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A matrix converter based drive for BLDC motor

Radhika R, Prince Jose

***Abstract*— This paper presents a matrix converter based drive for BLDC motor. Matrix converter is a popular direct conversion method. This property is made use in this paper for driving a three phase BLDC motor from a single phase supply. K map simplification is used to find out switching states.**

***Index Terms*— BLDC motor, matrix converter, speed control**

I. INTRODUCTION

Latest development in the field of electric motors has considerable impact in the industrial application. 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 [2]. 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. In brushless DC motor, commutation is done through electronically. Voltage source inverter fed BLDC motors [2], are used conventionally for driving such motor has limitation, such as it require a DC supply. Conversion of available AC supply to DC is resulted in higher cost due to presents of a bulky DC link capacitor [1].

Solution for this problem is to use a matrix converter [2] for driving brushless DC motor that can be operated from an available AC supply. Matrix converter is a single stage AC to AC converter. It is used to directly connect a load from a power supply without using an interlinking large capacitor or energy storage devices. Earlier, Matrix converter was employed for driving induction motor and permanent magnet synchronous motors.

Intensive research on matrix converter was started on 1980s by Venturini and Alesina [3]. They have advantages like sinusoidal input and output voltage, power factor control etc. But the difficulty with such converter is availability of single bidirectional switch and its triggering. However this difficulty can be overcome by employing soft commutation technique.

This paper presents a new matrix converter based drive for BLDC motor. This three phase motor is driven from a single phase AC supply.

II. CONVENTIONAL METHOD FOR DRIVING BLDC MOTOR

Conventionally BLDC motors are fed from voltage source inverter [4].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.

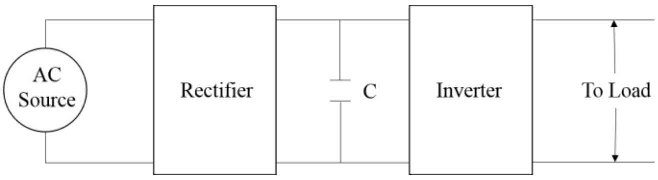

Fig 1. BLDC drive block diagram using VSI

As in Fig 1, In VSI based BLDC drives available AC supply is converted to a pulsating DC by passing it through a rectifier circuit and this DC is then converted back to AC supply by using an inverter. In the VSI scheme, an inter linking capacitor is necessary for smoothening the pulsating DC. This results in bulkier design and expense in cost. But this scheme is adopted widely.

III. MATRIX CONVERTER BASED CONTROL OF BLDC MOTOR

In matrix converter based control of brushless DC motor, it utilizes the advantage of single stage conversion [5]. In this single stage or direct conversion method it is entirely avoid the need of an intermittent stage that appear in the indirect method.

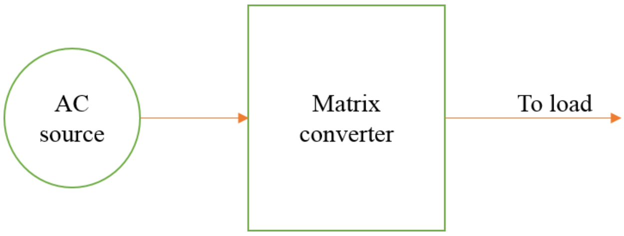

Fig 2 BLDC drive block diagram using Matrix converter

As the name indicates in direct conversion method matrix converter is the only one unit that appears between load and motor. Three phase star connected brushless motor with sensor [8] is directly connected to the single phase AC supply directly via the matrix converter. Matrix converter is control in accordance with status of Hall Effect sensor that comes from the motor.

Control strategies for matrix converter

From the development of matrix converter there are interesting developments in that field. Development of soft switching methods and new inventions in solid state devices resulted in development and use of matrix converter. Till the date there are several methods to control the matrix converter effectively [9].

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Brushless DC motor

Brushless motor are one of the motor that gaining popularity among industrial area in the recent days. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated [8]. BLDC motor has several advantages over ordinary motors. Some of these are

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

BLDC motors are similar like an ordinary synchronous machine, that is speed of field MMF that produced by the stator conductors and the speed of rotor are same which means there is no slip [6].

