of FULL LOAD

Fig. n : Speed on 75% of full load

Fig. o : Stator current on 75% of full load.

SPEED AND CURRENT OF MOTOR ON HALF LOAD

Fig. p: Speed on 50% of Full load

Fig. q : Current on 50% of Full Load

SPEED AND CURRENT ON 25% OF FULL LOAD.

Fig. r : Speed on 25% of Full load

Fig. s : Current on 25% of Full Load

From the above fig it can be seen that the speed increases as the load is decreased. The motor speed at 25% of full load is greater than 50% ,75% and full load speed. The stator current increases as the load increases.

V. CONCLUSION:

The results are obtained by designing control scheme for MLDC link inverter fed PMBLDC motor drive. Various speeds can be obtained by making use of MLDC link inverter. Thus both the results of Traditional inverter and MLDC link inverter can be compared and studied. It can be seen that by using Traditional inverter only one speed can be obtained and it cannot be controlled. But by making use of MLDC link inverter different speeds can be obtained. Thus it can be said that MLDC is better as compared to Traditional inverter.

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