**Published by :**
**http://www.ijert.org**
**International Journal of Engineering Research & Technology (IJERT)**
**ISSN: 2278-0181**
**Vol. 8 Issue 11, November-2019**

# An Innovative Speed Controlling Technique for a BLDC motor using Fuzzy - PID Controller

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*Abstract*—**Brushless DC Motors are widely used for many industrial applications because of their high efficiency, high torque and low volume. BLDC motors have a long traditional use as adjustable speed machines and in these applications, the motor should be precisely controlled to give the desired performance. The conventional PID speed controller is implemented to meet various design specifications like rise time, settling time, peak overshoot and the steady state error of the system. It is difficult to tune the parameters and get satisfied control characteristics by using normal conventional PID controllers. This paper provides an overview of different tuning methods of PID Controller applied to control the speed of the transfer function model of the BLDC motor drive and then to the mathematical model of the BLDC motor drive. The nonlinear characteristics of a BLDC motor such as saturation and friction could degrade the performance of conventional controllers. To improve the performance of the PID controllers, several strategies have been proposed, such as adaptive control techniques. One of the most successful adaptive control techniques is the fuzzy set theory. The field of fuzzy application rose from consumer products such as cameras, camcorder, washing machines and microwave ovens to industrial process control, medical instrumentation, and decision-support system. But rather than applying only fuzzy, the combination of conventional PID and fuzzy controller gives better performance characteristics.**

***Keywords— BLDC Motor, Modelling of Conventional PID Controller with T-L tuning method, Modelling of Fuzzy Logic Controller.***

## I. INTRODUCTION

Speed and torque are the fundamental quantities used to describe the operation of rotating machinery. Speed is usually expressed in shaft revolutions per minute or RPM. In adjustable speed drive applications, performance is usually discussed in terms of the speed, torque and other parameters that apply to the shaft of the motor.

Speed Regulation is generally defined as the percentage speed change that results from a given load change. The speed regulating capability of any constant speed motor or adjustable speed drive is defined as the maximum speed change as a percentage of base speed that results from increasing the load from 5% of rated load (essentially no load) to full load while holding constant all other variables that might cause a speed change. When torque regulation is used, the drive supplies a set torque and operates at the maximum speed permitted by the characteristics of the load [13].

The closed loop speed regulator compensates for any changes in the characteristics of the drive caused by changes in load or by outside influences such as line voltage and ambient temperature. With a closed loop speed regulator, the most important characteristic of the drive is its ability to rapidly respond to changes in requirements for torque. The relationship between torque regulation and speed regulation in a standard DC drive configuration illustrates the importance of torque response. Since the current in a motor directly determines torque, the torque controller is configured as a closed loop current regulator. The speed regulator then commands the current regulator to produce whatever torque is required to maintain the desired speed.

## II. BLDC MOTORS

### A. *Comparing Brushed and Brushless DC Motors*

A brushless dc motor (as shown in fig. 1) is a dc motor turned inside out, so that the field is on the rotor and the armature is on the stator. The brushless dc motor is actually a permanent magnet ac motor whose torque-current characteristics mimic the dc motor. Instead of commutating the armature current using brushes, electronic commutation is used. This eliminates the problems associated with the brush and the commutator arrangement, for example, sparking and wearing out of the commutator-brush arrangement, thereby, making a BLDC more rugged as compared to a dc motor[3]. Having the armature on the stator makes it easy to conduct heat away from the windings, and if desired, having cooling arrangement for the armature windings is much easier as compared to a dc motor.

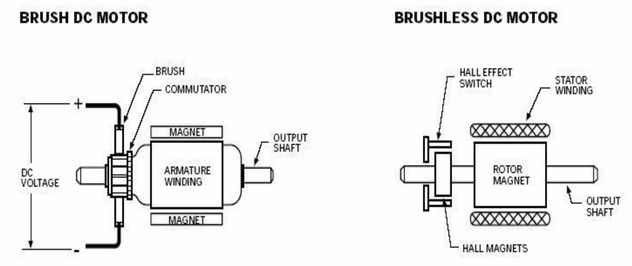

Fig.1 Brushed and Brushless DC motor

### B. *BLDC Motors*

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, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors. A few of these are[1]:

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

In addition, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors.

### C. *Controlling Methods*

BLDC motors have a long traditional use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance. The speed controllers that are designed to control the speed of BLDC motor used several conventional and numeric controller types, the controllers can be: proportional integral (PI), proportional derivative (PD), proportional integral derivative (PID). Because of its simplicity PID control is widely used in industrial applications. To improve the performance of the PID controllers, different tuning methods have been proposed[12]. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly.

