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FPGA based speed control of PMBLDC motor using SVPWM technique in fuzzy controller

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Abstract: The main aim of this paper is to control the speed of PMBLDC motor by implementing SVPWM technique in FPGA based Fuzzy controller.BLDC motors are electronically commutated. An electronic controller replaces the brush/commutators assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commentators' system. SVPWM techniques enjoy an assortment of advantages such as high output quality, less THD, low distortion and low rating of filter component. Also a current controlled technique for BLDC motor drives is used.Fuzzy logic controller enjoys the advantage of having low settling time ascompared to traditional controller and is simpler than latest complexcontrollers and speed control of PMBLDC motor is effective.The Spartan-3E family of Field-Programmable Gate Arrays (FPGAs) is specifically designed to meet the needs of high volume, cost-sensitive consumer electronic applications. The Spartan-3E family builds on the success of the earlier Spartan-3 family by increasing the amount of logic per I/O significantly reducing the cost per logic cell. New features improve system performance and reduce the cost of configuration.

I. INTRODUCTION

Brushless DC motors are small size, less noise, faster, more reliable, efficient and have ease of control of operation. BLDC motor drives are widely used in industrial traction applications. BLDC motors are used in electric vehicles, embroidery machines, aerospace, medical equipments, industrial applications etc.

BLDC motor has permanent magnet rotor and stator with windings. The windings are then connected to control electronics because of the absence of brushes and commutators. The control circuit energizes the appropriate winding [1]. The BLDC motors are driven by rectangular or trapezoidal voltage strokes coupled with the given position of the rotor. For sensing the actual position of rotor, we use either external or internal position sensors. Hall sensors are widely used for detection of rotor position [2]. Brushless DC motor controlling with digital control strategy for four quadrant operation are more advantageous when comparing with other motors of this range. Fuzzy control is used for improvement of overall performance of the BLDC motor.

The brushes which controls the commutation by physically connecting the coils at the correct moment in a universal motor, but in BLDC motor, the commutation is controlled by electronics. The control electronics have either position sensor inputs that gives information about when to commutate or use the back emf generated in coils.

BLDC motors are driven by DC voltage, the current commutation is controlled by solid state switches where electronic commutation takes place. We use hall effect sensors, which provides signals to the respective switches. We must know the rotor position of brushless DC motor before starting so, combining the three hall sensor signals, we can determine the exact sequence of commutation [3]. Cross sectional view of brushless DC motor is shown in fig.1.

