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PERFORMANCE ANALYSIS OF PERMANENT MAGNET SYNCHRONOUS MOTOR WITH PI & FUZZY CONTROLLERS

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Abstract— **An automatic control system is used to maintain system output within desirable limits by means of a control action. The error detector detects any deviation of the output from the reference input and gives an actuating signal for control action through a controller. Thus controllers play a major role in the control action a controller.The PI controller will control the speed, voltage and current. This project has two loops which contains the outer loop as a hysteresis loop and the inner loop as a pi controller loop. A feedback is given as it has an advantage over the open loop control.The modelling of the PMSM machine is done, so that the specification could be varied with respect to the required output. The output of the modelling is fed back to the controller as one of its input. The controller will get the measured input and the actual input and it will give the error output which is again fed to the machine.This project aims at modelling, simulation & performance analysis of Permanent Magnet Synchronous Motor with PI, Fuzzy tuned controllers. The inputs such as step are given to the PMSM as load disturbance and the response of the controllers are studied.**

***Key terms*—PI, Controllers, transformations, and currents.**

I INTRODUCTION

One of the most popular controllers is the proportional plus integral (PI) type, which is widely used in the field-orientated control and industrial applications of PMSMs. Since it is often difficult to measure the PMSM parameters, manipulation tuning is a frequently-used way to determine the PI coefficient instead of theoretical.Selection of the gain and time constant of such controllers by using symmentric-optimum principle is straight forward if the d-axis stator current is assumed to be zero. In the presence of the d-axis stator current,the d and q current channel are cross coupled and th model is non linear,as a result of the torque term.

Fuzzy control has been making rapid progress in recent trends.Fuzzy logic control has been widely exploited for nonlinear,high order & time delay system. The effective and efficient control using fuzzy logic has emerged as a tool to dealwithuncertain, imprecise or qualitative decision making problems.KvětoslavBelda, 2013, proposed a paper which deals with a mathematical modeling of the three-phase Permanent Magnet Synchronous Motors (PMSM) and their model-based control. These motors are used in drives of robots and machine tools. The construction of their mathematical model is discussed here with respect to a model-based control design. The model is composed via mathematical-physical analysis.[1].

In paper [2], Maryam Imanzadeh, 2014, as this paper shows, the driver with anti-windup and fuzzy highperformance and robust PI controller has been suggested for Permanent Magnet Synchronous Motor (PMSM). This controller is suggested for the design of the robust driver for three phase PMSM and the cost reduction of its control system. It's useful for the industrial application and automation and ultimately speed control and the improvement of the dynamic behavior of the PMSM. Antiwindup control strategy prevents the increase of the output beyond itssaturation point. So, it avoids the saturation.

The authors of [3] Wang Lina, on 2014, proposed a paper presents an auto-tuning method for a proportion plus integral (PI) controller for permanent magnet synchronous motor (PMSM) drives, which is supposed to be embedded in electro-mechanical actuator (EMA) control module in aircraft. The method, based on a relay feedback with variable delay time, explores different critical points of the system frequency response. The Nyquist points of the plant can then be derived from the delay time and filter time constant.The coefficients of the PI controller can then be obtained by calculation while shifting the Nyquist point to a specific position to obtain the required phase margin.

Mari´anT´arn´ıkon 2011, proposed a paper the classical theory of the direct Model Reference Adaptive Control is used to develop a control algorithm for Permanent Magnet Synchronous Motor (PMSM) in [4]. A PMSM model widely used in electric drives community is considered as base for control system development. Conventionally used controllers are replaced by adaptive ones. The resulting control system adapts to changes in any of PMSM parameters..

B.Jaganathan proposed a concept on 2010 regardingTuning of PID controllers is one of the important ways to achieve desired performance of a system in[5]. PMSM drives are the upcoming parts in the field of Hybrid Electric Vehicles, etc., Many methods are available for the tuning of PID controllers. In this paper an online tuning of PID controllers using Zeigler-Nichol's method for PMSM drives is presented to improve the transient response of the drive. A conventional PID controller is also used to control the machine.