The major problems in applying a conventional control algorithm (PI, PD, and PID) in a speed controller is the non-linearity of BLDC motor. The nonlinear characteristics of a BLDC motor such as saturation and friction could degrade the performance of conventional controllers [9]. To achieve desired level of performance the motor requires suitable speed controllers. In case of permanent magnet motors, usually speed control is achieved by using proportional-integral (PI) controller. Although conventional PI controllers are widely used in the industry due to their simple control structure and ease of implementation, these controllers pose difficulties due to nonlinearity, load disturbances and parametric variations. Moreover PI controllers require precise linear mathematical models. As the PMBLDC machine has nonlinear model, the linear PI controller may no longer be suitable.

The Fuzzy Logic (FL) approach applied to speed control leads to an improved dynamic behaviour of the motor drive system and motor becomes immune to load perturbations and parameter variations. . Fuzzy logic control (FLC) is one of the most successful applications of fuzzy set theory, introduced by L.A Zadeh in 1973 and applied (Mamdani 1974) in an attempt to control system that are structurally difficult to model.

In the last three decades, FLC has evolved as an alternative or complementary to the conventional control strategies in various engineering areas. Fuzzy control theory usually provides non-linear controllers that are capable of performing different complex non-linear control action, even for uncertain nonlinear systems. Unlike conventional control, designing a FLC does not require precise knowledge of the system model. Imitating the human way of learning, the tracking error and the rate of change of the error are two crucial inputs for the design of such a fuzzy control system [10]. Fuzzy logic control offers an improvement in the quality of the speed response. Most of these controllers use mathematical models and are sensitive to parametric variations. These controllers are inherently robust to load disturbances. Besides, fuzzy logic controllers can be easily implemented.

## III. MATHEMATICAL MODELLING OF BLDC MOTOR

The BLDC motor is supplied from battery through the inverter. The dynamic model of this system is shown in Fig. 2. It is derived under the following assumptions:

- All the elements of the motor are linear and core losses are neglected.
- Induced currents in the rotor due to stator harmonic fields are neglected.
- The electromotive force ea varies sinusoidal with the rotational electric angle θe.
- The cogging torque of the motor is negligible.
- Due to the surface mounted permanent magnets, winding inductance is constant (doesn’t change with the electric angle θe).
- Voltage drop across the diodes, thyristors and the connecting wires are ignored.

All above mentioned assumptions are practically satisfied. The magnetic and electric circuit is linear within the range of operation. Power losses in the inverter are practically negligible since the switching frequency of this low speed motor is low. Also the cogging torque doesn’t exist since there is coreless winding.

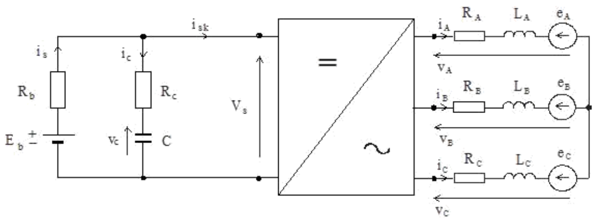

Fig. 2 Circuit diagram of supply-inverter-motor system

The equations that describe the model are as follows:
Voltage equations:

Voltage equation at the source side:

$$V_s = E_b - i_s . R_b - i_c . R_c \tag{1}$$

$$V_s = V_c + i_c . R_c \tag{2}$$

$$i_s = i_{sk} + i_c \tag{3}$$

Where:

$E_b$ and $R_b$ – voltage and resistance of the source (battery)
Rc – resistance in the capacitor circuit
is – source circuit current
isk – converter input current
Vc – voltage across capacitor

$$V_c = \frac{Q_c}{C} \qquad (4)$$

$Q_c$ – Charge in the capacitor
C – Capacitance
$i_c$ - Current flowing through the capacitor

$$i_c = \frac{dQ_c}{dt} \qquad (5)$$

Voltage equations at the motor side (fig. 4) are:

$$V_a = V_n + V_{sa}$$
$$V_b = V_n + V_{sb}$$
$$V_c = V_n + V_{sc} \qquad (6)$$

Where:

$V_{sa}$, $V_{sb}$, $V_{sc}$ are the inverter output voltages that supply the 3-Φ winding.
$V_a$, $V_b$, $V_c$ are the voltages across the motor armature winding.
$V_n$ – voltage at the neutral point

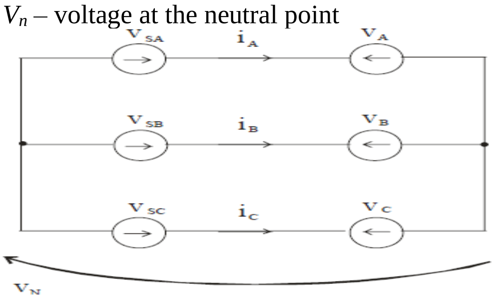

Fig. 3 Scheme to voltage equation at motor side

The equation across the motor winding

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R_a & 0 & 0 \\ 0 & R_b & 0 \\ 0 & 0 & R_c \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L_a & L_{ab} & L_{ac} \\ L_{ba} & L_b & L_{bc} \\ L_{ca} & L_{cb} & L_c \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \qquad (7)$$

