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Fuzzy logic Control of BLDC Motor for four Quadrant Operation

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Abstract— This project proposes the four quadrant operation of BLDC Motor with FUZZY Logic controller. During Braking operation time the energy is stored in a battery by regenerative braking. The speed control is achieved by using FUZZY controller. The controllers have the advantage over conventionally used P & PI controller. It eliminates the disadvantages such as nonlinearity load disturbance and load parameter variations. Moreover P & PI controller precise linear mathematical models. FUZZY Logic controller achieves improved dynamic behavior of the motor drives system due to load variation and parameter variation. FUZZY Logic control offers improvement in the quality of the speed responses. The simulation will be done for both FUZZY, and PI controller using MATLAB SIMULINK software and hardware is for implementation of FUZZY controller with BLDC motor.

Keywords- BLDC motor. DsPIC, fuzzy logic control, four quadrants, regenerative braking.

I. INTRODUCTION

A typical brushless motor has permanent magnets which rotate and a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutation 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/commutation system.

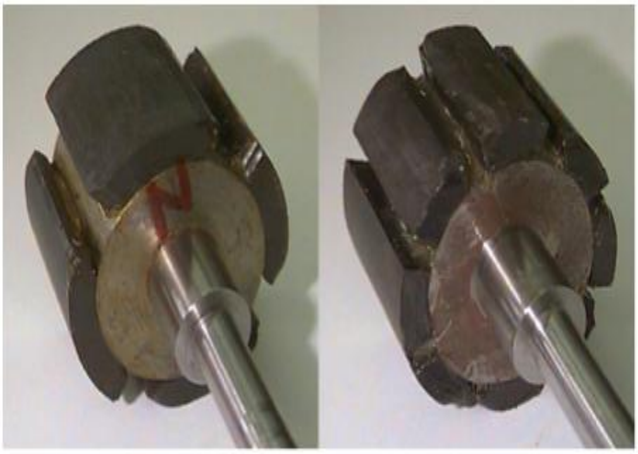

Fig 1 BLDC Motor Rotor Position

The motor has less inertia, therefore easier to start and stop. BLDC motor is potentially cleaner and faster, more efficient, less noisy and more reliable. The Brushless DC motor is driven by rectangular or trapezoidal voltage strokes coupled with the given rotor position. The voltage strokes must be properly aligned between the phases, so that the angle between the stator and rotor flux is kept close to 90 to get the maximum developed torque. BLDC motors are used in Automotive, Aerospace,

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Consumer, Medical, Industrial automation equipments and instrumentation. This paper is organized as describes the four quadrant operation of three phase BLDC motor, its features; the controller is explained in Section.

HALL EFFECT ROTOR POSITION SENSOR

The most commonly used sensors are hall sensors and optical encoders. Hall sensors work on the hall-effect principle that when a current-carrying conductor is exposed to the magnetic field, charge carriers experience a force based on the voltage developed across the two sides of the conductor. If the direction of the magnetic field is reversed, the voltage developed will reverse as well. For Hall-effect sensors used in BLDC motors, whenever rotor magnetic poles (N or S) pass near the hall sensor, they generate a HIGH or LOW level. signal, which can be used to determine the position of the shaft. The Hall element is constructed from a thin sheet of conductive material with output connections perpendicular to the direction of current flow. When subjected to a magnetic field, it responds with an output voltage proportional to the magnetic field strength. The voltage output is very small (μV) and requires additional electronics to achieve useful voltage levels. When the Hall element is combined with the associated electronics, it forms a Hall effect sensor. The heart of every micro switch Hall effect device is the integrated circuit chip that contains the Hall element and the signal conditioning electronics. Although the Hall effect sensor is a magnetic field sensor, it can be used as the principle component in many other types of sensing devices (current, temperature, pressure, position, etc.). Hall effect sensors can be applied in many types of sensing devices. If the quantity (parameter) to be sensed incorporates or can incorporate a magnetic field, a Hall sensor will perform the task. It shows a block diagram of a sensing device that uses the Hall effect. In this generalized sensing device, the Hall sensor senses the field produced by the magnetic system. The magnetic system responds to the physical quantity to be sensed (temperature, pressure, position, etc.) through the input interface. The output interface converts the electrical signal from the Hall sensor to a signal that meets the requirements of the application.

