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Four quadrant operation of BLDC motor

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Abstract

This paper presents the practical implementation of the control of three phases Brushless DC (BLDC) motor in all the four quadrants. This paper presents a concept wherein the kinetic energy is converted and stored in a battery. The battery thus charged can be used to run the same BLDC motor with no interruption in power supply. The digital controller dsPIC30F4011, which is very advantageous over other controllers, is used to achieve precise control.

The frequent change of direction of rotation and hence the change of quadrants results in frequent braking. During braking time the kinetic energy is wasted as heat energy. This paper presents a concept wherein the kinetic energy is converted and stored in a battery. The battery thus charged can be used to run the same BLDC motor with no interruption in power supply.

Keywords: BLDC motor, dsPIC30F4011, regenerative braking, four quadrant operation

1. Introduction

Brushless direct current motors (BLDC) are one of the advance motors used which are rapidly increasing their popularity and applications. BLDC motor has rotor with permanent magnets and stator with stacked steel laminations with windings inserted in slots. The motor has less inertia, therefore easier to start and stop. BLDC motors are potentially cleaner, faster, more efficient, less noisy and more reliable.

In the brushless DC motor, polarity reversal is performed by power transistors switching in synchronization with the rotor position. Therefore, 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 Equipment and Instrumentation.

2. Block Diagram

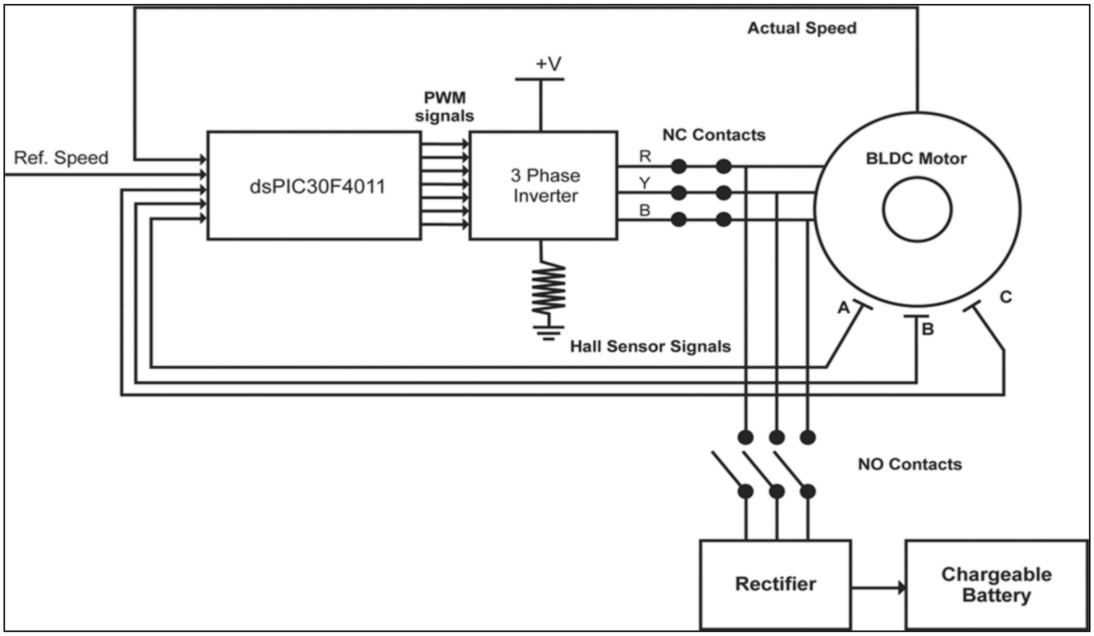

Fig 1: Proposed block diagram.

3. Digital control

The four quadrant control of three phase BLDC motor is achieved with dsPIC30F4011.The position signals from the three Hall sensors are read through the I/O lines. All I/O\ ports feature Schmitt trigger inputs for improved noise immunity. The input capture modules are useful for the modes such as frequency / pulse measurements and as additional sources of external interrupts.

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 dsPIC30F4011. This digital controller combines the Digital Signal Processor features and PIC microcontroller features, making it versatile.