Or in shorter version

$$V_a = R_a . I_a + L_a \frac{dI_a}{dt} + e_a \qquad (8)$$

Since the resistances of all the phases are equal

$$R_a = \begin{bmatrix} R_a & 0 & 0 \\ 0 & R_a & 0 \\ 0 & 0 & R_a \end{bmatrix} \qquad (9)$$

Since the self- and mutual inductances are constant for surface mounted permanent magnets and the winding is symmetrical:

$$L_a = L_b = L_c = L$$
$$L_{ab} = L_{ba} = L_{ca} = L_{ac} = L_{bc} = L_{cb} = M \qquad (10)$$

Substituting equations (8) and (9) in equation (7) gives the PMBDCM model as

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R_a & 0 & 0 \\ 0 & R_a & 0 \\ 0 & 0 & R_a \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \qquad (11)$$

The stator phase currents are constrained to be balanced i.e.

$$i_a + i_b + i_c = 0 \qquad (12)$$

This leads to the simplifications of the inductances matrix in the models as the

$$Mi_b + Mi_c = -Mi_a \qquad (13)$$

Therefore in the state space form

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R_a & 0 & 0 \\ 0 & R_a & 0 \\ 0 & 0 & R_a \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & 0 \\ 0 & 0 & L-M \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \qquad (14)$$

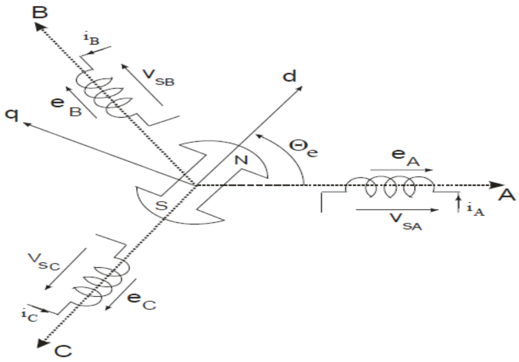

Fig. 4 Position of the rotor with respect to the phase A

The electromotive force induced in the phase *A* winding (see Fig. 4):

$$e_a = K_e \omega_m \, \mathrm{f_a}(\theta_e) \qquad (15)$$

Where

$K_e$ – Constant
$\omega_m$ -rotor angular speed

$$\omega_m = \frac{2}{P} \frac{d\theta_e}{dt} \qquad (16)$$

$\theta_e$ - Electrical angle (from fig. 4)
P- Number of pole pairs

Equation that links the supply and motor sides:

$$i_{sk} = \frac{1}{v_s}(i_a V_{sa} + i_b V_{sb} + i_c V_{sc}) \qquad (17)$$

This is derived from the equality of the powers at input and output of the inverter. Supply voltages for the phases ($V_{sa}$, $V_{sb}$ and $V_{sc}$) results from the operation of converter.

Motion equation:

$$T_J + T_D + T_S + T_L = T_e \qquad (18)$$

Where,

Torque due to Inertia, $T_J = J \frac{d\omega_r}{dt}$

where, *J* – Moment of inertia,

Torque due to viscous friction, $T_D = B . \omega_r$ where, *B* – Friction coefficient,

Torque due to Coulomb Friction, $T_s = \sin(\omega_r) T_d$

and, load torque, $T_L$

Electromagnetic torque for 3-phase motor

$$T_e = \frac{e_a i_a}{\omega_m} + \frac{e_b i_b}{\omega_m} + \frac{e_c i_c}{\omega_m} \qquad (19)$$

### A. *Voltage Source Inverter*

Three phase bridge inverters are widely used for ac motor drives and general purpose ac supplies. The input dc supply is usually obtained from a battery or from a single phase or three phase utility power supply through diode bridge rectifier and LC or C filter as shown in Fig. 5. The capacitor tends to make the input dc voltage constant. This also suppresses the harmonics fed back to the dc source.

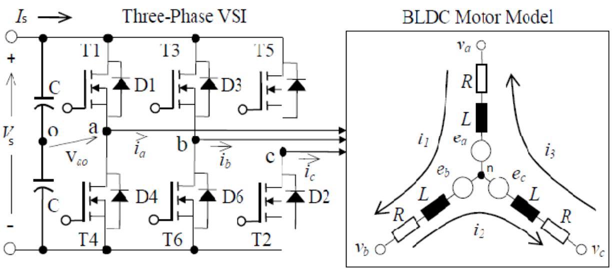

Fig. 5 Configuration of BLDC motor and Three Phase VSI system

The output voltages are plotted as shown in Fig. 6 below.