Similar like an ordinary motor brushless motor construction [11] is also consist of a stator and a rotor. Stator may be of a three phase construction or two phase construction. Generally three phase construction is adopted.

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor.

According to the shape of back emf, there are two types of brushless motors [13]. Sinusoidal back emf and trapezoidal back emf are made on the basis of the interconnection of coils in the stator windings to give the different types of back Electromotive Force.

IV. CONTROL STRATERGYS FOR BLDC MOTOR

To rotate the brushless DC motor the stator winding should be energized sequentially. This sequence is determined by the position of rotor. This position is determined by using Hall Effect sensors which are embedded in the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

Each commutation sequence has one of the windings energized to positive power (current enters into the winding), the second winding is negative (current exits the winding) and the third is in a non-energized condition. Torque is produced because of the interaction between the magnetic field generated by the stator coils and the permanent magnets. Ideally, the peak torque occurs when these two fields are at 90° to each other and then decreases as the fields move together. In order to keep the motor running, the magnetic field produced by the windings should shift position, as the rotor moves to catch up with the stator field. What is known as "Six-Step Commutation" defines the sequence of energizing the windings.

Speed control

In the control of BLDC motor using matrix converter we are using two inverters which are connected back to back.

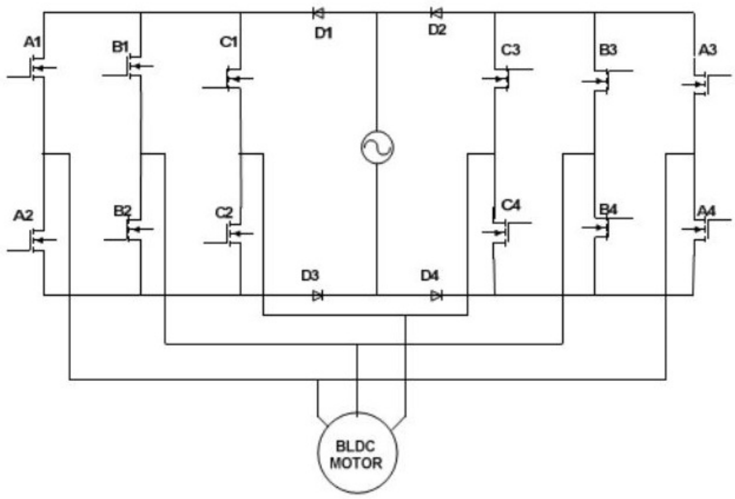

Fig.3 BLDC drive circuit diagram using Matrix converter

In this topology requires less switching devices, which improve the efficiency of converter. The switches in the inverter do not require anti-parallel freewheeling diodes [6]. The freewheeling paths are provided by forced commutation of the appropriate switching devices at the correct instant in time.

Twelve switches in this matrix converter as shown in fig.3 are grouped into two. A1, A2, B1, B2, C1and C2 switches in converter-1. A3, A4, B3, B4, C3 and C4 switches in converter-2. When the supply voltage is in its positive half cycle, the converter-1 supplies power to the load and the converter-2 provides freewheeling paths. When the supply voltage is in its negative half cycle, the converter-2 supplies power to the load and the converter- 1provides 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 to avoid the reverse voltages being applied to the switching devices.

VOLTAGE	HALL SENSOR OUT			SWITCH STATUS											
	X	Y	Z	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
0	0	0	1						1	1		1			1
0	0	1	0		1	1		1			1				
0	0	1	1		1	1						1			1
0	1	0	0	1			1						1	1	
0	1	0	1	1			1		1	1					
0	1	1	0					1			1		1	1	
1	0	0	1						1	1		1			1
1	0	1	0		1	1		1			1				
1	0	1	1		1	1						1			1
1	1	0	0	1			1						1	1	
1	1	0	1	1			1		1	1					
1	1	1	0					1			1		1	1	

Table 1 switching condition

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For the purpose of switching pattern calculation, taking four variables; voltage variable & three hall sensor outputs. Negative half cycle of voltage is termed as '0' and positive cycle as '1'. Hall effect sensor outputs are always '0' or '1'. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors.