II. FOUR QUADRANT OPERATION OF BLDC MOTOR

There are four possible modes or quadrants of operation using a Brushless DC Motor which is depicted .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 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. In regenerative braking, instead of wasting the power in external resistance the power generated during retardation is fed back towards the source i.e., the motor works as a generator developing a negative torque which opposes the motion and the generated energy is supplied to the source. For the generated energy to be supplied to the source two conditions should be satisfied. Back emf should be greater than supply voltage ($E > V$) for all speeds current has to reverse its direction For the above two conditions to be satisfied, increase the back emf so that it is greater than the supply voltage. In order to increase the back emf, increase the speed. The speed increases when the locomotive is moving down the gradient or by increasing the field flux. But increasing the field flux beyond rated is not possible as the permanent magnets are used in field system. So, for a source of fixed voltage of rated value regenerative braking is possible only for speeds higher than rated value and for a variable voltage source it is possible for below rated speeds also. During regeneration if the generated power is not absorbed by the load, it will be supplied to the

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line and the line voltage will rise to dangerous values leading to insulation break down. Hence regenerative braking should be used.

III. PROPOSED CONTROLLER

A. DSP CONTROLLER

The controller has a modified Hardware architecture, with a 16×16 bit register working 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 sources. The reference speed and the required duty cycle can be fed to the controller. The closed loop control is achieved using fuzzy logic controller.

B. FUZZY LOGIC CONTROLLER

The disadvantage of PI controller is its inability to react to abrupt changes in the error signal, ε, because it is only capable of determining the instantaneous value of the error signal without considering the change of the rise and fall of the error, which in mathematical terms is the derivative of the error denoted as Δε. To solve this problem, Fuzzy logic control is used.

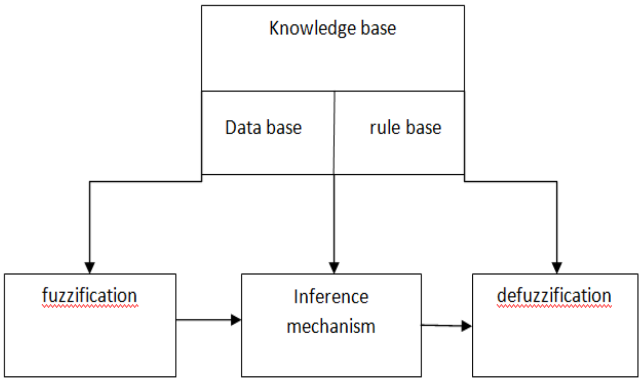

Fig 3 Fuzzy Logic Controller Structure

The determination of the output control signal, is done in an inference engine with a rule base having if-then rules in the form of ―IF ε is…..AND Δε is…..THEN output is……‖ With the rule base the value of output is changed according to the value of error signal, the rate of change of error. The structure and determination of rule base is done using trial and error method.

PWM MODULE

The PWM module simplifies the task of generating multiple synchronized Pulse width modulation (PWM) outputs. It has six PWM I/O pins with three duty cycle generators. The three PWM duty cycle registers are double buffered to allow glitch less updates of PWM outputs. For each duty cycle, there is a duty cycle register that will be accessible by the user while the second duty cycle registers holds the actual compared value used in the present PWM period. The output compare module generates an interrupt to trigger the relay circuit during regenerative mode.

IV. SIMULINK MODEL

The Simulink model of the BLDC motor. The closed loop controller for a three phase sensor less BLDC motor is modified using MATLAB/Simulink The fuzzy controller receives the signal as its input, converts it to appropriate voltage signls.The gate signals are generated by comparing actual speed with reference speed. Thus a closed loop speed control is achieved with the help of fuzzy controller. The simulation results are shown in fig. indicates that, when a negative torque is applied

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at a time 0.6s, there is a peak overshoot in the actual speed, which means it aids the motor to run. At other times the speed is stabilized with reference speed. The reference speed is 3500 rpm.

