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**RESEARCH ARTICLE**

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# INDIRECT TORQUE AND SPEED CONTROL OF 'PMBLDC' MOTOR WITH POWER FACTOR IMPROVEMENT USING FUZZY LOGIC CONTROLLER

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## ABSTRACT

The usage of mobile technology has been vast in recent years due to its simplicity, location independence and built in applications. The performance and speed of mobile computing is considerably less when compared to the computers and powerful servers due its limited resources and compatibility issues.Inorder to overcome these obstacles and to make efficient usage of mobile technology the Cloud based Mobile Augmentation (CMA) a latest technique is adopted to increase the storage capacity, resource availability and computational capability of the wireless devices. This led to the development of the latest technology in computer field which addresses all the novel issues in mobile computing known as MOBILE CLOUD COMPUTING (MCC).In this paper let us have a brief survey on MCC which includes the architecture, applications, challenges ,and its future research .

*Keywords*— Mobile Cloud Computing, compatibility issues, storage capacity, limited resource, cloud based mobile augmentation

## INTRODUCTION

Permanent magnet machines are applicable in key applications of critical importance, such as aerospace industry, tool drives, actuators and electric vehicle propulsion system since these needs to cater to servo applications. Hence, the necessity for precise control with quick response time is evident and obvious. Further these applications warrant the weight-density to be low and torque speed characteristics to be good. Also the inherent disadvantages of the conventional dc machines which necessitate the use of mechanical brushes and commutator problems have obviated these motors applied to such high performance applications. In this project PMBLDC motor, which can cater to large torque for high acceleration and deceleration rates is evaluated for its performance with respect to the parameters of the motor which

need to include also the effects of reluctance variations and other effects of magnetic saturation. The modelling of the PMBLDC motor has been carried out in this project with the reference frame as the rotor. The PMBLDC drive system which involves inherently an inverter controller arrangement which controls the duty cycle of the chopper using PWM technique has been taken up for implementation. The disadvantages of large distortion of the current waves is thus obviated using PWM technique in this project with the hysteresis band current controller taken up for the said purpose. The current is controlled within a narrow band of excursion from its allowable or pre-set deviation of current. Hence, hysteresis current controller is chosen for the current control of PMBLDC motor.

The functioning of the servomechanism of servo drive which accepts feedback from a motor or actuator and process this feedback to improve control of the servo system has been implemented with a PID controller. To eliminate the modelling the high degree of non-linearity the fuzzy logic approach for the design of controller has been taken up subsequently.

**KEYWORDS:** PMBLDC, PID Control, Fuzzy Logic Control, Indirect Torque Control, Speed Control, Power Factor Improvement.

## SCOPE OF THE PAPER

There is limited to the speed control aspects of PMBLDC motor with specified rating and is not applicable for all motor ratings. This project is limited to the implementation of the d-q axis model of PMBLDC motor and its speed control using PID controller and not other variations (PI & P controller). It is also envisaged to carry out alternate speed instead of PID with fuzzy logic technique only.

## INTRODUCTION

The need for permanent magnet brushless dc motor and its application in specific areas has been elucidated in this chapter. Also the various important characteristics, constructional aspects, parameters etc., has been compared and the merits and its demerits of the proposed motor for drive application have been explained. This chapter also explains the need for representing the motor in the d-q axis model with appropriate mathematical equations in detail.

In many adjustable speed drives the demand is for precise and continuous control of speed with long-term stability, good transient performance and high efficiency. The dc motor has satisfied some of these requirements, but due to the presence of commutator and brushes dc motors have a number of disadvantages as compared to ac motors.However permanent magnet motors which have permanent magnet on the rotor have the following advantages over induction motor

- The rare earth and neodymium boron permanent magnet has low inertia when compared with an Induction motor because of the absence of rotor cage; this makes faster response for a given torque. In other words, the torque to inertia ratio of these permanent magnet machines is higher.
- The permanent magnet machine has a higher efficiency than an induction machine. This is primarily because there are negligible rotor losses in permanent magnet machines.
- The induction motor requires a source of magnetizing current for excitation. The permanent magnet machine already has the excitation in the form of the rotor magnet.
- The permanent magnet machine is smaller in size than an induction motor of the same capacity. Hence it is advantageous to use permanent magnet machines, especially where space is a serious limitation. In addition, the permanent magnet machine weight is less. In other words, the power density of permanent magnet machine is higher. Because of above mentioned advantages, enhanced the brushless dc motor for adjustable speed applications.