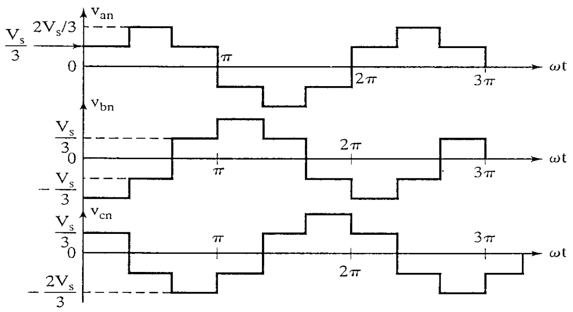

Fig. 6 Three phase output voltages on a three-phase VSI in 1800 mode

### B. *Current Controller*

The commanded value of current is compared to the actual phase currents of the motor and the errors are processed through a current controller.

The current controller can be of two types:

1) *PWM Current controller*
2) *Hysteresis current controller*

#### 1) PWM current controller:

The current error is fed into a controller, which could be proportional (P), proportional plus integral (PI) or proportional, integral and differential (PID). The most commonly used controller among them is the PI controller. The current error is amplified through this controller and emerges as a control voltage, Vc which is equivalent to the gating pulse of the inverter. Its realization is as follows:

The control voltage is compared with a ramp signal to generate on and off times, as shown in Fig. 7. On signal is produced if the control voltage is greater than the ramp signal; Off signal is generated when the control signal is less than the ramp signal.

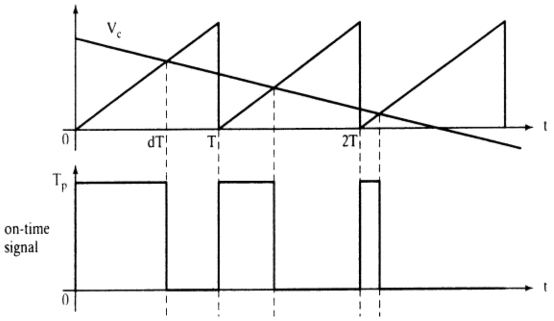

Fig. 7 Generation of base drive signals from current error

#### 2) Hysteresis current controller:

Instantaneous current control is not exercised in the PWM current controller; it acts only once a cycle. In between two consecutive switching, the current may exceed the maximum limit; if the PWM controller is sampled and held once a switching cycle, then the current is controlled on an average but not on an instantaneous basis. The Hysteresis controller overcomes such a drawback by converting a voltage source into a fast acting current source. The current is controlled within a narrow band of excursion from its desired value in the hysteresis controller. The hysteresis window determines the allowable or preset deviation of current , Δi. Commanded current and actual current are shown in Fig. 8 with the hysteresis windows. The voltage applied to the load is determined by the following logic:

$$\begin{array}{ll} i_a \le i_a^* - \Delta i, & set\ v_a = V_s \\ i_a \ge i_a^* + \Delta i, & reset\ v_a = 0 \end{array}$$

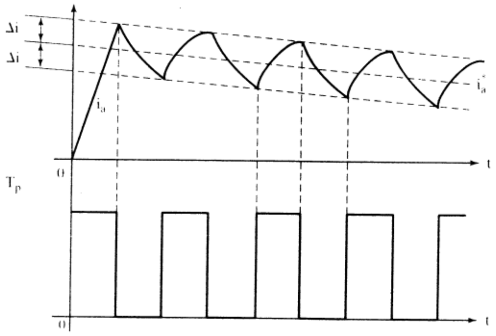

Fig. 8 Hysteresis current controller

The window Δi can either be externally set as a constant. The chopping frequency is a varying quantity, unlike the constant frequency in PWM controller. This has the disadvantage of higher switching losses in the devices with increased switching frequency.

A qualitative comparison of the PWM and hysteresis controllers is summarized in the table 1 below.

TABLE 1:- COMPARISON OF CURRENT CONTROLLERS

| **Characteristics** | **Current controllers** | |
|---|---|---|
| | **Hysteresis** | **PWM** |
| Switching Frequency | Varying | Fixed at carrier frequency |
| Speed of Response | Fastest | Fast |
| Ripple current | Adjustable | Fixed |
| Filter size | Dependent on Δi | Usually small |
| Switching losses | Usually high | Low |

### C. *Overall Speed Controller*

The closed loop speed regulator compensates for any changes in the characteristics of the drive caused by changes in load or by outside influences such as line voltage and ambient temperature. With a closed loop speed regulator, the most important characteristic of the drive is its ability to rapidly respond to changes in requirements for torque. The fig. 9 shows the overall closed loop speed controlled BLDC drive.

