International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 6, August - 2012

Real Time Modelling and Simulation of BLDC Motor

Neeraj Priyadarshi,

Department of Electrical; Engineering,CTAE,Udaipur(Rajasthan)

Email:neerajrjd@gmail.com

***Abstract*- Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as appliances, automotive, aerospace, medical, industrial, automation equipment and instrumentation. BLDC motors have many advantages over brushed DC motors and induction motors, such as better speed versus torque characteristics, high dynamic response, high efficiency and higher speed ranges. These applications have made it important to develop BLDC motor controllers. The design of motor controllers would require machines for testing purposes. This paper therefore presents the development of a virtual motor. The BLDC motor will be modeled and simulated in MATLAB/SIMULINK. The BLDC motor characteristics will be implemented on a single chip. This will function as a virtual motor for easy testing and validation purposes in the industry and also for educational purposes.**

Keywords : BLDC simulation, SIMULINK model, virtual motor.

I. INTRODUCTION

Conventional dc motors are highly efficient and their characteristics make them suitable for use as servomotors. However, their only drawback is that they need a commutator and brushes which are subject to wear and require maintenance. When the functions of commutator and brushes were implemented by solid-state switches, maintenance-free motors were realized. These motors are now known as brushless dc motors. The construction of modern brushless motors is very similar to the ac motor, known as the permanent magnet synchronous motor. The stator windings are similar to those in a poly phase ac motor, and the rotor is composed of one or more permanent magnets. Brushless dc motors are different from ac synchronous motors in that the former incorporates some means to detect the rotor position to produce signals to control the electronic switches. The most common position sensor is the Hall element, but some motors use optical sensors. Although the most orthodox and efficient motors are three-phase, two-phase brushless dc motors are also very commonly used for the simple construction and drive circuits.

Although it is said that brushless dc motors and conventional dc motors are similar in their static characteristics, they actually have remarkable differences in some aspects. When we compare both motors in terms of present-day technology, a discussion of their differences rather than their similarities can be more helpful in understanding their proper applications. When we discuss the functions of electrical motors, we should not forget

ISSN: 2278-0181
Vol. 1 Issue 6, August - 2012

the significance of windings and commutation. Commutation refers to the process which converts the input direct current to alternating current and properly distributes it to each winding in the armature. In a conventional dc motor, commutation is undertaken by brushes and commutator; in contrast, in a brushless dc motor it is done by using semiconductor devices such as transistors.

II.MATHEMATICAL MODEL OF BLDC

The dynamic model of the BLDC motor is arrived from the following set of equations.

$$V_a = R\, i_a + L_1 \left(\frac{d}{dt} i_a\right) + e_a \qquad (1)$$

$$V_b = R\, i_b + L_1 \left(\frac{d}{dt} i_b\right) + e_b \qquad (2)$$

$$V_c = R\, i_c + L_1 \left(\frac{d}{dt} i_c\right) + e_c \qquad (3)$$

Where R is the stator resistance per phase assumed to be equal for all three phases.

The emfs e_a , e_b , e_c are trapezoidal where E_p is the peak value.

$$E_p = (Blv)\, N = \lambda_p\ \omega_m \qquad (4)$$

where N = number of conductors in series per phase.

v = velocity, rpm

l= length of the conductor, m

r = radius of the rotor bore, m

ω_m = angular velocity, rad/sec

B=flux density of rotor magnets, Tesla

λ_p= back emf constant, V/rad/sec

If there is no change in the rotor reluctance with angle because of non salient rotor and assuming symmetric phases,
$L=L_{aa}=L_{bb}=L_{cc}$
$M= L_{ab}=L_{ba}=L_{ac}= L_{ca}=L_{bc}=L_{cb}$
L_1=L-M since the stator phase currents are balanced $(i_a+ i_b + i_c =0)$
The instantaneous induced emfs are

$$e_a = f_{as}(\theta_r)\ \lambda_p\ \omega_m \qquad (5)$$

$$e_b = f_{bs}(\theta_r)\ \lambda_p\ \omega_m \qquad (6)$$

$$e_c = f_{cs}(\theta_r)\ \lambda_p\ \omega_m \qquad (7)$$

where $f_{as}(\theta_r)$, $f_{as}(\theta_r)$, $f_{as}(\theta_r)$ have the same shape as the emfs with max magnitude of +/-1