3.1 Complete drive system

The schematic diagram of the drive arrangement of the three phase BLDC motor is shown in Fig. 1. The position signals obtained from the hall sensors of the motor are read by the I/O lines of the dsPIC controller. The PWM module of the controller generates appropriate PWM signals, which are applied to the three phase inverter. 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 controller has a modified Harvard architecture, with a 16×16 bit working register array. It has two 40 bit wide accumulators. All the DSP instructions are performed in a single cycle. The three external interrupt sources, with eight user selectable priority levels for each interrupt source helps to get the Hall sensor inputs from the motor. The reference speed and the required duty cycle can be fed into the controller. The closed loop control is achieved with the PI controller. This digital controller combines the Digital Signal Processor features and PIC microcontroller features, making it versatile.

4. Four quadrant operation

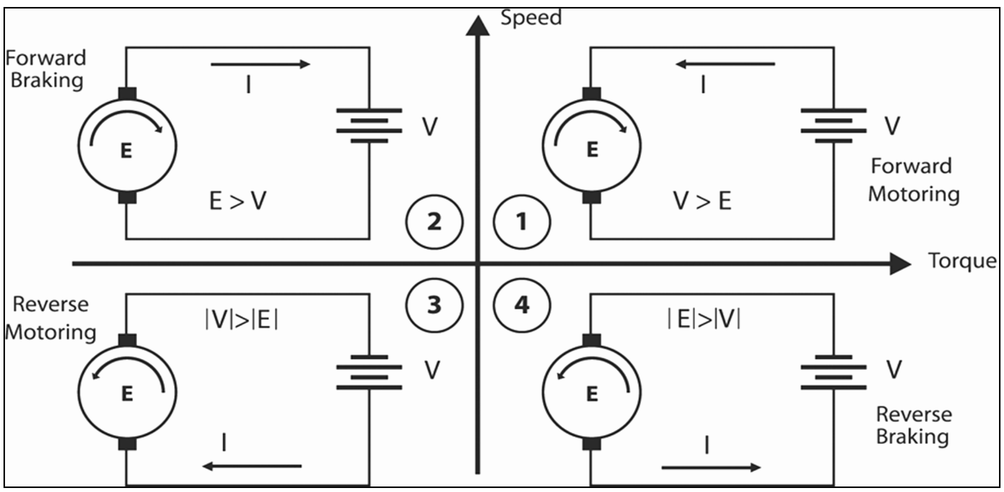

Fig 2: Operation in Four quadrants

There are four possible modes or quadrants of operation using a Brushless DC Motor which is depicted in Fig. 2. When BLDC motor is operating in the first and third quadrant, the supplied voltage is greater than the back emf which is forward motoring and reverse motoring modes respectively, but the direction of current flow differs. When the motor operates in the second and fourth quadrant the value of the back emf generated by the motor should be greater than the supplied voltage which are the forward braking and reverse braking modes of operation respectively, here again the direction of current flow is reversed.

The BLDC motor is initially made to rotate in clockwise direction, but when the speed reversal command is obtained, the control goes into the clockwise regeneration mode, which brings the rotor to the standstill position. Instead of waiting for the absolute standstill position, continuous energization of the main phase is attempted. This rapidly slows down the rotor to a standstill position. Therefore, there is the necessity for determining the instant when the rotor of the machine is ideally positioned for reversal. Hall Effect sensors are used to ascertain the rotor position and from the Hall sensor outputs, it is determined whether the machine has reversed its direction. This is the ideal moment for energizing the stator phase so that the machine can start motoring in the counter clockwise direction.

5. Results & Discussion

The significant advantages of the proposed work are: simple hardware circuit, reliability of the control algorithm, excellent speed control, smooth transition between the quadrants and efficient conservation of energy is achieved with and without load conditions. The designed and implemented prototype model may be implemented even for higher rated motors. Arcing might occur during the switching on and off of the relay contacts, when implemented in higher rating motors. But if the proposed method is implemented in low power motors, like motor used in sewing/embroidery machines, arcing will be very less which is not even visible. This concept can be well utilized in the rotation of spindles, embroidery machines and electric vehicles where there is frequent reversal of direction of rotation of the motor.

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