Switching design

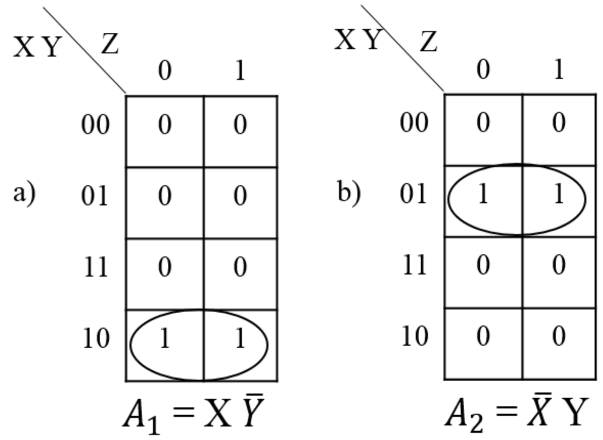

Fig.4. K map algorithm a) For switch A1 b) For switch A2

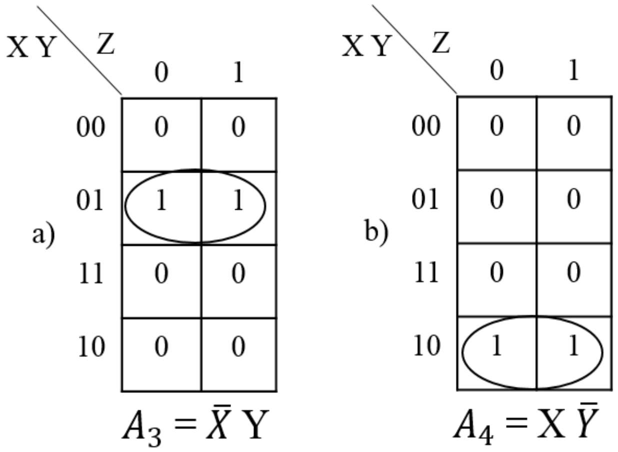

Fig.5. K map algorithm a) For switch A3 b) For switch A4

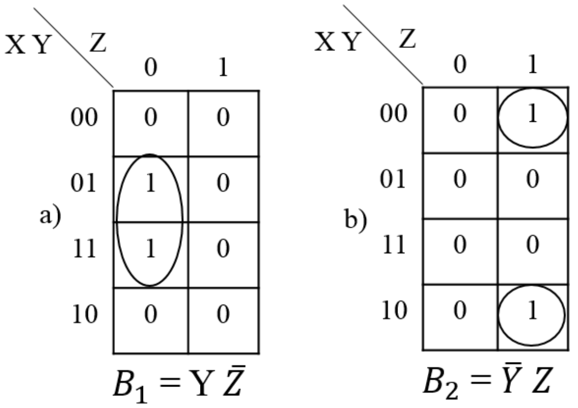

Fig.6. K map algorithm a) For switch B1 b) For switch B2

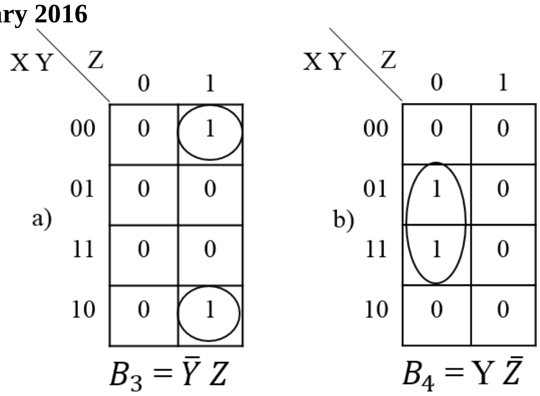

Fig.7. K map algorithm a) For switch B3 b) For switch B4

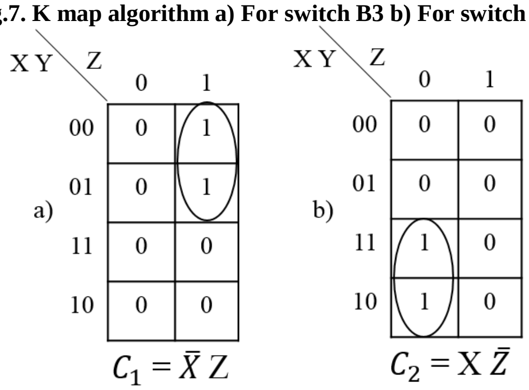

Fig.8. K map algorithm a) For switch C1 b) For switch C2

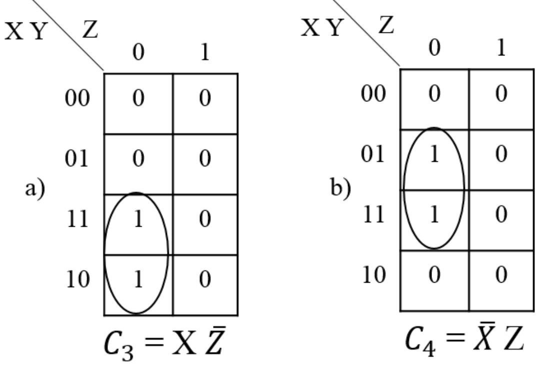

Fig.9. K map algorithm a) For switch C3 b) For switch C4