The authors of [6], Ying Wu, on 2012, proposed a mathematical model of the permanent magnet linear synchronous motor (PMLSM), three-closedloop control system is presented in this paper. Combined the advantages of traditional PID control algorithm andfuzzy control algorithm, according to the characteristics of linear motor and the possible factors of uncertainty, a set of adaptive fuzzy PID control system is designed for the speed loop of the proposed control system, moreover, fuzzyinference rules is established to realize the Fuzzy PID controlling of the speed loop. In the end, the simulation models of the motor and the whole control system are built on Matlab/Simulink platform to compare and analyzethefuzzyPID control and conventional PID control. Simulation results show that the designed fuzzy PID speed loop controller can significantly improve the response performance of linear motor.

II PERMANENT MAGNET SYNCHRONOUS MOTOR

The Permanent Magnet Synchronous motor (PMSM) is a rotating electric machine where the stator is a classic three phase stator like that of an induction motor and the rotor has surface-mounted permanent magnets. In this respect, the Permanent Magnet Synchronous motor is equivalent to an induction motor where the air gap magnetic field is produced by a permanent magnet. The use of a permanent magnet to generate a substantial air gap magnetic flux makes it possible to design highly efficient PM motors.

A PM Synchronous motor is driven by sine wave voltage coupled with the given rotor position. The generated stator flux together with the rotor flux, which is generated by a rotor magnet, defines the torque, and thus speed of the motor. The sine wave voltage output have to be applied to the 3- phase winding system in a way that angle between the stator flux and the rotor flux is kept close to 90° to get the maximum generated torque. To meet this criterion, the motor requires electronic control for proper operation.

For a common 3-phase Permanent Magnet Synchronous motor, a standard 3-phase power stage is used. The same power stage is used for AC induction and

BLDC motors. Rotor doesn't require any supply nor does it incur any loss.

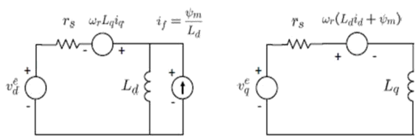


Fig 1 equivalent circuit of PMSM

The three phase frame is converted into two phase stationary frame so that the accuracy over the output will be very high. The two phase frame contains the d axis and q axis. The d axis stands for direct axis and q axis stands for quadrature axis. The equivalent circuit diagram is shown. From this circuit we derive the equations for the modelling of the PMSM. Then the Park's transformation is implemented.

The PMSM will get the input and the load disturbance is given then the output such as the winding current, speed and the torque is observed. The PI controller is designed by Ziegler Nicholas method and the Fuzzy is done by Sugeno method. And finally the Fuzzy logic controller will have the best output accuracy.

1. PARK'S TANSFORMATION

The d-q axis is two axis frame which enables us to access in an efficient way and this transformation from 3-phase to 2-phase is thro the Park's transformation.

Fig 2 the equations for three phase to two phase d-q frame

Theta is given so that the output could be obtained with respect to the input. Theta gives the position of the rotor and it is obtained from the modelling of the PMSM. The d-q transformation will get the output from the transformer or the 3-ph source. It is then converted into a two phase by means of the equation derived from the equivalent circuit diagram of the PMSM in the direct and quadrature axis. The axis will always will be in phase shift. So theta is needed for bringing up the best output

2. FUZZIFICATION

The first block inside the controller is fuzzification, which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degree of membership for each linguistic term that applies to that input variable.

3. DEFUZZYFICATION

Defuzzification is a technique of covering the final combined fuzzy conclusion into a crisp one. The defuzzification output is in turn applied to the plant.The following four strategies are commonly used in defuzzification:

1. Max criterion method.
2. Mean of maximum method.
3. Center of area method(center of gravity) and
4. Weighted average method.

Of the four method, the area method(center of gravity) is the most widely used technique since the defuzzification value tends to move smoothly around the output fuzzy region, i.e. change in fuzzy set topology one model to the next usually result is smooth transition in the expected value.

III CONTROLLERS

Any system, whose outputs are controlled by some inputs to the system, is called a control system. Uses model along with feedback provided by system output to generate a new system input. Controller needs accurate mathematical model of system.

PI CONTROLLER

The P stands for the Proportional and the I stands for the Integral controller. A PI controller is a special case of PID controller in which the derivative (D) of the error is not used. PID controller calculation involves three separate constant parameters. P depends on present error. I depends on accumulation of past error. D depends on prediction of future errors.