The electromagnetic torque T_e, is given by

$$T_e = \lambda_p[f_{as}(\theta_r)\ i_a + f_{bs}(\theta_r)\ i_b + f_{cs}(\theta_r)\ i_c] \qquad (8)$$

The equation of motion is

$$J\,(d\,\omega_m\ /dt) + B\,\omega_m = T_e - T_l \qquad (9)$$

where J = inertia, Kg m^2
B = friction coefficient, Nm/rad/sec
T_l = load torque

Electrical rotor speed and position are related by

$$(d\,\theta_r / dt) = (P/2) * \omega_m \qquad (10)$$

III.PROPOSED SCHEME

The basic block diagram of a BLDC motor is shown in Fig. 1. The proposed scheme shown in Fig. 2, has a virtual motor in the place of the physical motor. The virtual motor is supposed to give the same output as would a physical motor.

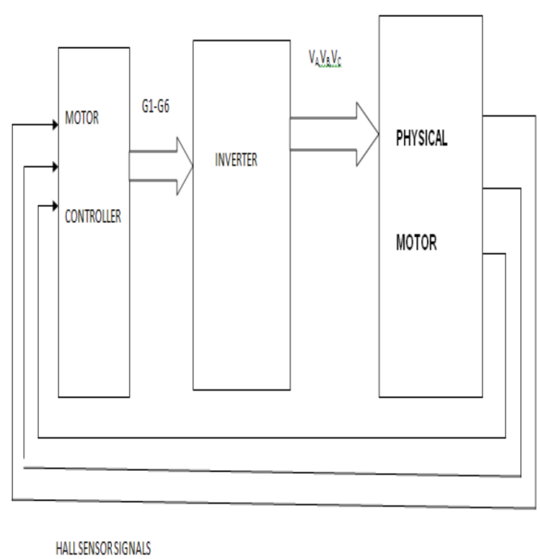

Fig. 1 Basic BLDC drive

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 6, August - 2012

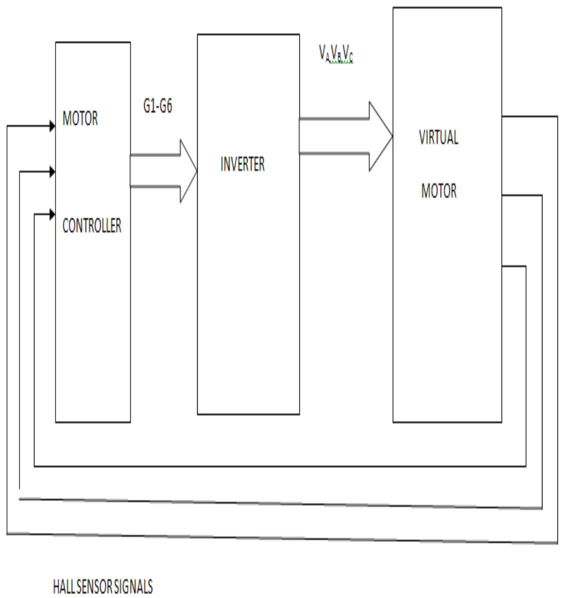

Fig. 2 Proposed scheme of virtual motor

The hall sensor output from the virtual motor is fed back to the motor controller that gives appropriate gating signals for the inverter switches. The virtual motor has various modules in it. A module to solve the differential equations to give motor characteristics, an inverter module and also a module to generate the hall sensor signals. Since, the signals from the virtual motor are digital and so is the gating signals the whole work can further be simplified as shown in Figure 3.