V. SIMULATION RESULTS

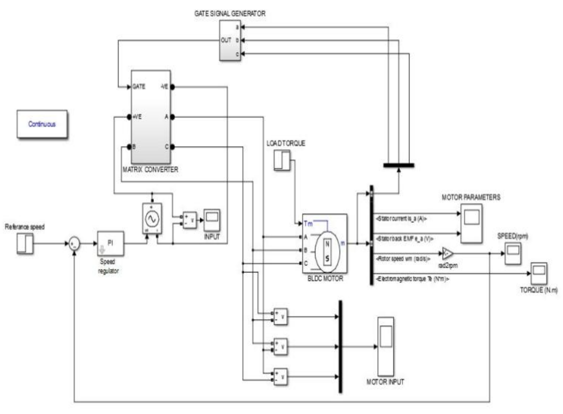

Fig.10. simulation of proposed scheme

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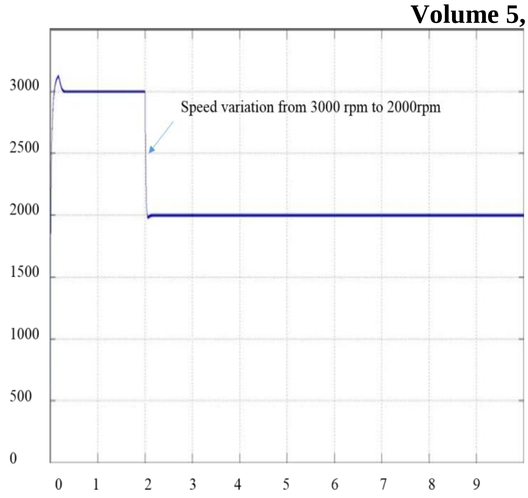

Fig.11. speed variation curve

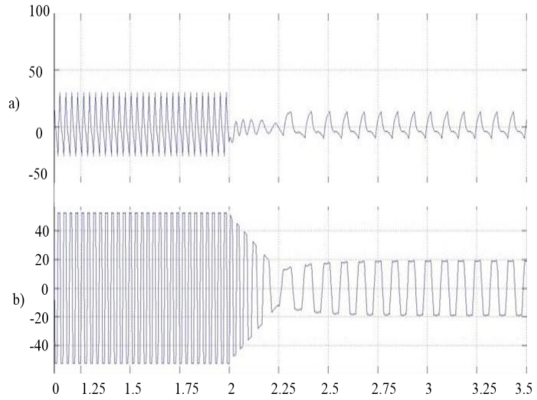

Fig.12.motor parameters a) rotor current b) motor back emf

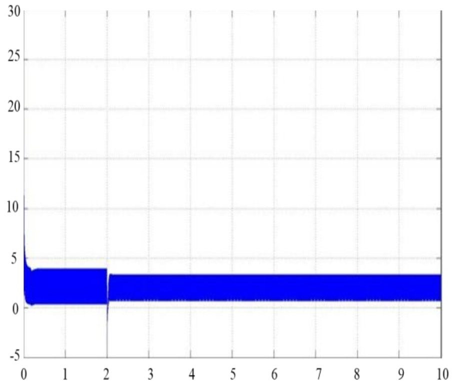

Fig.13.torque variation

Motor is working properly and speed is changes from one to other within a minimum time interval. However requirement of a variable gain amplifier is require for the proposed scheme.