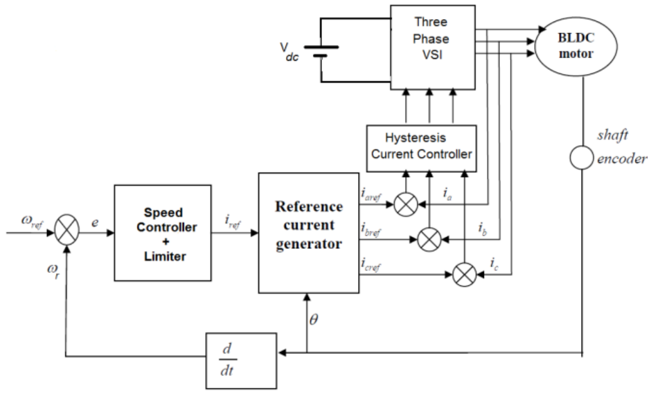

Fig. 9 Overall closed loop speed control of BLDC Motor

The speed controllers that are designed to control the speed of BLDC motor used several conventional and numeric controller types, the controllers can be: proportional integral (PI), proportional derivative (PD), proportional integral derivative (PID). Because of its simplicity PID control is widely used in industrial applications. Stability of PID controller can be guaranteed theoretically, and zero steady-state tracking error can be achieved for linear plant in the steady-state region.

## IV. TYPES OF CONTROLLERS

### A. *Conventional PID Controller*

The proportional – integral – derivative (PID) controller operates the majority of the control systems in the world. It has been reported that more than 95% of the controllers in the industrial process control applications are of PID type as no other controller match the simplicity, clear functionality, applicability and ease of use offered by the PID controller. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly. In ideal or non-interacting form, the PID controller as shown in the fig 10 is described by the following transfer function:

$$G_c(s) = k_c\left(1+\frac{1}{\tau_i s}+\tau_d s\right)$$

Where, $k_c$- Proportional gain, $\tau_i$- Integral time, $\tau_d$- Derivative time

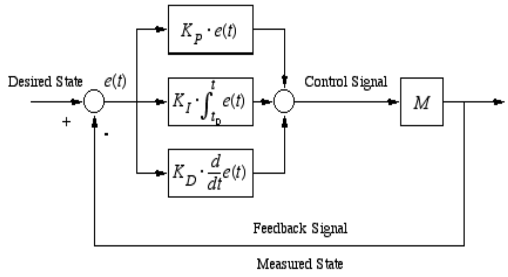

Fig. 10 Block diagram of a PID controller

With the PID controller, there are no oscillations with least settling time.

### B. *Adaptive Control Techniques*

Adaptive control use to change the control algorithm coefficients in real time to compensate for variations in environment or in the system itself. In drives, electrical and mechanical parameters do not remain constant. A sudden increase of $T_l$ or J reduces speed. These effects can be reduced by high gain negative feedback loop [5]. But this may cause under damping or instability. Therefore real time adaptation of the controller is required. Different adaptive control techniques are:

1) Model Reference Adaptive Control (MRAC)
2) Sliding mode control
3) Fuzzy control
4) Neural network control

One of the most successful expert system techniques applied to a wide range of control applications has been the Fuzzy Set Theory, which has made possible the establishment of "intelligent control".

### C. *Fuzzy Controller*

Fuzzy logic has rapidly become one of the most successful of today's technology for developing sophisticated control system. In industrial electronics the FLC control has become an attractive solution in controlling the electrical motor drives with large parameter variations like machine tools and robots [5]. Fuzzy logic controllers are designed particularly for non-linear dynamic systems with many inputs and outputs which are so complex, that it is very difficult or even impossible to build exact mathematical model. The basic structure of a fuzzy logic controller is shown in Fig. 11. Its fundamental components are Fuzzification, control rule base, inference mechanism and defuzzification.

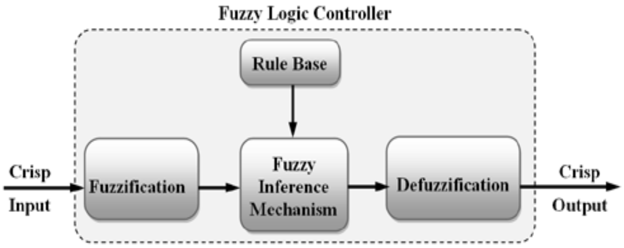

Fig. 11 The structure of a fuzzy logic controller

## V. FUZZY CONTROLLER DESIGN FOR BLDC DRIVE

In the system block diagram shown in fig. 12, the fuzzy controller is directly connected to the process of the system and the feedback signal is sent to the fuzzy controller directly.

