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Practical Implementation Of Four Quadrant Operation Of Three Phase Bldc Motor With Different Loads

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Abstract: **Brush Less Direct Current (BLDC) motors are attaining higher priority in industrial automation, computers, aerospace, military, household appliance and traction applications because of its high efficiency, high power density and low maintenance cost. This makes the control of BLDC motor in all the four quadrants very vital. To control a BLDC machine, it is generally required to measure the speed and position of rotor by using the sensor. Using the measured value of rotor position, each inverter phase acting at precise time will be commutated. This paper deals with the digital control of three phase BLDC motor in all four quadrant operation. The motor is controlled in all the four quadrants without any loss of power; in fact energy is conserved during the regenerative period. This energy is stored in a battery storage system during regenerative period and can be fed back to the inverter mains during shortage of supply from the source. The FPGA controller is implemented which is more advantageous over other conventional controllers as it is computationally intensive, highly parallelizable tasks, best in class accuracy, reliability and maintenance. A PI controller in closed loop configuration is used for speed control. The torque ripple in each quadrant operation is also reduced using a closed loop operation with the aid of a low pass filter. The operation modes of the proposed system are simulated using MATLAB and results are validated.**

Keywords: **BLDC motor; FPGA; PI Controller; and Regenerative breaking;**

I. INTRODUCTION

Brushless DC motor has the following features such as simple in construction, high reliability, and high power density, light electromagnetic pollution, less noisy, potentially cleaner and faster. It is used extensively in servo motors and low power drive systems. BLDC motor uses three or more hall sensors to obtain rotor position and speed measurements. It is normally a DC motor. It has rotor and stator windings. It consists of rotor with permanent magnet and a stator with windings. . The brushes and commutator have been eliminated and the windings are connected to the control electronics. The commutator is replaced by control electronics and it energizes the proper winding. The BLDC motor is easier to start and stop due to less inertia. The Brushless DC motor is driven by rectangular or trapezoidal voltage strokes coupled with the given rotor position. In order to get the maximum developed torque the voltage strokes must be aligned properly between the phases, so that the angle between the stator flux and the rotor flux is kept close to 90º. BLDC motors often incorporate either internal or external position sensors to sense the actual rotor position or its position can also be detected without sensors. BLDC motors are used in Automotive, Aerospace, Consumer, Medical, Industrial Automation equipments and instrumentation. The PI and the PID controller have been widely used as a control method of servo driving in industrial control fields. A driving specific property can be estimated well, once a control constant is properly set. But the control constant should be changed in order to maintain an optimum driving state if the driving point or the motor parameters are changed. Recently the fuzzy controller has appeared which is based on knowledge or an experience of expert rather than on a complicate mathematical modeling. The fuzzy controller works well using experimental information even if not having mathematical modeling. Moreover, the fuzzy controller is capable of real time control using fuzzy rule base.

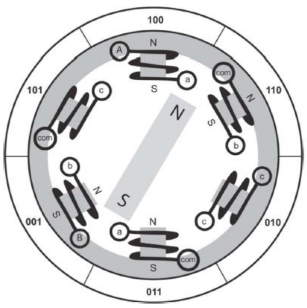

Fig.1.1. BLDC Motor Star connected.

II. METHODOLOGY

Brushless DC motor is also known as electronically commutated motor are synchronous motor that are powered by DC electric source via integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. Brushless DC Motor is shown in fig. By using solid state switches current commutation can be controlled. The rotor position determines the commutation instants. The Hall Effect sensor is used to find the rotor shaft position which provides corresponding signals to the respective switches. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating either N or S pole is passing near the sensors. The numbers shown around the peripheral of the motor diagram in Fig. represent the sensor position code. The north pole of the rotor points to the code that is output at that rotor position. The numbers are sensor logic levels where the Most Significant bit is sensor C and the Least Significant bit is sensor A. The exact sequence of commutation can be determined by proper signals obtained from the hall sensors. These signals are decoded by combinational logic to provide the firing signals for 120° conduction on each of the three phases. BLDC motor operates in all four quadrants without loss of power. There are four modes of operation namely forward and reverse motoring, forward and reverse braking as shown in Fig. BLDC motor performs motoring and generating modes. It is said to be V-I characteristics or speed-torque characteristics of BLDC motor. In first and third quadrant it acts as a motor and in second and third quadrant it acts as a generator. If the applied voltage is greater than the back emf which is forward motoring and reverse motoring modes respectively, but the direction of current flow differs. If the back emf generated by the motor should be greater than the applied voltage which is said to be the forward braking and reverse braking modes of operation respectively, here also the direction of current flow is reversed. Normally BLDC motor is made to rotate in clockwise direction, if the speed reversal command is obtained; the control goes to anticlockwise mode that is regeneration mode which brings the rotor to the standstill position. In this position continuous energisation of the main phase is attempted. By using Hall Effect sensors the position of the rotor can be determined. From this outputs the direction of the machine is determined whether the machine has reversed its direction. At this moment the stator phase is energized so that the machine can start motoring operation in counter clockwise direction. In motoring mode electrical energy is converted in to mechanical energy and in regenerative mode motor acts as a generator so that the mechanical energy is converted in to electrical energy. The wasted energy is again converted into useful energy and it can be stored in batteries.