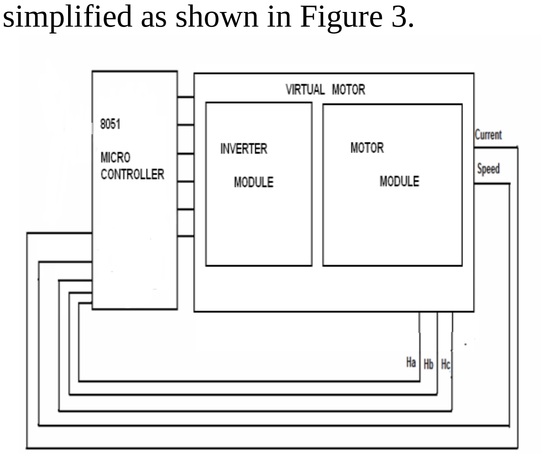

Fig. 3 Proposed Scheme with motor and inverter modules

The coding for the controller as well as virtual motor is developed using embedded C in the keil software. The flowchart for the entire program module is as shown in Fig. 4. It consists of the motor module which is a numerical solver of the differential equations 1 to 10. The position θ, obtained from this is used for emf module to generate the back emf (trapezoidal) functions of equations 5 to 7. It is also used to generate three Hall sensor outputs. Controller takes the speed and current samples and generates error and Proportional and Integral action is done to correct the same. The inverter module is activated by the gate pulses generated by the controller. The output of the inverter module is the three phase voltages which are supplied to the motor. The virtual motor solver gives, three phase currents i_a, i_b, i_c, speed ω and position θ as output.

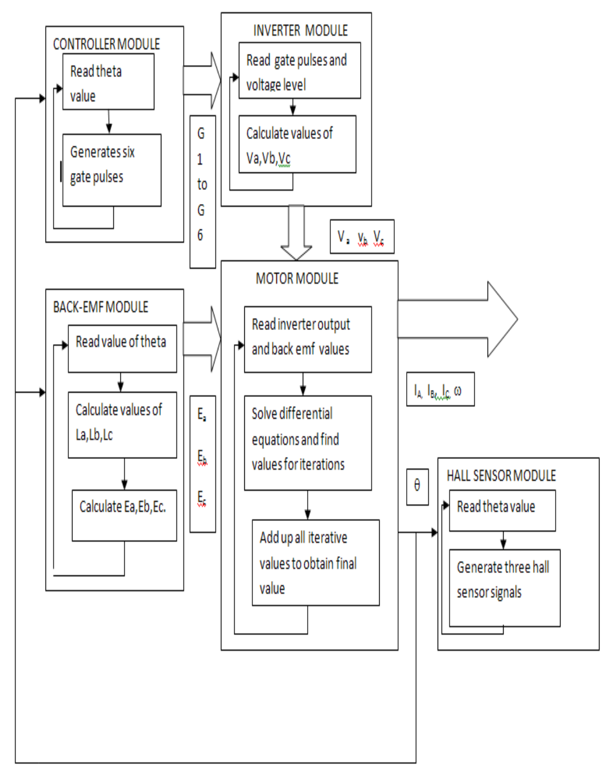

Fig. 4 Flowchart for the entire software module

IV. MATLAB MODEL.

The BLDC motor model shown in Fig. 4 was developed and simulated in MATLAB using the dynamic equations 1 to 10.