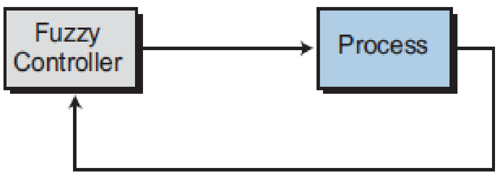

Fig. 12 Fuzzy controller design for BLDC Drive

By considering BLDC drive as the process, the fuzzy speed controller is designed as follows.

The speed of the motor is compared with its reference value and the speed error is processed in Fuzzy logic speed controller.

$$e = \omega_{ref} - \omega_r$$

Where, $\omega_{ref}$ – Reference speed
$\omega_r$ - Speed of the motor

The change in error is obtained from the derivative of error as

$$\Delta e = de/dt$$

The output variable is the torque component of the reference $i_{ref}$. The controller observes the pattern of the speed loop error signal and correspondingly updates the output so that the actual speed $\omega_r$ matches the command speed $\omega_{ref}$.
The input variable speed error and change in speed error is defined in the range from

$$-1 \leq e \leq +1$$
$$-1 \leq \Delta e \leq +1$$

and the output variable torque reference current $i_{ref}$ is defined in the range from

$$-1 \leq i\_ref \leq +1$$

The overall block diagram of the drive with fuzzy controller is shown in the fig. 13 below.

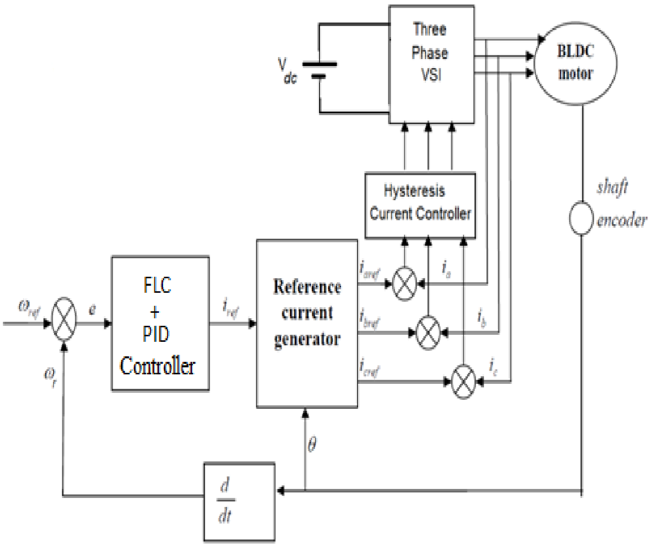

Fig. 13 Fuzzy speed control block diagram of the BLDC motor

## VI. SIMULINK MODELS AND RESULTS

For a BLDC motor with the following specifications, the overall closed loop block diagram of the drive is obtained as shown in fig. 14

P=4; Motor rating=0.5HP; $R_a$=0.7Ω/ph; L=0.0272H; M=0.015H; $K_b$=0.5128V/ rad/ sec; $K_t$=0.49N-m/A; J=0.0002kg-m/s$^2$; B=0.02N-m/ rad /sec; $V_{dc}$=160V; $f_c$=2KHz; N=700rpm; $V_{cm}$=10V

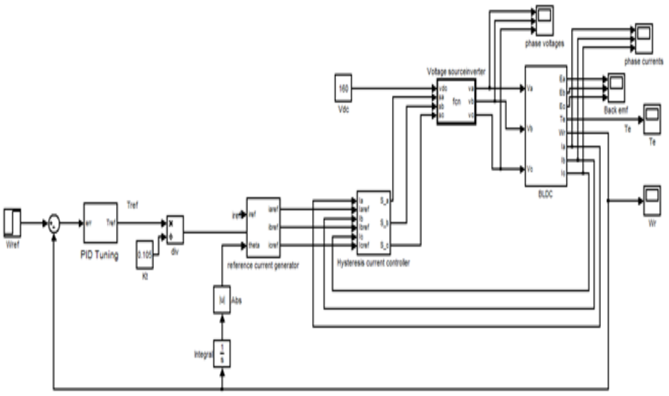

Fig. 14 Simulink model of the BLDC Motor Drive

For PID Controller, with Tyerus – Luben Tuning method, the controller parameters are chosen as

$$k_p = k_u/2.2 = 1.70455$$
$$\tau_i = 2.2\tau_u = 9.9\times10^{-4}$$
$$\tau_d = \tau_u/6.3 = 7.14286\times10^{-5}$$
$$k_i = k_p/\tau_i = 1721.76263$$
$$k_d = k_p\ \tau_d = 1.2175\times10^{-4}$$

With the above parameters, the speed response obtained from simulation are shown in fig. 15 below.