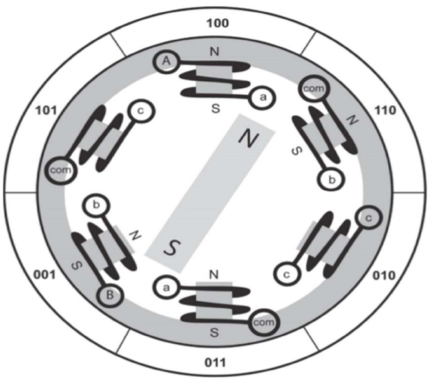

Fig. 1 Cross sectional view of BLDC motor

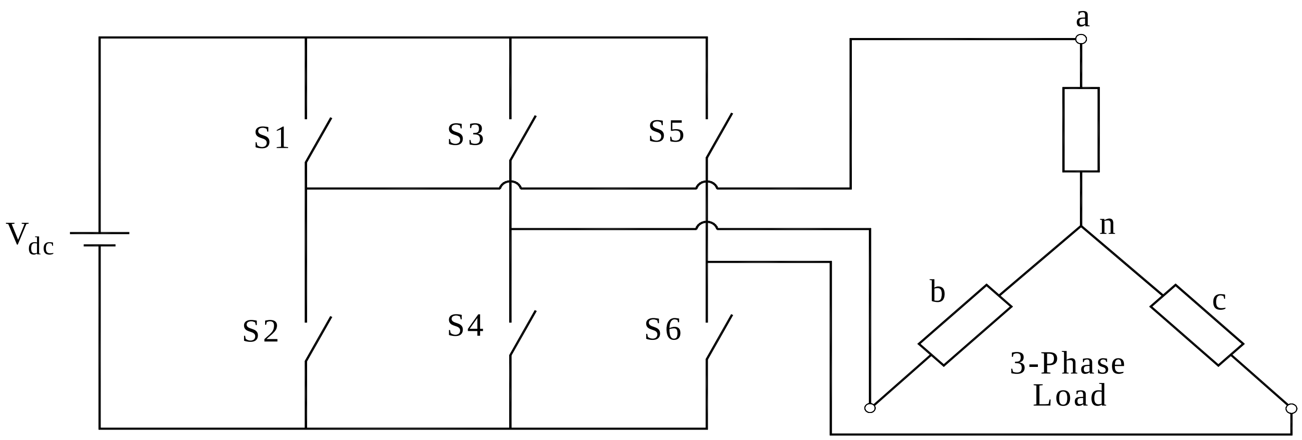

Fig. 2 Power Circuit topology of a three-phase VSI.

The confusion arises because a brushless dc motor does not directly operate of a dc voltage source A PMBLDC motor has a rotor with permanent magnets and a stator with windings. It is essentially a dc motor turned inside out. The brushes and commutator have been eliminated and the windings are connected to the control electronics. The control electronics replace the function of the commutator and energize the proper winding [4]. PMBLDC motor has trapezoidal back EMF and quasi-rectangular current waveform. BLDC motors are rapidly becoming popular in industries such as appliances, HVAC industry military equipments, hard disk drive, and Electric traction because of their high efficiency, high power factor, silent operation, compact, reliability and low maintenance.

SVPWM techniques enjoy an assortment of advantages such as high output quality, less THD, low distortion and low rating of filter component [5]. Also a current controlled technique for BLDC motor drives is used.Sinusoidal PWM has been commonly used as popular PWM technique in many Power Electronics Applications, especially in AC motor control like V/F control of AC induction motor. SV-PWM utilise the available DC bus voltage by 15% more than sine PWM. It will be shown that SV-PWM can directly transform the stator voltage vectors from α-β Co-ordinate system to pulse width modulation signals.

A single phase vector (the desired reference vector) is resolved onto α-β co-ordinate and used for generating the PWM signals. Hence there is no error from the input stage [6]. In case of sine PWM, 3 separate sine waves are compared with triangular carrier to generate the PWM signals. If there is an error in the three input sine waves, then the inverter output waveforms will not be balanced. In this case, the SV-PWM has become advantageous.In a sinusoidal PWM, 3 separate sine modulating waveforms are generated and compared individually with a triangular carrier waveform to produce pulses for driving the inverter switches. Hence each pulse is treated individually. This method will not make full use of the inverters DC supply voltage [7]. The asymmetrical nature of this sine PWM produces high harmonics distortion in the supply.

A three phase voltage source inverter (VSI) contains six switching blocks. Each block consists of a semiconductor switch such as a MOSFET or IGBT and an anti-parallel diode. Ideally a bidirectional voltage/current switch with lower total losses at higher switching frequencies is desired. Most common switches used in switching power supplies are IGBTs and MOSFETs which have similar characteristics. Three phase VSIs are used to interface between dc and ac systems in distributed power generation system. Different control techniques have been applied to the three phase grid connected VSI for the control of active and reactive power along with constant dc link voltage [8]. However, designing a controller with help of a small signal model is a well-known practice in dc-dc converter. Transfer functions of the control variables need to be identified for designing a control system. The transfer functions are deduced using averaged switched modeling technique. In modern days power electronics converters are widely employed in all the applications. As the switches are involved in these applications, non-linearity occurs in the system. So the power stage must be linearized in order to design a linear feed-back control. In this work a three phase grid connected VSI with LC filter has been considered for modeling. As it is quite difficult to design a controller in case of three phase ac system, so first three phase ac system (abc) is transformed into synchronous rotating reference frame (dq) and the transformation is known as Park's transformation. The resulting model from the corresponding transformation is known as large signal model which involves dc quantities due to the transformation to the rotating reference frame.
Table 1. Switching ON and OFF sequence in VSI

