# Speed Control of Radial Flux BLDC Motor by using Closed Loop Control for Electric Vehicle

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*Abstract*— BLDC Motor with high torque and wide speed range is the primary requirement for in-wheel electric vehicle application. Radial flux permanent magnet (RFPM) brushless direct current (BLDC) motors are the solution for electric vehicles, because of their shape, flexibility, compactness, robustness, high efficiency, wide speed range and high torque. In this paper, RFPM BLDC motor is proposed for wide range of speed conrtrol. It has single side configuration with 24 stator poles and 36 permanent magnets (PM) on rotor disc. In most of the applications of RFPMBLDC motor, the speed control is very important. To achieve accurate speed control, closed loop control using microcontroller is proposed in this paper. Microcontroller is used to drive the motor by sensing rotor position using Hall sensors. The effective braking scheme is also proposed. To verify the performance of the proposed RFPM BLDC motor, simulation is carried out and results are analysis. A prototype of RFPM BLDC motor is designed in order to validate the performance of the motor.

***Key words:*** Radial Flux Machine, BLDC Motor, Closed Loop Control, Electric Vehicle, Microcontroller, Permanent Magnet Motor

## I. INTRODUCTION

With every factory unit becoming computerized, mechanized and increasingly dependent on electric energy, motors with features such as space conservation, high efficiency and flexibility are being considered for commercial applications. As the hybrid drives entered the automobile industry, the demand for high efficiency also increased. This requirement is fulfilled by Radial flux permanent magnet (RFPM) brushless direct current (BLDC) motor. The research is directed much more seriously towards this field. The research is being done in the areas of design, control and thermal aspects etc. With the advent of technology, permanent magnet (PM) materials such as are cheaper as compare The research is directed much more seriously towards this field. The research is being done in the areas of design, control and thermal aspects etc. With the advent of technology, permanent magnet (PM) materials such as NdFeB are cheaper as compare to old materials and concepts as well as new applications has placed permanent magnet machines in a prominent position[1]. The inherent features of Radial flux BLDC, such as high efficiency, high compactness and wide operation speed range, make these machines suitable for direct drive applications [2].

In direct drive applications like electric vehicle, the direct coupling of the shafts of the machine and application gives compactness to the circuit. This compactness is also a reason of elimination of gearbox. Furthermore, PM machines have magnetized motor. Thus, the PM motors use low electrical energy which, in turn, make it highly efficient. The

These machines to work at lower speeds make them applicable for direct drive low speed applications. The main focus of this paper is to operate RFPM BLDC motor by closed loop control. To have a wide speed operation and closed loop control, a microcontroller is used.

## II. CLOSED LOOP CONTROL

The RFPM BLDC motors work over a wide range of speed. This property makes it useful for robotics, factory automation, vehicular applications etc. Motor speed can be adjusted by speed control systems. Generally, a speed control system consists of speed feedback system, a motor, an inverter, a controller and a speed setting device. A properly designed closed loop controller makes the system immune to changes in parameters. Proportional integral (PI) controller can be used to make a closed loop speed control of the motor. Speed of the BLDC motor is directly proportional to the applied voltage. Any diversion of actual speed from reference speed will be given as an error signal to PI controller which takes appropriate corrective action to change the duty cycle of applied gate signal. A Hall sensor can also use as a speed sensing device. The difference between the reference speed and actual speed is fed to the PI controller as the error signal. The values of proportional and integral gain are set such that the overshoot and the settling time to reach steady state should be as low as possible so as to have a better motor operation.

## III. MICROCONTROLLER

The assembly of microcontrollerdsPIC33EP256MC202 (3.3V, 18F) with Hall sensor circuitry. The Hall sensor output is in mill volt; hence, a signal conditioning circuit is used to convert this mill volt signal to the acceptable.

Level of voltage for microcontroller. This microcontroller is a twenty eight pin integrated circuit. 26th -21st pins are used to generate pulse width modulation (PWM) signals and these signals are fed to the driver circuit of the inverter. Microcontroller receives analog signal from Hall sensor. Using analog to digital (ADC) module of controller, these analog signals are converted into digital form. A program written for closed loop speed control of motor is fetched in this controller. If the speed of motor drops below the reference speed, the controller changes the pulse width of the switches used in inverter and motor will return to its reference speed.

## IV. SIMULATION STUDY

To study the performance of RF BLDC motor, simulation is carried out in PROTEUS (Version8) environment for different operating conditions.

