Matrix Converter Based Four Quadrant Operation of Three Phase BLDC Motor Using Digital Control Strategy

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Abstract— Brushless DC (BLDC) motor drives are becoming more popular in industrial applications. Four quadrants method is use to control the BLDC motor in all the four quadrants. This paper deals with the novel matrix converter based drive techniques for digital control of three phase BLDC motor. Hall Effect sensor sense the signals obtained from rotating position of BLDC motor and send it to the microcontroller. Microcontroller provides the signals to the appropriate switching devices, which have to be turn on and off in accordance with switching algorithm table. If the proposed method is implemented in low power motors, like motors used in sewing/embroidery machines, arcing will be very less which is not even visible. The need of the proposed work is to make simple hardware circuit which is more reliable, more efficient, less noisy, excellent speed control and smooth transition between the quadrants.

Key words: BLDC Motor, novel matrix converter, Hall Effect sensor, four quadrant method

I. INTRODUCTION

In some applications, when speed control is require, we would select DC Brushed motors. Commonly, large size of DC Brushed motors are use and have a much maintenance, lower efficiency and also it has a very high temperature etc. In material science and electric technology development it comes to achievement of new motor for speed control – Brushless DC motor. In BLDC motor, the brushes are not present, so that it is maintenance free, better performance no matter in high or low speed region, direction changes in CW/CCW occurs. When the power output is same, half size of BLDC motor is use as compare to DC Brushed motor. Nowadays, to reduce the cost of BLDC motor so many studies have been carried out.

Usually, BLDC motor uses three or more hall effect sensors to obtain the actual rotor position and speed measurements. Therefore to obtain the reliable speed measurements, it would be necessary to inverse the time difference between two successive Hall - sensor signals. BLDC motor consist of rotor with permanent magnets and a stator with windings. It is also known as electronically commutated motor that are powered by DC electric source via inverter, which produces ac electric signal to drive the motor. The brushes and commutator have been eliminated and the windings are connected to the control electronics. The control electronics replaces the function of the commutator and energize the proper winding. The motor has less inertia, therefore, it is easy to start and stop. Some of the qualities of BLDC motor are good potential, more efficient, comparatively faster and more reliable. BLDC motor is driven by DC voltage but current commutation is controlled by solid state switches. The rotor positions are used to determine the commutation instant. The rotor position is sensed by a Hall Effect Sensor, which provides signal to the respective switches. BLDC motors are used in Automotive, Aerospace, Consumer, Medical, Industrial Automation equipment and instrumentation [1].

II. FOUR QUADRANT OPERATION OF BLDC MOTOR

There are four possible modes or quadrants of operation of Brushless DC motor is shown in Fig.1.

When the BLDC motor is operating in the first and third quadrant the supplied voltage is greater than the back emf which are the forward motoring and reverse motoring modes of operation respectively, but the direction of current flow is reversed. When BLDC motor operating in the second and fourth quadrant, the value of back emf generated by the motor is greater than the supplied voltage which is forward braking and reverse braking modes of operation respectively, here also the direction of current flow is reversed.

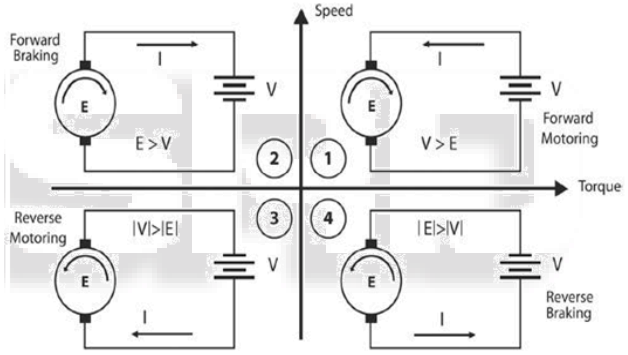

Fig. 1: Operating Modes

III. COMPLETE DRIVE SYSTEM

The digital pulse width modulation control of BLDC motor will be efficient and cost effective. The digital control of the four quadrant operation of the three phase BLDC motor is achieved with microcontroller. The digital controller combines the digital signal processor features and PIC microcontroller features, making it versatile. The required duty cycle and the reference speed can be fed into the controller.