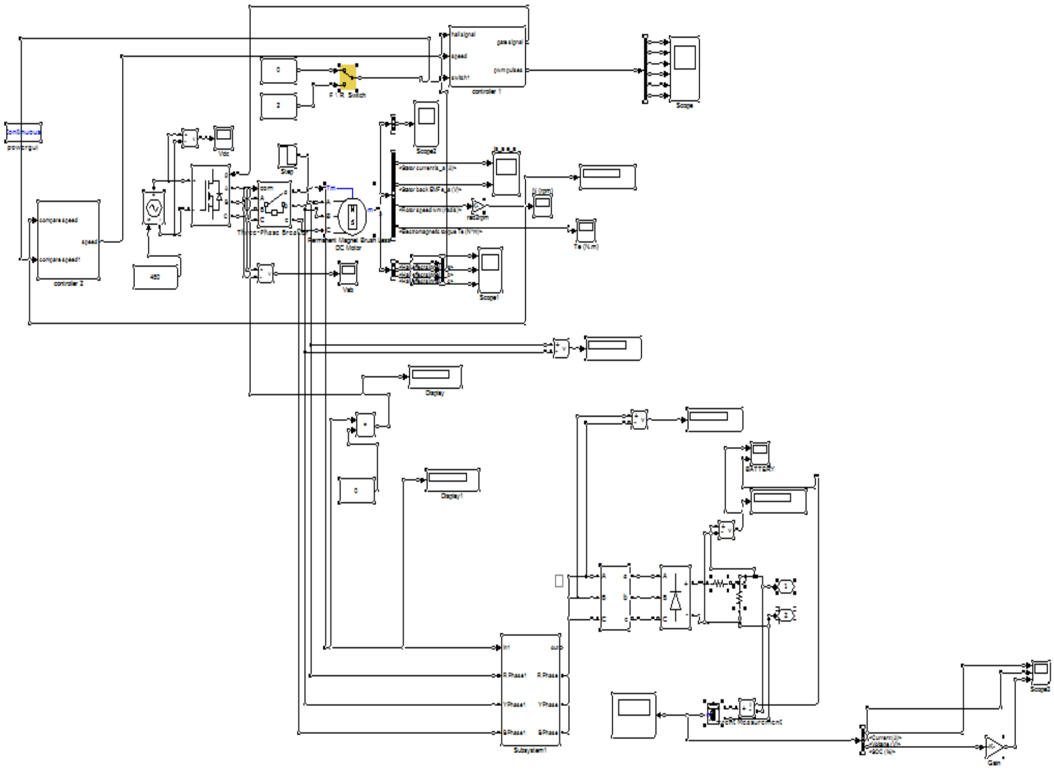

Fig 4 Simulation

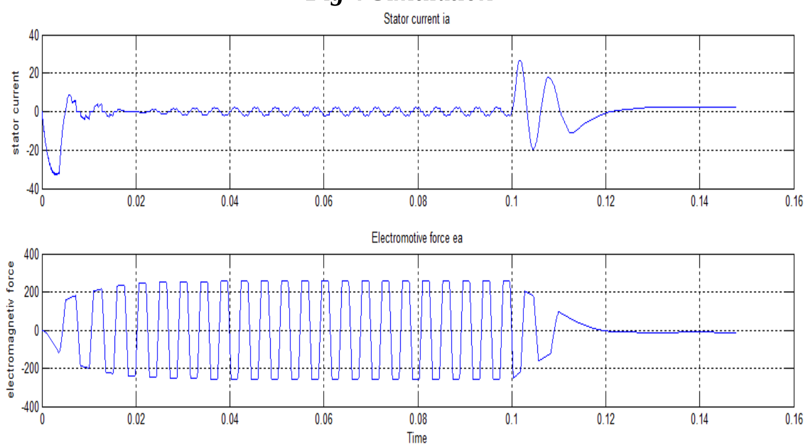

Fig 5 Stator current and Back EMF

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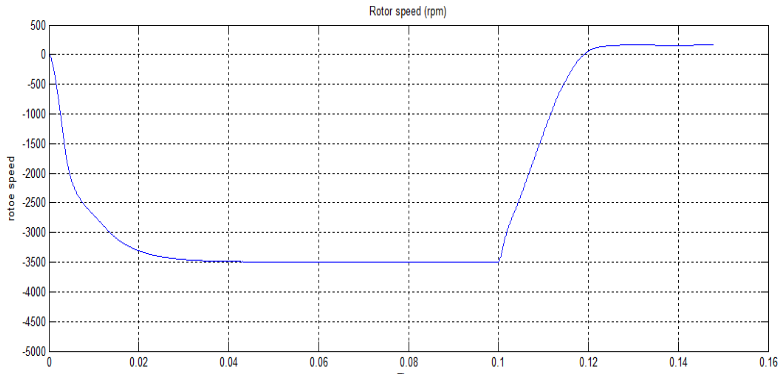

Fig 6 Reverse motoring speed (N)

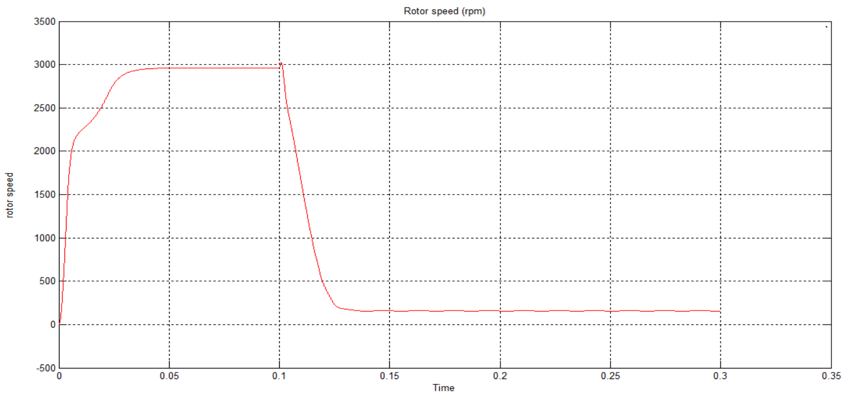

Fig 7 Forward motoring speed (N)

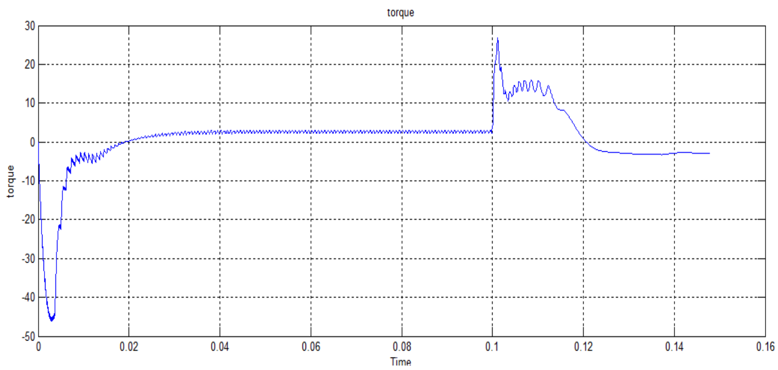

Fig 8Torque waveform

III. CONCLUSIONS

A control scheme is proposed for BLDC motor to change the direction from CW to CCW and the speed control is achieved both for servo response and regulator response. The motor reverses its direction almost instantaneously, it will pass through zero, but the transition is too quick. The time taken to achieve this braking is comparatively less. The generated voltage during the regenerative mode can be returned back to the supply mains which will result in considerable saving of power. This concept may well be 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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