There are two types of permanent magnet motors. They are PMSM (Permanent Magnet Synchronous Motor) and PMBLDC (Permanent Magnet Brushless DC Motor). Depending upon the application a choice is made between a PMSM and PMBLDC.

An electric drive system is considered “high performance” when rotor speed can be made to follow preselected trajectory. This is essential in applications such as robotics, guided manipulation and dynamic actuation where precise rotor movement must be achieved. Several types of electric motors have been proposed for HPD (High Performance Drive) applications. Apart from above mentioned advantages, advances in high-energy permanent magnet materials and power electronics have widely enhanced the brushless dc motor for these applications.

For this brushless dc motor conventional controllers require accurate mathematical models describing the dynamics of the system under control. Even if a model can be obtained for the system under control one of the main difficulties with conventional tracking controllers for electric drives is their inability to capture unknown load characteristics over a widely ranging operating point. This makes tuning of respective parameters difficult.

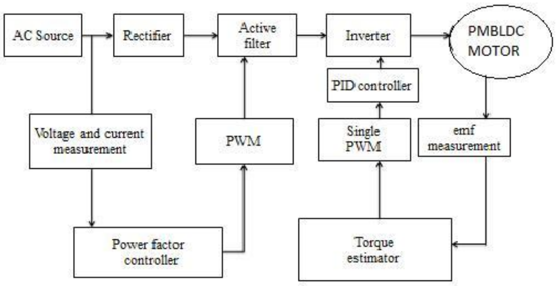

Fig 1. Block diagram of the proposed approach

## ELECTROMAGNETIC TORQUE ESTIMATION

Because of the rotor position dependant terms in the dq frame stator flux linkages and inductances, conventionaltorque estimation in stator reference frame used for sinusoidal ac motors is no longer valid for BLDC motor, therefore,a new torque estimation algorithm is derived in dq frame consisting of actual dq-axes back EMF constants and currents. Instead of the actual back EMF waveforms, Fourier approximationof the back EMFs could have been adopted in torqueestimation, but the results would not truly represent the realityand more complex

## ESTIMATION OF ELECTRICAL ROTOR POSITION:

Electrical rotor position θre, which is required in the line-to line Park transformation and torque estimation algorithm can be found by

computations are required.The torque estimation is the key factor of two line-

to-line back EMF waveform seba(θre) and eca(θre) are obtained offline and converted to the ba–ca frame back EMF constants kba(θre) and kca(θre).The line-to-line Park transformation matrix is used to obtain the dq reference frame back EMF constants kd(θre) and kq(θre), where θre is the electrical rotor angularposition. Then, they are stored in a look-up table for electromagnetictorque estimation.The electromagnetic torque Tem estimation algorithm can bederived for a balanced system in dq reference frame by equating the electrical power absorbed by the motor to the mechanicalpower produced (Pi = Pm = Temωm) as follows:

$$\begin{aligned} T_{\mathrm{em}} &= \frac{3P}{4\omega_{re}}(e_q(\theta_{re})i^r_{qs} + e_d(\theta_{re})i^r_{ds}) \\ &= \frac{3P}{4}(k_q(\theta_{re})i^r_{qs} + k_d(\theta_{re})i^r_{ds}) \end{aligned}$$

Where P is the number of poles, ωre is the electrical rotor speed, eq(θe) and ed(θe), irQs and irds, kq(θe), and kd(θe) are the dq axes back EMFs, currents, and back EMF constants accordingto the electrical rotor position, respectively. As it can be noticedthat the right-hand side equation in eliminates the speed.

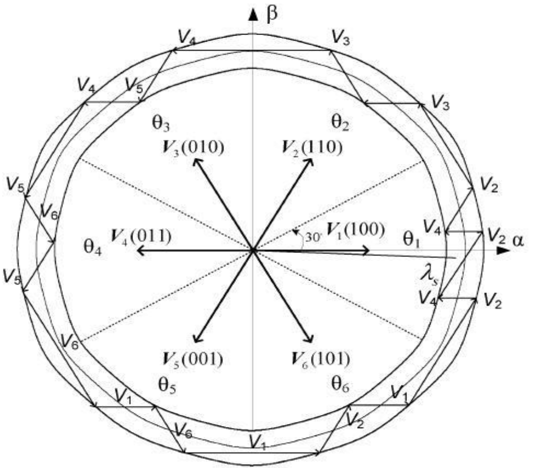

Fig.2.Stator flux linkage

$$\theta_{re} = \tan^{-1}\left(\frac{\varphi_{s\beta} - L_s i_{s\beta}}{\varphi_{s\alpha} - L_s i_{s\alpha}}\right)$$