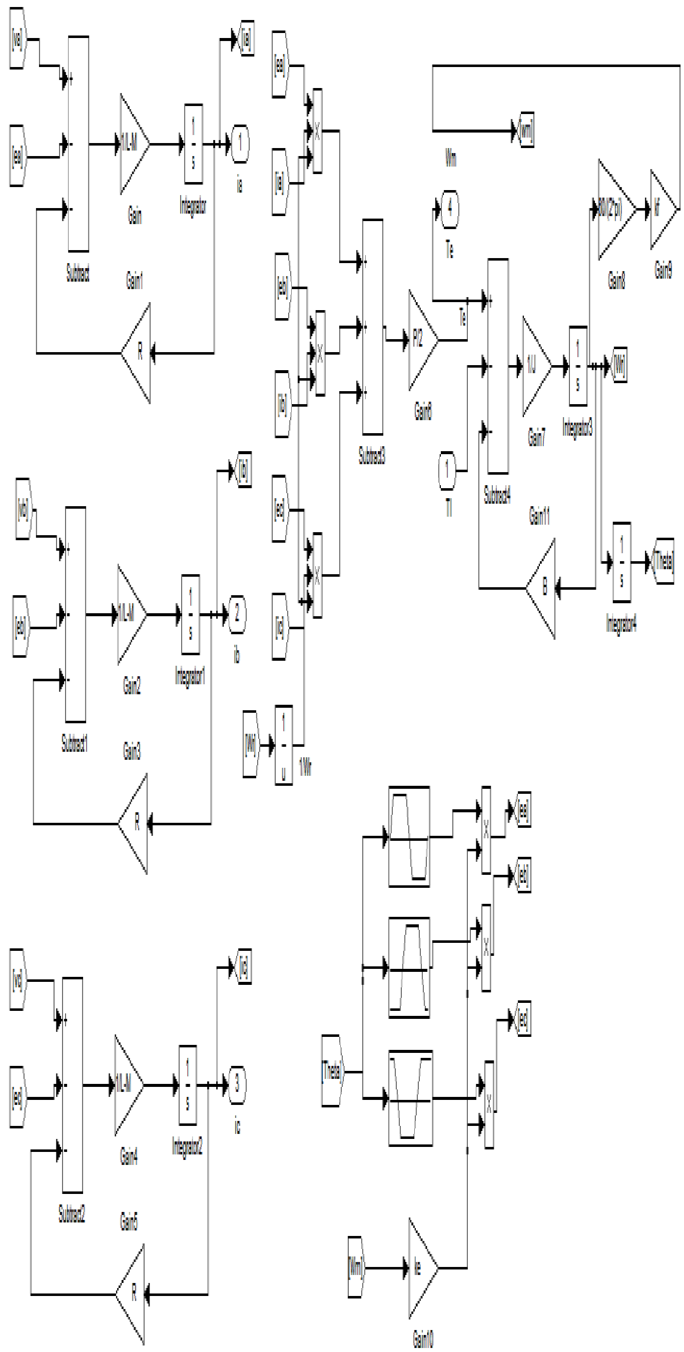

Fig.4 MATLAB model of BLDC

V. RESULTS

The simulation results for MATLAB model of BLDC is shown in Fig. 5 and 6.

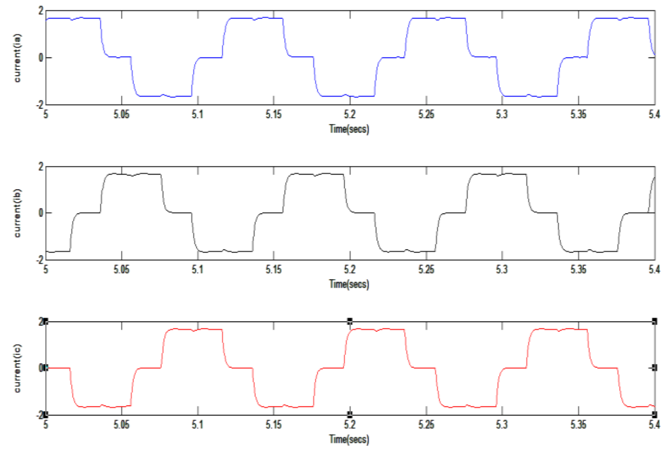

Fig. 5 Current Waveforms

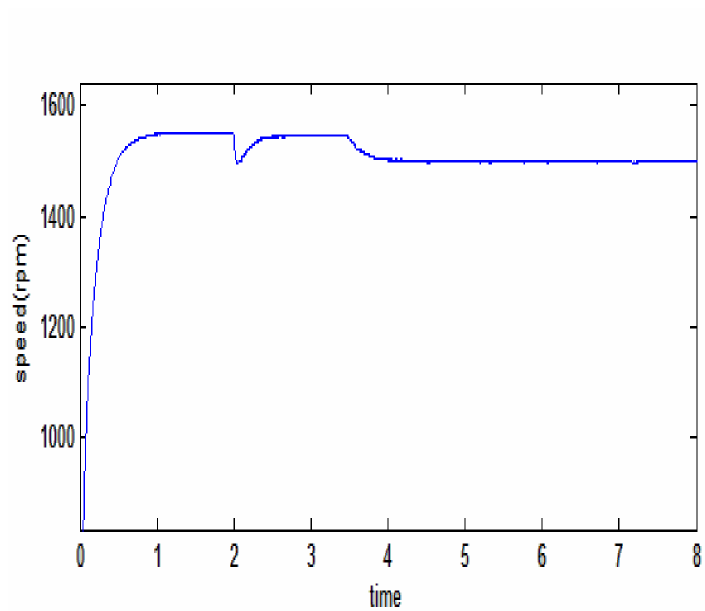

Fig. 6 Speed waveform

The results of the program modules simulated in Keil Software are shown in Fig. 7 to 12.

