International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 10 (November 2014) www.ijirae.com

EMBEDDED CONTROL OF BRUSHLESS DC MOTOR USING FUZZY LOGIC CONTROLLER

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ABSTRACT: ***Brushless DC(1) (BLDC) motor drives are becoming more popular in industrial, traction applications(2). This makes the control of BLDC motor in all the four quadrants very vital. This paper deals with the digital control of three phase BLDC motor. The motor is controlled in all the four quadrants without any loss of power; in fact energy is conserved during the regenerative(3) period. The digital controller dsPIC30F4011(4), which is very advantageous over other controllers, as it combines the calculation capability of Digital Signal Processor and controlling capability of PIC microcontroller(5), to achieve precise control.***

Keywords: Brushless DC, traction applications, regenerative, dsPIC30F4011, PIC microcontroller.

I. INTRODUCTION

Brushless DC 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. The motor has less inertia, therefore easier to start and stop. BLDC motors are potentially cleaner, faster,more efficient, less noisy andmore 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 flux and the rotor flux is kept close to 90 to get the maximum developed torque. 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.

I-1 FOUR QUADRANT OPERATION OF BLDC MOTOR

I-1.1 BLDC Motor:

Brushless DC Motors are driven by DC voltage but current commutation is controlled by solid state switches. The commutation instants are determined by the rotor position. The rotor shaft position is sensed by a Hall Effect sensor, which provides 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. 1 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 the sensor logic levels where the Most Significant bit is sensor C and the Least Significant bit is sensor A. Based on the combination of these three Hall sensor signals,the exact sequence of commutation can be determined. These signals are decoded by combinational logic to provide the firingsignals for 120 conduction on each of the three phases.

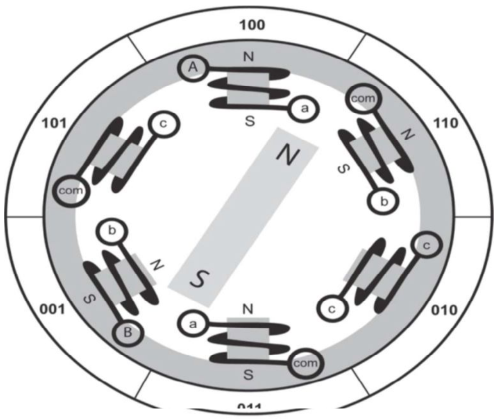

Figure 1: BLDC Motor Star connected.

I-2. Four Quadrant Operation

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 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.

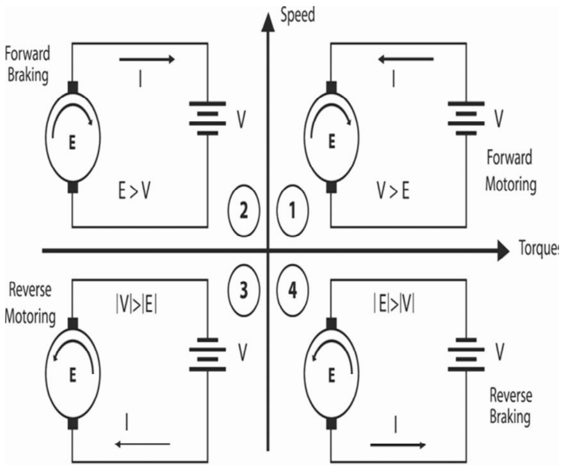

Figure 2: Operating Modes.

II. DIGITAL CONTROLLER

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. The controller has a modified Harvard architecture, with a16x16 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.

II-1 PI Controller

The regulation of speed is accomplished with PI Controller. By increasing the proportional gain of the speed controller, the controller's sensitivity is increased to have faster reaction for small speed regulation errors.