To solve the common problems for integrators, a special integrationalgorithm for estimating the stator flux linkage proposed in this study. Although the method is designedfor sinewave systems, the algorithm is still applicableto a BLDC motor with varying stator flux linkage amplitude in the second algorithm in which is themodified integrator with an amplitude limiter is used for thestator flux linkage estimation. The maximum amplitude of thestator flux linkage reference approximated as 2kLLπ/(3√3) Is set for the limiter when the motor speed is less than the basespeed. If the motor operates in the flux-weakening region, thelimiter value should be selected properly, but this is not in the scope of this paper.

**FUZZY LOGIC**

One can circumvent the need for rigorous mathematical modelling with the use of fuzzy logic. Unlike the reasoning based on classical logic, fuzzy reasoning aims at the modelling of reasoning schemes based on uncertain or imprecise information. The past several years have witnessed a rapid growth in the number and variety of applications of fuzzy logic. The most visible applications are in the realms of consumer products, intelligent control and industrial systems. Less visible, but of growing importance, are applications relating to data processing, fault diagnosis, man-machine interfaces, quality control and decision support systems. Although fuzzy logic has been and still is controversial to some extent, its successes are now too obvious to be denied. Fuzzy logic is an innovative technology that enhances conventional system design with engineering expertise.

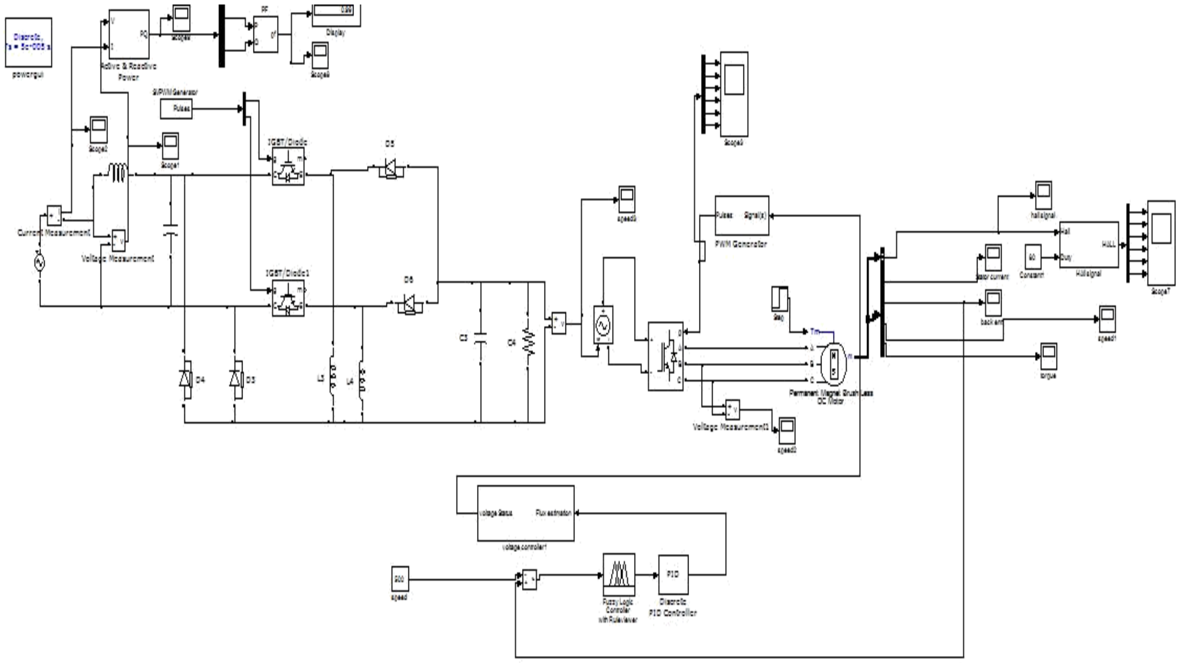

Fig2 Simulink diagram

The use of fuzzy logic can help tocircumvent the need for rigorous mathematical modelling. Fuzzy logic is a true extension of conventional logic, and fuzzy logic controllers are a true extension of linear control models. Hence anything that was built using conventional design techniques can be built with fuzzy logic, and vice-versa. However, in a number of cases, conventional design methods would have been overly complex and, in many cases, might prove simpler, faster and more efficient. The key to successful use of fuzzy logic is clever combination with conventional techniques. Also, a fuzzy system is time-invariant and deterministic. Therefore any verification and stability analysis method can be used with fuzzy logic.