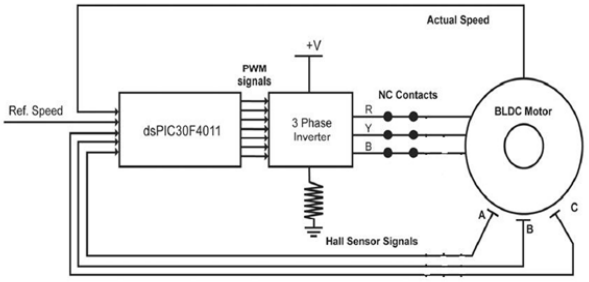

Fig. 2: Close Loop Drive

The schematic diagram of the drive arrangement of

the three phase BLDC motor is shown in Fig.2. BLDC motor is a brushless motor it do not use brushes for the commutation. So that the commutation is performed electronically by using an array of switching devices based on the rotor position information and the rotor position information is obtained from the Hall Effect sensors. Whenever the rotor magnetic poles pass near the Hall Effect sensors, indicating either North Pole or South Pole, the rotor position is sensed by the Hall Effect sensors which provides signal to the respective switches and according to that exact sequence of commutation is determined. These signal are decoded by combinational logic to provide the firing signals for 120^0 conduction on each of the three phases.

The hall sensor inputs which gives the position of rotor is fed to the microcontroller. The microcontroller compares it with the reference speed and generates an error signal. The PWM module of the controller generates appropriate PWM signals, which are applied to the three phase inverter at the appropriate time to trigger the appropriate switches. In three phase inverter circuit proposed matrix converter is used shown in Fig.2.in which switching devices have to be turn on and off in accordance with the switching algorithm table 1.

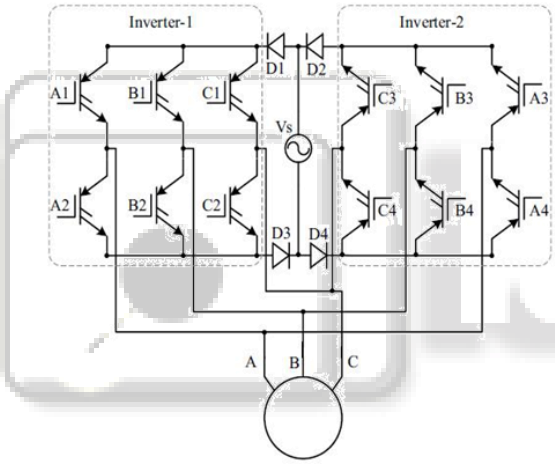

Fig. 3: Proposed Matrix Converter based BLDC motor Drive

Fig.3. consist of two single phase to three phase inverters. Inverter-1 comprised of switches A1, A2, B1, B2, C1 and C2. Inverter-2 comprised of switches A3, A4, B3, B4, C3 and C4. During the positive half cycle, power supplied to the load by inverter-1 and freewheeling path are provided by inverter-2. During negative half cycle, power Supplied to the load by inverter-2 and freewheeling path are provided by inverter-1. Reverse voltage applied to the switching devices can be avoided by applying the proper input voltage half cycle for selected inverter.

The precaution should be taken to operate the converter in safe mode to avoid the occurrence of high current due to supplying input voltage. In case of safe operating mode, don't turn on both switches at a time. Second precaution is to avoid the higher voltage, don't open circuited the output lines at a time. The matrix converter is the most popular and widely used converter topology in the family of direct converters.

The practical implementation of the four quadrant control of three phase BLDC motor based on advanced matrix switching will be developed. The hardware model consists of BLDC motor, MOSFET gate drive, power supply, Hall Effect sensor. The simulation model of the proposed matrix converter based on BLDC motor will be modeled using MATLAB and the simulation results will be analyzed.

Supply Voltage Vs	Hall Sensor Output	Switches in the main path	Switches in the freewheeling path
Positive	1 0 0	A1 C2	A4 C3
Positive	1 1 0	B1 C2	B4 C3
Positive	0 1 0	B1 A2	B4 A3
Positive	0 1 1	C1 A2	C4 A3
Positive	0 0 1	C1 B2	C4 B3
Positive	1 0 1	A1 B2	A4 B3
Negative	1 0 0	A4 C3	A1 C2
Negative	1 1 0	B4 C3	B1 C2
Negative	0 1 0	B4 A3	B2 A2
Negative	0 1 1	C4 A3	C1 A2
Negative	0 0 1	C4 B3	C1 B2
Negative	1 0 1	A4 B3	A1 B2

Table 1: Switching Algorithm for A Brushless DC Motor With Trapezoidal Back EMF

IV. CONCLUSION

The mentioned work is to make simple hardware circuit which is more reliable, more efficient, less noisy, excellent speed control and smooth transition between quadrants. If mentioned method is implemented in higher rating motors, arcing might occur during the switching on and off of the relay contacts. But If the mentioned method is implemented in low power motors like motors used in sewing/ embroidery machine, arcing will be very less which is not even visible.

In the above mentioned method four quadrant methods for BLDC motor is used, which is most useful method to detect the forward and reverse direction of motor. It is also useful method to run the motor without using brushes arrangement. So that without brush there is no need for commutation and no loss of power. By using the above mentioned method we must have to improve the performance of motor.

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