The six gate signals are generated from the controller module. These six gate pulses shown in Fig 8 , are given as input to the inverter module.

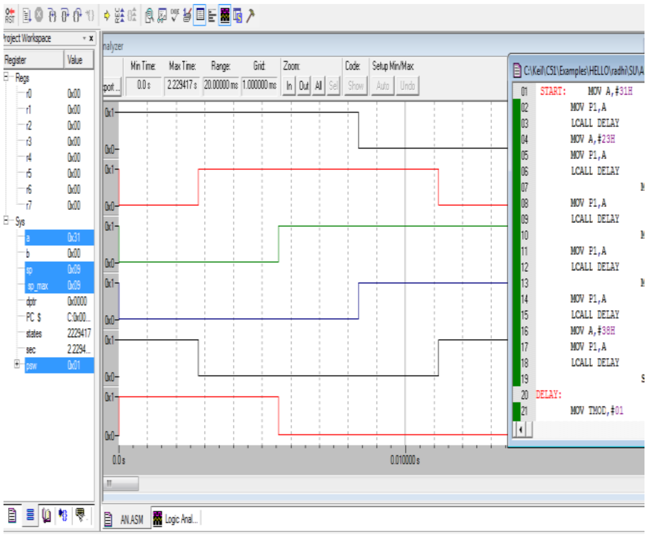

Fig.7 Gate Pulses

The output from the inverter modules are the three phase voltages Va, V_b, and Vc. These voltages are given to the motor module as one set of inputs.

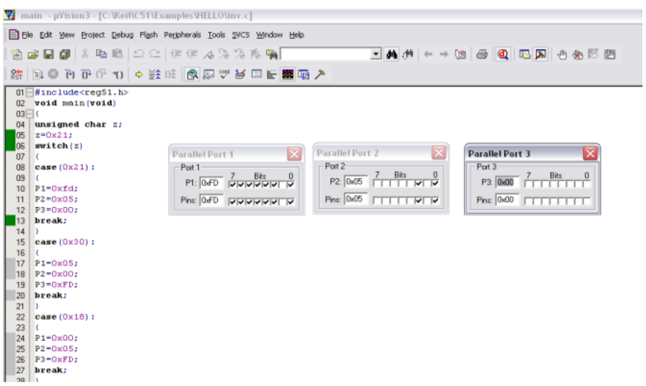

Fig. 8 Inverter module output

The output from the motor module are the three currents i_a, i_b, i_c and speed, ω.

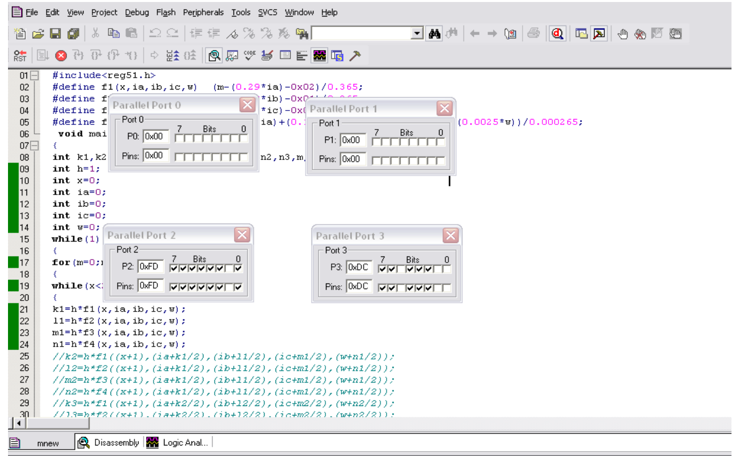

Fig. 9 Motor module output

The back emf module gives the voltages Ea,Eb,Ec which is the second set of inputs to the motor module

