A NOVEL TOPOLOGY OF MATRIX CONVERTER FOR DRIVING A BLDC MOTOR

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Abstract—This paper presents a novel matrix converter based topology with less number of semiconductor switches. The proper switching sequence of matrix converter is used to drive BLDC motor directly from single phase without dc link capacitor. A matrix converter fed BLDC motor is simulated in MATLAB. The proposed technique is simple to implement and cost effective.

Keywords—Permanent magnet (PM), Brushless DC motors (BLDC).

I. INTRODUCTION

Latest advance in permanent magnet materials, solid state devices and microelectronic have resulted in new energy efficient drives using permanent magnet brushless DC motors (PMBLDCM). Brushless DC motors are very popular in a wide array of applications in industries such as appliances, automotive, aerospace, consumer, medical, industrial automation for its reliability, high efficiency, high power density, low maintenance requirements, lower weight and low cost. As the name implies, BLDC motor do not have brushes for commutation. Instead they are electronically commutated. BLDC motor have many advantages over brushed DC motor and induction motors, like better speed-torque characteristics, high dynamic response, high efficiency, noiseless operation and wide speed ranges. Electronic commutation of stator windings is based on rotor position with respect to the stator winding. Brushless DC motors are traditionally driven by Pulse Width Modulated Voltage Source Inverters (PWM-VSI). However it has certain disadvantages like need of additional filter elements at input and output, the poor quality of output waveforms, harmonics depends on stability of DC link voltage and so on. Compared with these conventional converters matrix converters has the most desirable feature. Earlier, Matrix converter was employed for driving induction motor and permanent magnet synchronous motors. Many control methods of matrix converters have been proposed which includes Alesina Venturini (AV) method, Pulse Width Modulation (PWM) method, Space Vector Modulation Technique (SVM) etc [5].

In general, power electronic converters can be classified in to two sub-categorias.
1) Indirect Converters - The input is rectified, smoothed by an intermediate DC link capacitor and inverted using an array of power electronic switches
2) Direct Converters -The output is synthesized directly from the input by piecewise sampling of input signal using an array of power electronic switches.

Indirect converter consists of two stages of conversion. The first stage consist of a bridge rectifier, in which, the three phase AC supply is fed to the rectifier so that the rectifier performs the operation of AC to DC conversion. After this conversion, it was fed to the energy storage element which is usually a capacitor. The inverter performs the operation of DC to AC conversion which is provided at the second stage. The intermediate DC link capacitor used in indirect conversion topologies, requires a large space for its installation, which results in bulkier and heavier converter housing.

A direct AC-to-AC converter does not contain dc link capacitor. Converter has a simple structure and many attractive features. The three phase matrix converter is a single stage converter which has nine bi-directional switches, to connect, directly a three phase voltage source to a three phase load.
A Novel Topology Of Matrix Converter For Driving A BLDC Motor

The matrix converter (MC) is the most popular and widely used converter topology in the family of direct converters due to its inherent advantages listed below:

• Ability to generate a load voltage with arbitrary amplitude and frequency.
• Sinusoidal input and output waveforms with unity power factor at any load.
• Regeneration capability, due to the inherent bidirectional nature of the converter.
• Compact and relatively simple power circuitry.

The disadvantages of the matrix converters, which have been reported in literature, can be listed as follows.

• No discrete solid state device, which is capable of bidirectional power transfer.
• Additional protective circuitry should be employed to avoid input side short circuits and output side open circuits.
• No inherent ride through capability due to the absence of DC link capacitor.
• Maximum achievable voltage transfer ratio between input and output is lower.

II. OPERATION OF BLDC MOTOR

A BLDC motor employing a voltage source inverter (VSI) is as shown in Fig 3.

During the period 0 to 600, the current IA enters through the phase A and leaves through the phase B. When Tr1 and Tr2 are on, terminal A and phase B respectively connected to positive and negative terminal of the dc source Vd. A current will flow through the path consisting of Vd, Tr1, phase A, phase B and Tr6 and rate of change of current IA will positive. When Tr1 and Tr6 are turned off this current will flow through a path consisting of phase A, phase B, diode D3, Vd and diode D4. Since the current has to flow against voltage Vd the rate of change of IA will be negative.

III. METHODOLOGY

1. CONVENTIONAL TOPOLOGY

Fig 4. Single phase to three phase matrix converter A typical topology of a single phase to three phase matrix converter is shown in Fig. 4. Each bidirectional switch cell is realized by two back-to-back solid state switches, since there is no single solid state device, which is capable of bidirectional power transfer. As illustrated in Fig. 2, T1 and T2 resemble one bidirectional switch cell. These switches are controlled in such a way that the voltage output is a sinusoid of the required frequency and amplitude.

2. NOVEL TOPOLOGY

Fig 5. Proposed matrix converter based BLDC motor drive A novel topology of single phase to three phase matrix converter as shown in fig 5 is used to drive BLDC motor. It requires low device count compared to the topology shown in fig 4 and has regeneration capability.