VI. CONCLUSION

While considering the importance of brushless motor in the industrial area, its speed control with minimum cost and simplicity must be ensured. In this speed control using matrix converter assure all these requirements. However some modifications are require to improve its performance much better. Also some other methods must introduce to eliminate the need of variable output voltage source. When we are employing powerful modulation methods, like predictive control, to matrix converter we can avoid it

REFERENCES

[1] P. D. Ziogas, Y. G. Kang, and V. R. Stefanovic, “Rectifier-inverter frequency changers with suppressed DC link components,” IEEE Trans. Ind. Applicat., vol. IA-22, pp. 1027–1036, Nov./Dec. 1986.

[2] I. Boldea and S. A. Nasar, “Torque Vector Control (TVC)—A class of fast and robust torque speed and position digital controller for electric drives,” EMPS, vol. 15, pp. 135–148, 1988.

[3] A. Alesina and M. G. B. Venturini, “Analysis and design of optimum- amplitude nine-switch direct ac–ac converters,” IEEE Trans.Power Electron., vol. 4, pp. 101–112, Jan. 1989.

[4] P. Pillay and R. Krishnan, “Modeling, simulation and analysis of permanent-magnet motor drives, part II: The brushless DC motor drive,” IEEE Transactions on Industry Applications, vol. 25, no. 2, pp. 274–279, Mar/Apr. 1989.

[5] D. G. Holmes and T. A. Lipo, “Implementation of a controlled rectifier using ac–ac matrix converter theory,” IEEE Trans. Power Electron., vol. 7, pp. 240–250, Jan. 1992.

[6] L. Zhong, M. F. Rahman, W. Y. Hu, and K. W. Lim, “Analysis of direct torque control in permanent magnet synchronous motor drives,” IEEE Trans. Power Electron., vol. 12, no. 3, pp. 528–536, May 1997.

[7] J. Seok, J. Kim, and S. Sul, “Over-modulation strategy for high-performance torque control,” IEEE Transactions on Power Electronics, vol. 13, No. 4, July 1998, pp 786- 792.

[8] J. P. Johnson, M. Ehsani, and Y. Guzelgunler, “Review of sensorless methods for brushless DC,” in Conference Record of the IEEE 34th IAS Annual Meeting, 1999, pp. 143–150.

[9] Patrick W. Wheeler, member, IEEE, josé rodríguez, senior member, IEEE, jon C. Clare, member, ieee,lee empringham, member, IEEE, and alejandro weinstein “matrix converters: A technology review” IEEE transactions on industrial electronics, vol. 49, no. 2, April 2002

[10] F. B. Christian Klumpner, “Using reverse blocking IGBTs in power converters for adjustable speed drives,” in Conference Record of the IEEE 38th IAS Annual Meeting, 2003, pp. 1516–1523.

[11] S. Bala, G. Venkataraman, “Matrix Converter BLDC drive using reverse-blocking IGBTs,” Proceedings of 21st Annual IEEE- APEC Conf. 2009, pp. 660-666.

[12] J. Rodriguez, M. Rivera, J. W. Kolar, P. W. Wheeler “A Review of Control and Modulation Methods for Matrix Converters,” IEEE Transactions on Industrial Electronics Vol. 59, No. 1, pp. 58-70, January 2012.

[13] Manali a. Pawar, n.T. Sahu, a.Y.Fadnis, s.Y.Ambatkar “ A novel topology of matrix converter for driving a BLDC motor” international journal of electrical, electronics and data communication, issn: 2320-2084 volume-2, issue-2, Feb.-2014.

AUTHOR BIOGRAPHY

Radhika R received B-tech degree in electrical and electronics engineering from Government Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India in 2005 and received M-tech degree in power systems from National Institute of Technology, Calicut, Kerala, India in 2012.Her research interests are primarily in power quality.

Prince Jose received B-tech degree in electrical and electronics engineering from Government Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India in 2010 and received M-tech degree in power electronics and control from Government engineering college, Idukki, Kerala, India in 2014. His research interests are primarily in power electronic converters and their control and signal processing.