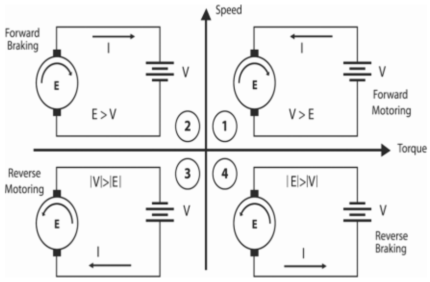

Fig.2.1. Four Quadrants of operation Modes.

III. AN OVERVIEW OF PROPOSED SYSTEM

Four quadrant Zero current transition converter was implemented for DC motor and single controllable switch for four quadrant operation was implemented. The common regenerative braking methods include adding an extra converter, or adding an extra ultra capacitor, or switching sequence change of power switches. But the method of adding a converter not only increases cost but also reduces conversion efficiency. The method of adding an ultra-capacitor doesn't require extra DC-DC converter, but it needs a sensor to detect the ultra-capacitor voltage. This makes the circuit very complex and hard to implement. Moreover ultra capacitor is very expensive. The method proposed in this paper is simple and reliable. It conserves energy in a rechargeable battery during the regenerative braking mode. Relay circuits are employed to run the motor during the accelerating mode and charge the battery during the regenerative mode. The position signals obtained from the Hall sensors of the motor are read by the I/O lines of the dsPIC controller. The Hall sensor inputs give the position of the rotor which is fed to the controller. The controller compares it with the reference speed and generates an error signal. The required direction of rotation either clockwise or counter clockwise can also be fed to the digital controller. The PWM module of the controller generates appropriate PWM signals, which are applied to the three phase inverter. Whenever there is a reversal of direction of rotation it implies there is a change in the quadrant. When the motor is operating in the motoring mode, in the clockwise direction, the relay contacts are normally open. But when braking is applied or when a speed reversal command is received, the relay contacts are closed. The kinetic energy which will be wasted as heat energy is now converted into electric energy which is rectified and stored in a chargeable battery. The braking energy can be given back to the power source. But it increases the complexity of the circuit, the DC power generated has to be inverted to be given back to the mains.

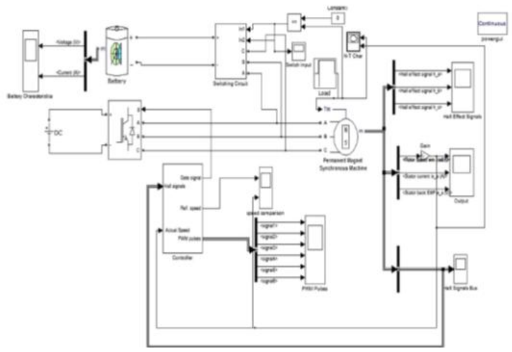

Fig.3.1. Proposed System.

IV. CONCLUSION

A modular design is described for both the inverter and the permanent magnet BLDC motor and a control scheme is proposed for the modular brushless dc motor drive for changing its direction instantaneously. The transition from clockwise to counter clockwise rotation of the motor is too quick. In the regenerative mode of operation, the generated voltage is fed back to the supply, so that there will be a saving of power. The modular design of the inverter and the BLDC motor is very advantageous and economical as the power rating of the drive can be changed by removing or adding the inverter and motor modules. The effect of PWM strategies and the results can be achieved by the variation of Proportional and Integral constants of the PI controller. For best results, Tuning process is done by trial and error method and the Proportional Constant and Integral Constant are 0.1 and 0.03 respectively. The simulation results have shown that the four quadrant operation of BLDC motor drive employing modular design is well suited for applications such as hybrid electric vehicles, traction system. The advantages of this proposed project is reliability of controlling techniques, superior performance in speed control, efficient conservation of energy on load and no load conditions, quicker and smooth transition from braking to motoring and vice-versa. The disadvantage of this model is arcing might occur when a proto type model is designed for higher rating motors, and if the motor rating is small, this is not a serious issue and hence, can be negligible.

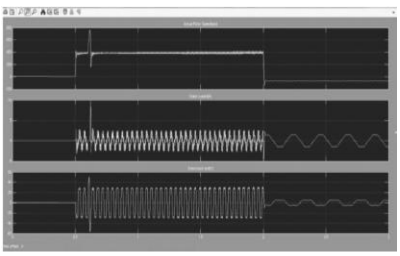

Fig.4.1. Output of Simulink model Rotor speed(rpm).

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