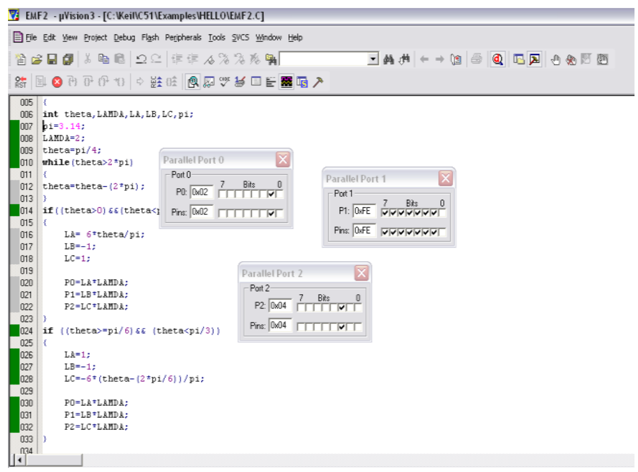

Fig.10 Back emf module output.

The hall sensor module generates the output according to the rotor position theta

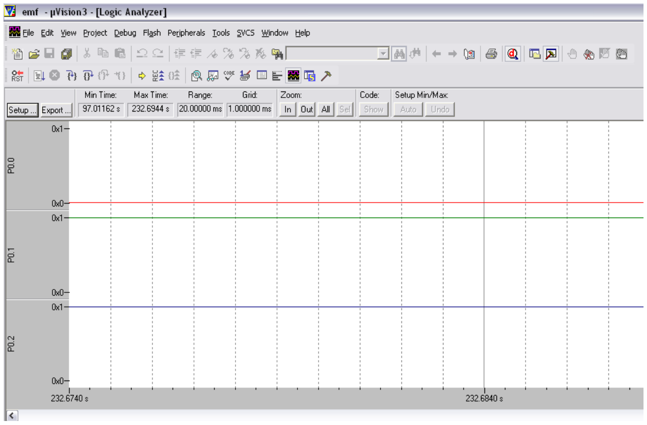

Fig.11 Hall Sensor module output.

VI.CONCLUSION

The advantage of working with a virtual motor rather than a physical motor is that it makes it easier to test various motor controllers being developed each day. It is a common engineering practice to test a motor controller against a simulated motor model running in real-time before using the controller in real-life conditions. This project is the same with the motor created on a microcontroller chip. The microcontroller chip has the dynamic characteristics of the BLDC written in it using embedded C coding. This is a simple solution with no much complexities attached. The coding is simple and the mathematical solution used is just the basic preliminary Runga Kutta Solution. Thus the future scope is abundant for this project and if developed further would be a turning point in making BLDC testing and validation less expensive and less complex

REFERENCES

[1] Text Book by BIMAL K.BOSE,PHI publications private-limited, 5th edition PRAGASEN PILLAY, MEMBER, IEEE, AND RAMU KRISHNAN, MEMBER, IEEE, “Modelling, Simulation and Analysis of Permanent-Magnet Motor Drives, Part 1: The Permanent-Magnet Synchronous Motor Drive,” in proc. IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL 25, NO.2, MARCH/APRIL 1989.

[2] PRAGASEN PILLAY, MEMBER, IEEE, AND RAMU KRISHNAN, MEMBER, IEEE, “Modelling, Simulation and Analysis of Permanent-Magnet Motor Drives, Part 11: The Permanent-Magnet Synchronous Motor Drive,” in proc. IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL 25, NO.2, MARCH/APRIL 1989.

[3] Modern Power Electronics and AC Drives Text Book by BIMAL K.BOSE,PHI publications private-limited, 5th edition.

[4] Improved Analytical Model of a Permanent-Magnet Brushless DC Motor by Kumar, P.; Bauer, P.; Magnetics, IEEE Transactions on Volume 44, Issue 10, Oct. 2008Page(s):2299 – 2309

[5] S. Abourida, C. Dufour, J. Bélanger, T. Yamada, T. Arasawa, “Hardware-In-the-Loop Simulation of Finite-Element Based Motor Drives with RT-LAB and JMAG”, EVS-22 Symposium, Yokohama, Japan, October 23-28, 2006.

[6] O. A. Mohammed, Fellow IEEE, S. Liu, Member IEEE, and Z. Liu,”A Phase Variable PM Machine Model for Integrated Motor Drive Systems”, 35th Annual IEEE Power Electronics Specialists Conference, Aachen, Germany, 2004, pp. 4825-4831

[7] Hendershot Jr. J.R.; Miller, T.H.E. (1994). “Design of Brushless Permanent-Magnet Motors”