 

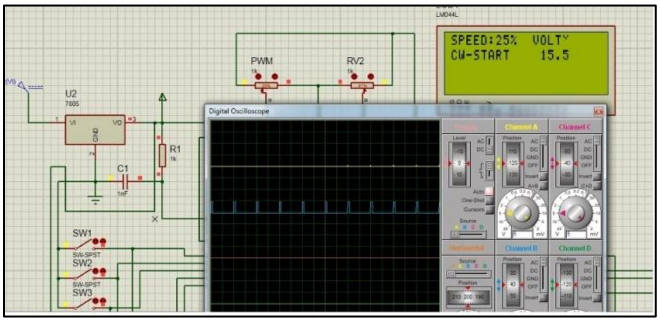

Fig. 1: Speed on 25% in PWM

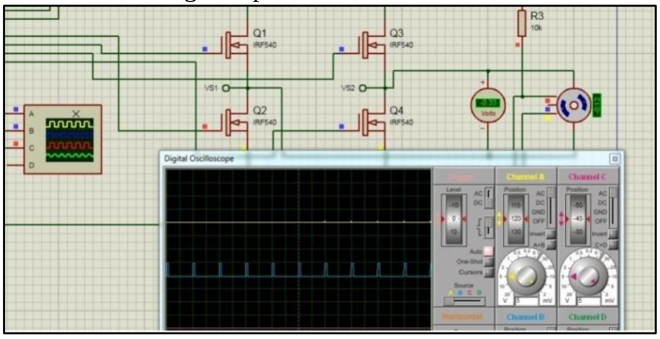

Fig. 2: Motor Voltage Variation at 25% PWM Speed

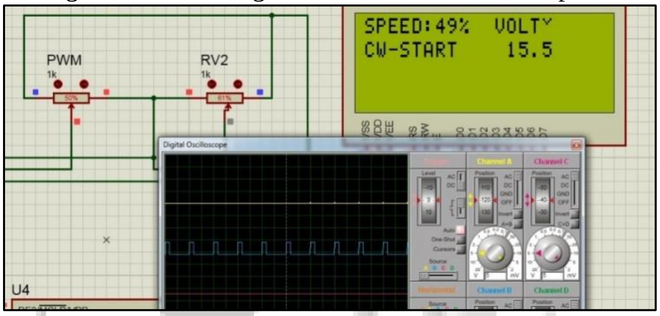

Fig. 3: Speed on 50% in PWM

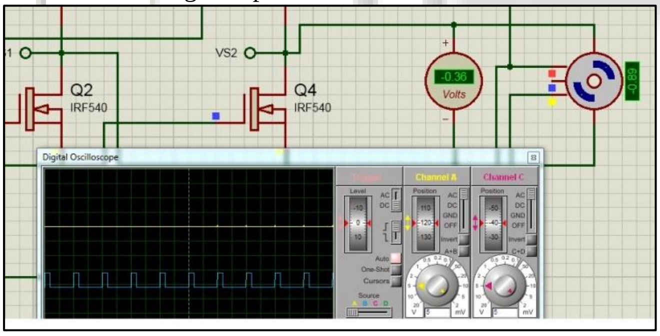

Fig. 4: Motor Voltage Variation at 50% PWM Speed

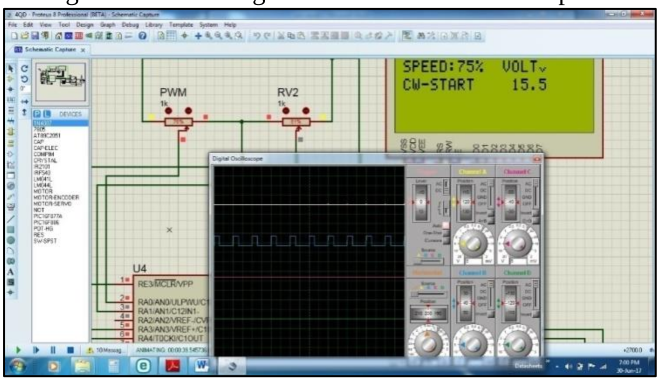

Fig. 5: Speed on 75% PWM

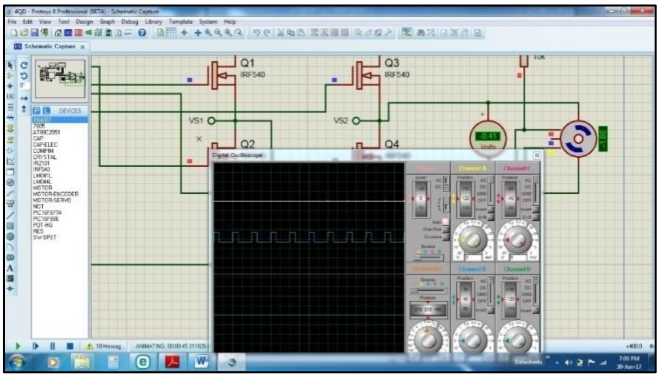
Fig. 6: Motor Voltage Variation at 75% PWM Speed