Space Voltage Vector	State	Conduction of IGBTs	
		On	Off
V0	0 0 0	$S_2\ S_3\ S_6$	$S_1\ S_3\ S_5$
V1	1 0 0	$S_1\ S_3\ S_6$	$S_3\ S_2\ S_5$
V2	0 1 1	$S_1\ S_3\ S_6$	$S_5\ S_2\ S_3$
V3	0 1 0	$S_2\ S_3\ S_6$	$S_1\ S_5\ S_3$
V3	1 1 0	$S_2\ S_3\ S_5$	$S_1\ S_3\ S_6$
V5	1 0 0	$S_2\ S_3\ S_5$	$S_1\ S_3\ S_6$
V6	1 0 1	$S_1\ S_3\ S_5$	$S_2\ S_3\ S_6$
V7	1 1 1	$S_1\ S_3\ S_5$	$S_2\ S_3\ S_6$

Fuzzy control is based on fuzzy logic-a logical system that is much closer in spirit to human thinking and natural language than traditional logical systems. During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input- output relations. The fuzzy logic controller (FLC) based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy [9]. Fuzzy Logic controller has better stability, small overshoot, and fast response.

The Fuzzy Logic tool was introduced by Lotfi Zadeh (1965), and is a mathematical tool for dealing with uncertainty. It offers to a soft computing partnership the important concept of computing with words. It provides a technique to deal with imprecision. The fuzzy theory provides a mechanism for representing linguistic constructs such as "many," "low," "medium," "often," "few." In general, the fuzzy logic provides an inference structure that enables appropriate human reasoning capabilities. Fuzzy logic systems are suitable for approximate reasoning. Fuzzy logic systems have faster and smoother response than conventional systems and control complexity is less [10]. The basic building block of a fuzzy inference system is shown in figure.

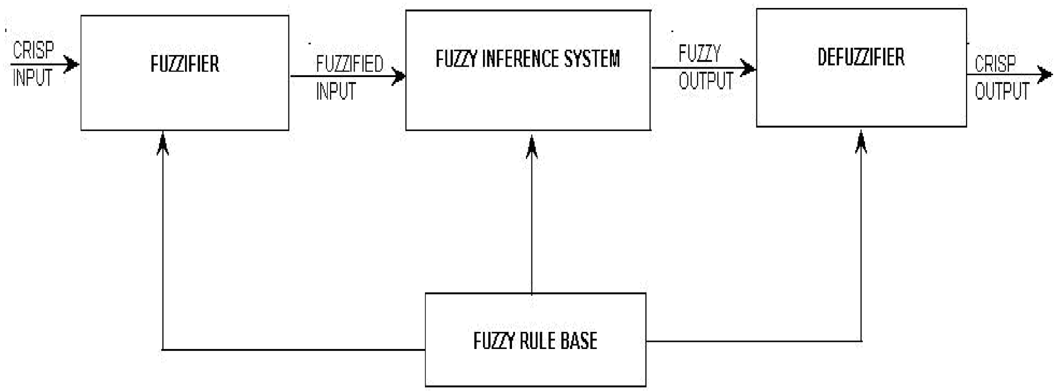

Fig. 3 Block diagram of a fuzzy inference system.

II. BLOCK DIAGRAM

2.1. Power supply

Most of the electronic equipment's and devices require a DC source for their operation. We can get this DC power from the storage batteries. But they are costly and require frequent maintenance and replacement. The easily available power is AC.

2.2. Transformer

The action of a transformer is such that a time-varying (AC) voltage or current is transformed to a higher or lower value, as set by the transformer turns ratio. The transformer does not add power, so it follows that the power (V × I) on either side must be constant. That is the reason that the winding with more turns has higher voltage but lower current, while the winding with less turns has lower voltage but higher current. The step down transformer converts the AC input with the higher level to some lower level.

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2.3. Bridge rectifier

A bridge rectifier converts the AC voltage into DC voltage. A four – transistor converter (Bridge Rectifier) that can generate the highest output power than other types of rectifiers.