## FUZZY LOGIC VS PROBABILITY THEORY

People working extensively with the probability theory have often denied the usefulness of fuzzy logic in applications, claiming that all kinds of uncertainty can be expressed with probability theory. But this is a false notion. Probability theory only allows the modelling of stochastic uncertainty, which deals with the uncertainty of whether a certain event will take place or not. In contrast, lexical uncertainty deals with the uncertainty of the definition of the event itself. Probability theory cannot be used to model this because the combination of subjective categories in human decision processes does not follow its axioms. The fuzzy set theory matches everyday reality better than the standard set theory because not all the phenomena and observations can have only two definite states. For instance, many terms in engineering like high voltage,‟ „high frequency,‟ „low power‟ etc., are not sharply defined. A certain voltage can partially belong to a set of high voltages, but not absolutely, as in the standard set theory. The same is true for any given frequency or power. So a measure of the degree of membership of a given value is defined. As such, a measure called the membership function (compatibility function) has been introduced into fuzzy set theory.

## FUZZY CONTROL:

The control algorithm of process that is based on FL or fuzzy inference system is defined as a fuzzy control. In general, a control system based on Artificial Intelligent (AI) is defined as intelligent control. A fuzzy control essentially embeds the experience and intuition of a human plant operator, and sometimes those of a designer and/or researcher of a plant. The design of a conventional control system is normally based on the mathematical model of a plant.

Power electronics system models are ill defined. Even if a plant model is well known there may be parameter variation problems. Sometimes, the model is multivariable, complex, and non-linear, such as dynamic d-q model of an ac machine. Vector or field oriented control of a drive can overcome this problem, but accurate vector control is nearly impossible, and there may be wide parameter variation problem in the system. To combat such problems, various adaptive control techniques were used. On the other hand, fuzzy control is basically an adaptive and nonlinear control, which gives robust performance for a linear or nonlinear plant with parameter variation. FL applications in power electronics and motor drives are somewhat recent. Fuzzy adaptive, hybrid fuzzy controller gathered

$$u(t) = MV(t) = K_p e(t) + K_i \int e(\tau)\,dt + K_d \frac{(de(t))}{dt}$$

Where,

$K_p$ : Proportional gain, a tuning parameter

$K_i$ : Integral gain, a tuning parameter

$K_d$ : Derivative gain, a tuning parameter

$e$ : Error=SP-PV

$\tau$ : Time or instantaneous time (the present)

A PID controller calculates an "error" value as the difference between a measured process variable (PV) and a desired set point (SP).The controller attempts to minimize the error by adjusting the process control inputs. PID Controller will eliminate the steady state error of any process through the integral action on error and expectation output changes through derivative action on the error with respect to the set point of process.

From the transfer function of BLDC motor we can derive Conventional PID Controller parameters Proportional gain, Integral time, integral gain, Derivative time and Derivative gain Integral gain can be obtained by the following equation

$$K_i = \frac{K_p}{\tau_i}$$

$$K_d = K_p \times \tau_d$$

Similarly, derivative gain can be obtained from proportional gain and derivative time by the following equation

The Transfer function of selected BLDC motor as given as

$$G(s) = \frac{23.86}{0.00341s^2+0.3019s+1}$$

The above transfer equation Due to input delay value 0.5 the above transfer function can be modified as follows,

$$G(s) = \frac{23.86\ \exp(-0.5^*s)}{0.00341s^2+0.3019s+1}$$

For the above mentioned transfer function, Gain margin, phase margin, gain cross over frequency and phase cross over frequency values are calculated and given below

**Parameters used for PID controller modelling**

| **S.No** | **Name of the parameters** | **Numerical value** |
|---|---|---|
| 1 | Gain margin | 0.9914 |
| 2 | Phase margin | -11.8914 |
| 3 | Gain cross over frequency | 64.7783 |
| 4 | Phase cross over frequency | 65.1867 |