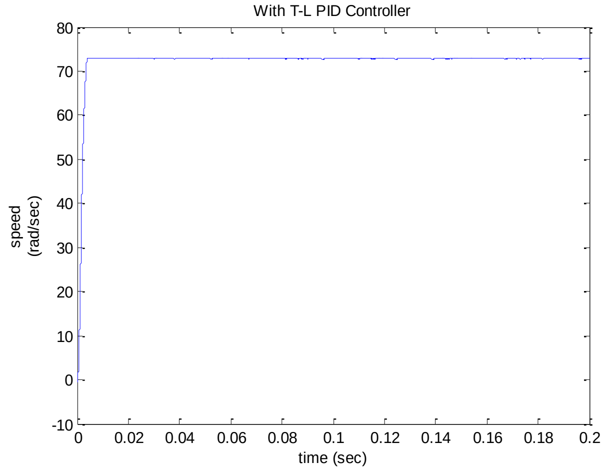

Fig. 15 Response with Conventional PID Controller

Rise time = 0.003sec
Settling time = 0.004sec
Peak Overshoot = 0.124 rad/sec
Steady state error = 0.507rad/sec

When the simulations are carried out using Fuzzy Controller instead of PID, the following speed response is obtained as shown in fig. 16 below.

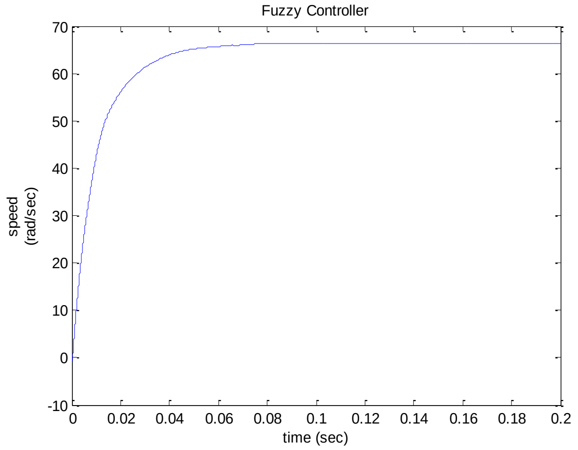

Fig. 16 Response with Fuzzy Controller

Rise time = 0.02sec
Settling time = 0.03sec
Peak Overshoot = 0
Steady state error = 2.633 rad/sec

When the simulations are carried out using Fuzzy +PID Controller using Tyerus-Luben PID Tuning Method, the controller parameters are chosen as below.

$k_p=k_u/2.2=1.8182$
$\tau_i=2.2\tau_u=0.0176$
$\tau_d=\tau_u/6.3=1.26984\times10^{-3}$
$k_i=k_p/\tau_i=103.3058$
$k_d=k_p\ \tau_d=2.3088\times10^{-3}$

The speed response obtained from Fuzzy + PID Controlled BLDC Motor drive is as shown in fig. 17 below.

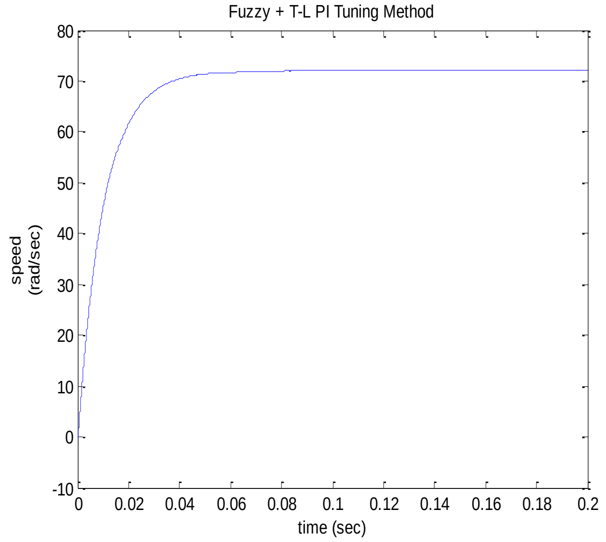

Fig. 17 Response with Fuzzy + PID Controller

Rise time = 0.0125sec
Settling time = 0.034sec
Peak Overshoot = 0
Steady state error = 1.2355rad/sec

The three phase trapezoidal back emf waveforms are obtained from the rotor position and the actual phase currents obtained from the hysteresis current controller are plotted in the fig. 18 and fig. 19 below.