IV. NOVEL TOPOLOGY

The novel topology used for the converter is similar to the “Separation and Link” topology, which shown in Fig. 4. Both the “Separation and Link” method, and the topology presented here use two single phase to three phase (1×3) inverters for positive and negative half cycles of the input single phase voltage source. The novel converter topology requires less switching devices, which improve the efficiency of converter. The switches in the inverter do not require anti-parallel freewheeling diodes as mentioned in the “Separation and Link” method. The freewheeling paths are provided by forced commutation of the appropriate switching devices at the correct instant in time. The methodology shown in Fig. 5, can be resolved into two single phase to three phase (1×3) inverters.

• A1, A2, B1, B2, C1 and C2 switches in “inverter-1”.
• A3, A4, B3, B4, C3 and C4 switches in “inverter-2”.

Fig 3. Trapezoidal BLDC motor fed from voltage source inverter
When the supply voltage is in its positive half cycle, the inverter-1 supplies power to the load and the inverter-2 provides freewheeling paths. When the supply voltage is in its negative half cycle, the inverter-2 supplies power to the load and the inverter-1 provides freewheeling paths. The four diodes named as D1, D2, D3 and D4 in Fig. 3, are used to select the appropriate half cycle of the input voltage source to the relevant inverter and avoid the reverse voltages being applied to the switching devices. Also they prevent the input side short circuits. For the safe operating conditions of converter there are two following conditions.

• No two switches in a same leg should turned on, which result in high currents due to the short circuit of input voltage source
• No output line left open, which result in high over voltages due to the inductive nature of the load.

Switching algorithm with a three phase brushless DC Machine. The commutation of the switching devices of converter was simulated by processing the Hall effect sensor signals, and energizing the appropriate windings of the machine model accordingly. Following switching algorithm tabulated in Table I is derived assuming a trapezoidal back Electromotive Force (EMF) brushless DC machine as the output. The freewheeling paths are provided by firing the relevant switches in the opposite side of the converter as tabulated in Table I.

### TABLE I

<table>
<thead>
<tr>
<th>Supply voltage</th>
<th>Switches in main path</th>
<th>Switches in freewheeling path</th>
<th>Hall sensor output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>A1 C2</td>
<td>A4 C3</td>
<td>1 0</td>
</tr>
<tr>
<td>Positive</td>
<td>B1 C2</td>
<td>B4 C3</td>
<td>1 1 0</td>
</tr>
<tr>
<td>Positive</td>
<td>B1 A2</td>
<td>B4 A3</td>
<td>0 1 0</td>
</tr>
<tr>
<td>Positive</td>
<td>C1 A2</td>
<td>C4 A3</td>
<td>0 1 1</td>
</tr>
<tr>
<td>Positive</td>
<td>C1 B2</td>
<td>C4 B3</td>
<td>0 0 1</td>
</tr>
<tr>
<td>Positive</td>
<td>A1 B2</td>
<td>A4 B3</td>
<td>1 0 1</td>
</tr>
<tr>
<td>Negative</td>
<td>A4 C3</td>
<td>A1 C2</td>
<td>1 0 0</td>
</tr>
<tr>
<td>Negative</td>
<td>B4 C3</td>
<td>B1 C2</td>
<td>1 1 0</td>
</tr>
<tr>
<td>Negative</td>
<td>B4 A3</td>
<td>B2 A2</td>
<td>0 1 0</td>
</tr>
<tr>
<td>Negative</td>
<td>C4 A3</td>
<td>C1 A2</td>
<td>0 1 1</td>
</tr>
<tr>
<td>Negative</td>
<td>C4 B3</td>
<td>C1 B2</td>
<td>0 0 1</td>
</tr>
<tr>
<td>Negative</td>
<td>A4 B3</td>
<td>A1 B2</td>
<td>1 0 1</td>
</tr>
</tbody>
</table>

FIG. 5. Hall sensor output

V. SIMULATION FOR PROPOSED TOPOLOGY

VI. SIMULATION RESULTS

Simulation results of BLDC motor under no load are shown in Fig. 7. It shows back-EMF, current produced in phase A of motor. Rotor speed of BLDC is shown in fig 8. Pulsating torque of BLDC is shown in Fig. 9. Table II shows BLDC motor specification to investigate performance of advanced model.

Fig 7. phase a current and back emf waveform with supply voltage
CONCLUSION

A novel topology allows the machine to be driven directly from the single phase mains without an intermediate DC link capacitor and with lesser number of semiconductor devices. The simulation model has been developed for a BLDC motor with the help of Matlab.

REFERENCES


TABLE II
BRUSHLESS DC MOTOR PARAMETER

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator Phase resistance</td>
<td>2 Ω</td>
</tr>
<tr>
<td>Stator phase inductance</td>
<td>5 mH</td>
</tr>
<tr>
<td>Torque constant</td>
<td>0.2 Nm(Apeak)–1</td>
</tr>
<tr>
<td>Inertia (J)</td>
<td>0.0008 kgm2</td>
</tr>
<tr>
<td>Friction factor (F)</td>
<td>0.001 Nms</td>
</tr>
<tr>
<td>Back EMF</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>Rated power</td>
<td>320 W</td>
</tr>
<tr>
<td>No. of pole pairs</td>
<td>4</td>
</tr>
</tbody>
</table>

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