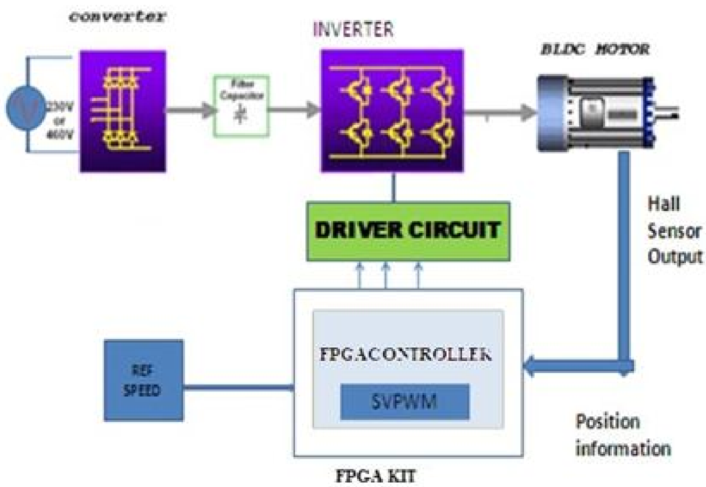

Fig. 4 Block diagram of the proposed scheme

2.4. Filter

The function of this circuit is to remove the fluctuations or pulsations (called ripples) present in the output voltage supplied by the rectifier. Of course, no filter can, in practice, give an output voltage as ripple-free as that of a DC battery but it approaches it so closely that the power supply performs as well.

2.5. Regulator

The regulator down-convert a DC voltage to a lower DC voltage of the same polarity. Its main function is to keep the terminal voltage of the DC supply constant even when

1. AC input voltage to the transformer varies (deviation from 220V are common).
2. The load varies

2.6. Inverter

Inverter is convert to dc supply into ac supply. here, six pulse IGBT based inverter is connected to the BLDC motor.

2.7. Sensor

` Hall effect sensor is used to sense the position from BLDC motor. The feedback signal is applied to the FPGA controller.

III. HARDWARE DISCRIPTION

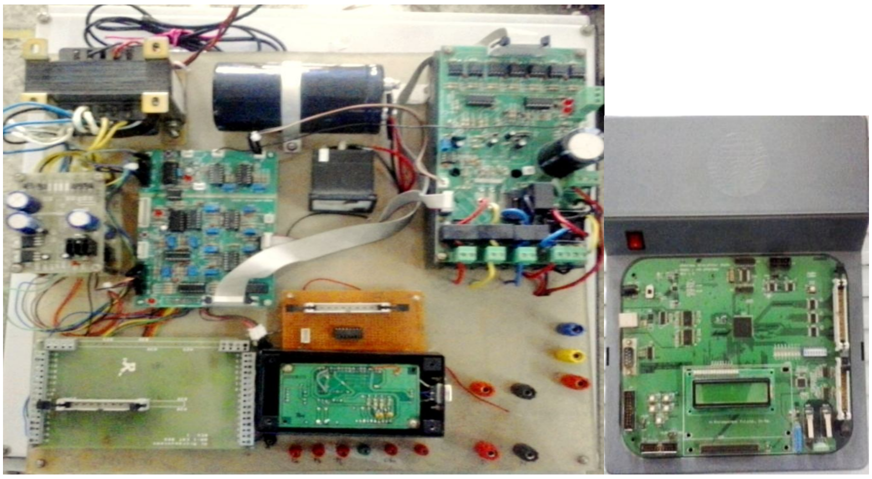

Fig. 5 Hardware is FPGA based speed control of PMBLDC motor using SVPWM technique in fuzzy controller

In FPGA based BLDC motor speed control high efficiency compared to DSP based speed control technique. Three phase ac supply is connected to the converter bridge. here acsupply is convert into dc supply by using a converter. The parallel connected capacitor is used to reduce the ripple carry error signal. The dc output voltage is connected to the inverter .It is used to convert the dc to ac voltage. FPGA kit is connected to the driver circuit. LCD display is used to shown thecontrol the motor speed value. The output voltage settling time value should be minimized by using this hardware.

IV. CONCLUSION

This paper has presented the speed control of PMBLDC with implementation of SVPWM technique in Fuzzy controller which reduces the harmonics induced by power electronics devices present in driver circuit and reduces the settling time. In future implementation, we may add neural network or advanced techniques in contemporary time period to attain desired speed as set by user in a very short period of time. This me increase the coding and cost of project but it may be very useful in industries and applications that require precise speed levels of PMBLDC motor.

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