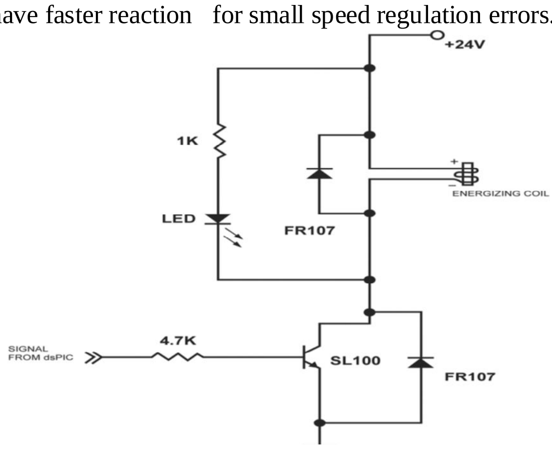

Figure 3:Relay Circuit

II-2 PWM Module

The PWM module simplifies the task of generating multiple synchronized Pulse Width Modulated (PWM) outputs. It has six PWMI/O pins with three duty cycle generators. The three PWM duty cycle registers are double buffered to allow glitches updates of the PWM outputs. For each duty cycle, there is a duty cycle register that will be accessible by the user while the second duty cycle register holds the actual compared value used in the present PWM period.

III. FUZZY LOGIC CONTROL

Microcontrollers have made using fuzzy logic control popular for last decade. Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity. Fuzzy logic and fuzzy control feature a relative simplification of a control methodology description. The fuzzy set theory has established itself as a new methodology for dealing with any sort of ambiguity and uncertainty.

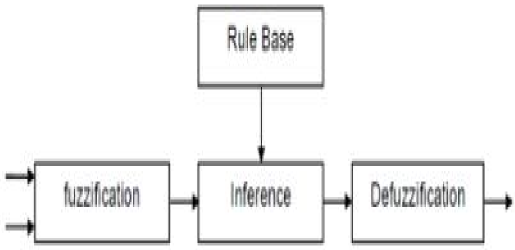

Figure 4: Fuzzy logic Control

IV- MATLAB-SIMULATION

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses includes

1. Math and computation
2. Algorithm development
3. Data acquisition
4. Modeling, simulation, and prototyping
5. Data analysis, exploration, and visualization
6. Scientific and engineering graphics
7. Application development, including graphical user interface building.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN.

V- SIMULATION MODEL

The first major part of the simulation model is the PV subsystem, which appears as a block with two inputs, irradiance in W/m2 and temperature in K as shown in Fig..The two outputs of the system are voltage and current. The PV model provides great facility by accepting a set of irradiance and temperature as inputs to modify the output. The subsystem contains the equations of the PV array parameters.

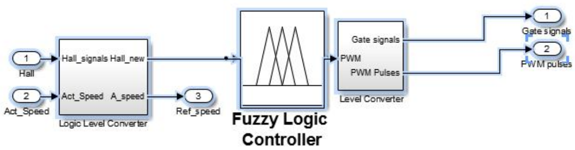

Figure 5: Fuzzy Tool based MATLAB applications

V-1: Output

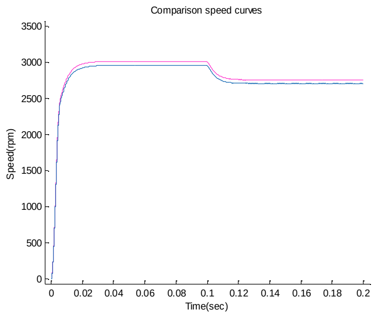

Figure 6:Graphs of reference and actual speed

V-2: FUZZY LOGIC CONTROL:

The fuzzy controller is basic part of fuzzy logic control which is composed of 3 parts: fuzzification s, inference engine and defuzzification. The inputs to a fuzzy logic controller are usually an error E and a change in error ΔE. These are created in the fuzzyfication stage.

$E(n) =(P(n) - P(n-1))/(V(n) - V(n-1))$

and

$\Delta E(n) = E(n) - E(n-1).$

VI- CONCLUSION

In this paper, 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.

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