The ultimate gain value can be calculated from gain cross over values as given by,

$$P_{cu} = \frac{2\pi}{gco} = \frac{2\times 3.14}{64.7783} = 0.09694$$

The ultimate gain will provide the Conventional PID parameters values

Similarly Integral time (Ti) and Integral gain numeric values can be obtained from loop tuning formulas,

$$T_i = \frac{P_u}{2}$$

$$T_i = \frac{0.09694}{2} = 0.0485$$

From integral time, integral gain numeric value can be calculated by the following formula,

$$K_i = \frac{K_p}{T_i}$$

$$= \frac{0.0594}{0.0485} = 1.225$$

Finally, Derivative time (Ti) and derivative gain also, numeric values can be obtained from loop tuning formulas,

$$T_d = \frac{P_u}{8}$$

$$T_d = \frac{0.09694}{8} = 0.0121$$

We can obtain derivative gain,

$$K_d = K_p \times T_d$$

$$= 0.0594 \times 0.0121$$

$$= 0.072$$

Therefore, the conventional three mode (P+I+D) controller parameters are calculated and summarized.

**Parameters of PID controller**

| S.No | Controller parameters | Numerical values |
|---|---|---|
| 1 | Proportional gain | 0.0594 |
| 2 | Derivative gain | 0.072 |
| 3 | Integral gain | 1.225 |

## SUMMARY AND CONCLUSIONS:

This project has presented the modelling, simulation and analysis of a PMBLDC drive. A systematic approach on the evaluation and implementation of the motor model has been presented. The performance of the hysteresis current controller has been examined in which simulations included the state space model of the motor and speed controller and real time model of the inverter switches.

The following are the conclusions drawn, which is also a part of the recommendation for the hardware aspects/requirements.

- Based on the error output form the motor stator which obtained after equating the actual and reference current, a range of error values which can be used for ascertaining the firing characteristics which may be subsequently a good input data for hardware aspects has been obtained. The range has been found as -0.1201 to 0.5855. The appendix-3 gives another detail on the basis of this observation.

- It has been obtained that various values of torques for varying speeds the hysteresis band for its lower and upper cut off values was best in the range between –0.4 to 0.4. For moderate speed control characteristics the hysteresis band had its range between -0.35 to +0.35–0.2 to 0.2 and on the higher scale of – 0.6 to 0.6

## SIMULATION RESULT

The simulation diagram fig 4 gives the torque control of a Permanent Magnet BLDC motor using PID and fuzzy controller.

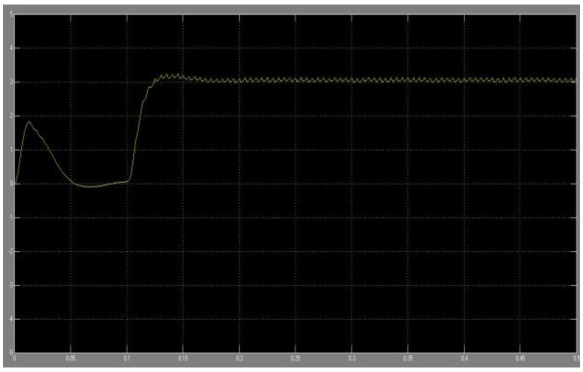

Fig No. 4 Toque Control

The figure 5 shows the speed control waveform of the PMBLDC motor

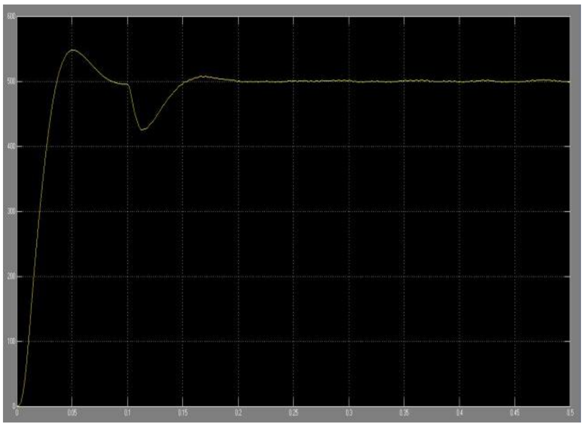

Fig No. 5 Speed Control

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