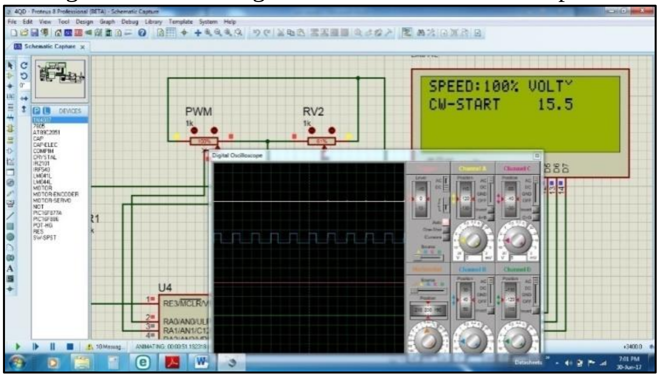

Fig. 7: Speed on 100% PWM

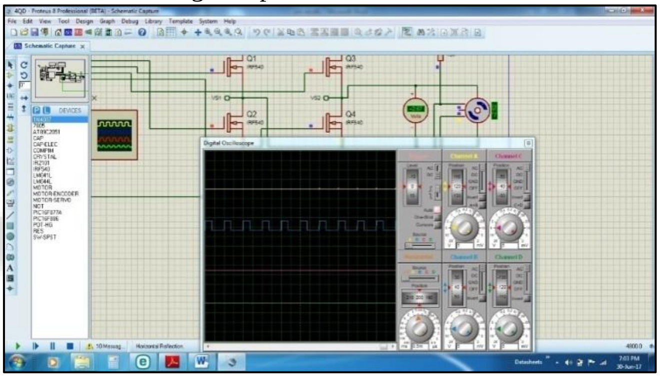
Fig. 8: Motor Voltage Variation at 75% PWM Speed

The above Fig. shows PROTEUS result is out at 25%-100% Speed of PWM technique. According to the speed variation the motor voltage is also changes. The motor result is taken as negative in clockwise rotation and positive at anticlockwise direction of motor rotation. The Q1 and Q4 switch is operate at anticlockwise direction, the result is taken by motor variation voltage. The Q2 and Q3 switch is operate at clockwise direction, and result is taken at software. The fig.1 shows the PWM speed variation at 25%of PWM speed according that in Fig.2 taken result is out at motor voltage variation. We are going to check the different result of speed in different parentage of duty cycle in PWM, According that the motor voltage is vary that is given a simulation. If the at 50% duty cycle of Speed is rotate at 1500 RPM in the first half then in second half is double at 3000 RPM. If that result is not come then Hall Effect feedback is work and corrected by using closed loop control system. It sense the speed of variation by microcontroller PIC and give the signal to the control system there Hall effect sensor control the speed of RFBLDC motor.

 

## V. APPLICATIONS

PM synchronous machines are fast becoming popular due to the rise in low speed applications. The recent developments in electrical vehicle and renewable energy, direct drives electrical machines are becoming the need of the hour. Majority of applications have requirements in terms of high efficiency, saving of space, economic feasibility amongst other characteristics. RFPM BLDC motors fulfill these requirements. Their disc shape, multistage capability and high torque density are added advantages. The three most important applications are listed below. However, three applications may be the most relevant including electric vehicle due to the numbers of documents and amount of research a review of the literature reveals in the search for information about axial flux machines: wind power ,electric vehicles, blowers and elevation..

## VI. CONCLUSION

The availability of rare earth permanent magnet materials at low cost with high energy product allows rethinking of many traditional drive problems. Attractive features of an RFBLDC motors are good solution for the application like electric vehicle. Single side, RF BLDC motor has been designed and fabricated for electric vehicle application. For steady and accurate operation, closed loop control of motor using Hall sensor is good solution and implemented using microcontroller. Breaking of motor and its advantages over other braking technique, leads to the effective braking control of motor. Simulation study is carried out at different operating conditions. The simulation results prove the effectiveness of proposed scheme. Performance of the motor after reduction in the stator coils can also be tested. Further torque control loop can be added and the performance of drive can be tested under the different torque conditions.

## APPENDIX

1) Motor voltage = 24V
2) Rated Speed = 1500 rpm
3) Stator phase resistance Rs = 12 ohm
4) Stator phase inductance Ls = 0.005 H
5) Torque Constant = 4 N.m / A_peak
6) Pole pairs = 2

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