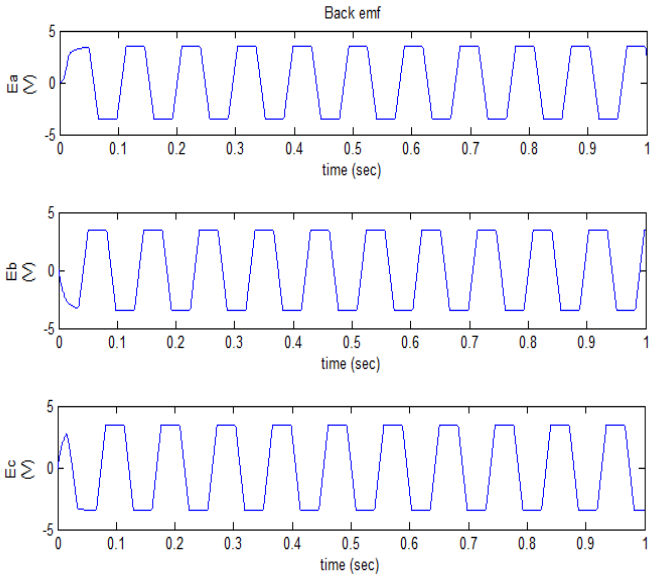

Fig. 18 Three phase Trapezoidal back emf

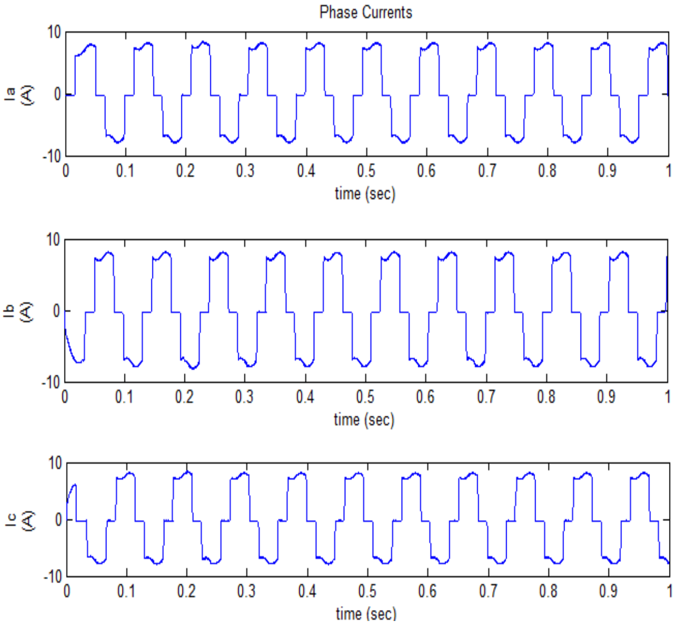

Fig. 19 phase currents developed in the motor

## VII. CONCLUSION

BLDC motor gained popularity rapidly in the market due to its advantages over the other motors. A BLDC motor drive is a system in which a permanent magnet excited synchronous motor is fed with a variable frequency inverter controlled by a shaft position sensor. BLDC motors have electronic commutator, instead of brushes, thus they have higher efficiency, long operating life, rugged construction and noiseless operation. BLDC motors find applications in every segment of the market such as home appliances, industrial control, automation, aviation etc. In these applications, the motor should be precisely controlled to give the desired performance. The speed controllers that are designed to control the speed of BLDC motor use several conventional and numeric controller types, which include proportional integral (PI), proportional derivative (PD), proportional integral derivative (PID).

Conventional PID controllers with Tyreus-Luyben tuning method are used to control the speed of BLDC drive.

But, a disadvantage with the conventional PID Controller is the peak overshoot. In order to reduce the peak overshoot and improve the transient performance of the drive, a Fuzzy controller is implemented..

It is observed that the rise time is increased, peak overshoot is zero and settling time is reduced to more than half for fuzzy tuned PID controller when compared to conventional PID controller. Transient and steady state responses are improved by using fuzzy tuned controllers than using the conventional controllers.

## VIII. FUTURE SCOPE

There are a large number of possible avenues for advancement of control of BLDC drives. A major research area is that of sensorless control. This typically means that measures have been taken to eliminate the expensive rotor position sensor, but not necessarily current or voltage sensors.

In short, the BLDC motor drive is effective in high-performance drive applications. Rapid torque response is readily achieved as vector control of BLDC drives is much more straight forward than it is for induction motor drives. The capital cost can be high, but the high efficiency can at least partially offset this in high-power applications. For these reasons, the BLDC drive is expected to continue to be competitive for the near future.

For attaining better results, Work can be extended by adding Neuro-Fuzzy technique to the system. The field of Neuro – Fuzzy technology plays a key role in controlling Motor drives. The present work is concluded with sophisticated applications of BLDC drive control.

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