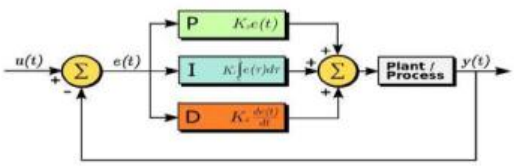


Fig3 PID controller

The Proportional has a gain of K_p and the Integral has a gain of K_i. The equation for this controller output is:

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau$$

The proportional gain makes a change to the output that is proportional to the current error value. But the contribution of the integral term is proportional to both the magnitude of the error and the duration of the error.

IV MODELLING OF PMSM

The PMSM is a machine which consists of stator and rotor. The PMSM flux distribution is sinusoidal. Number of conductors is not same in each portion due to sinusoidally distributed conductors. No external field excitation is required because of PM in rotor.

Permanent magnet motors use of permanent magnets to establish the flux instead of creating it from the stator winding. Replacing the electromagnetic excitation by PM has several advantages. Most obvious one is the absence of excitation losses in PM motor. It gives sinusoidal distribution of magnetic flux in the air gap.

According to the classical theory of electrical machines, the PMSM drive system is equivalent to that of the DC motor when a decoupling control is possible known as vector control. The vector control decouples the torque component and flux producing current in the motor through its stator excitation by applying instantaneous vector theory.

Permanent magnet synchronous machines have been widely used in variable speed drives for over a decade now. The most common applications are servo drives in power ranges from a few watts to some kilowatts.

A permanent magnet synchronous machine is basically an ordinary AC machine with windings distributed in the stator slots so that the flux created by stator current is approximately sinusoidal and uses permanent magnets to produce the air gap magnetic field rather than using electromagnets. These motors have significant advantages, attracting the interest of researchers and industry for use in many applications.

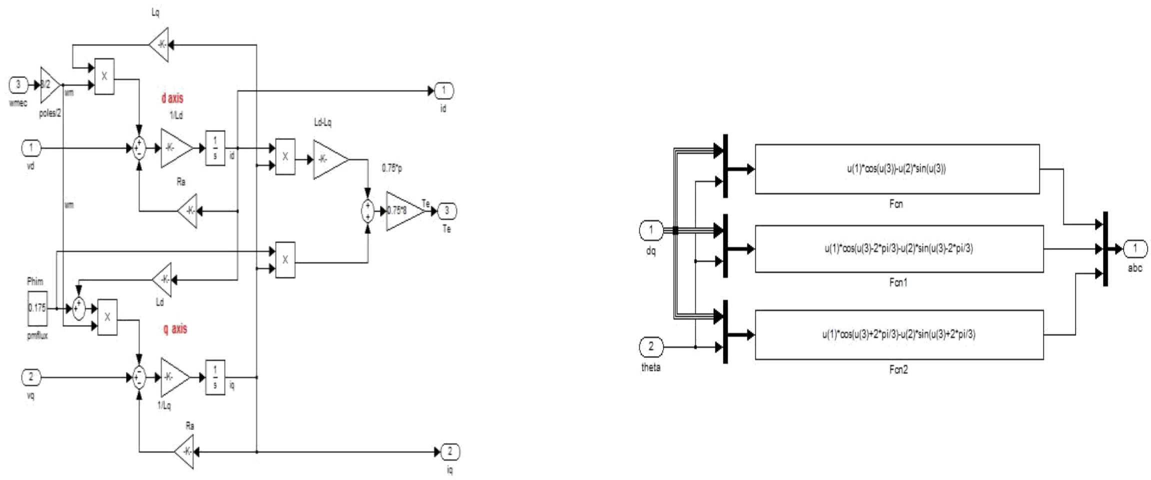


Fig 4 Modeling of PMSM

The modeling of PMSM is done so that different input could be given at different requirement. The following assumptions are made before establishing the mathematical model of PMSM:

1. Neglects the saturation of the electric motor ferrite core.
2. Neglects turbulent flow and hysteresis loss in electric.
3. The current in electric motor is symmetrical three phase sinusoidal current.

V SIMULATION RESULTS

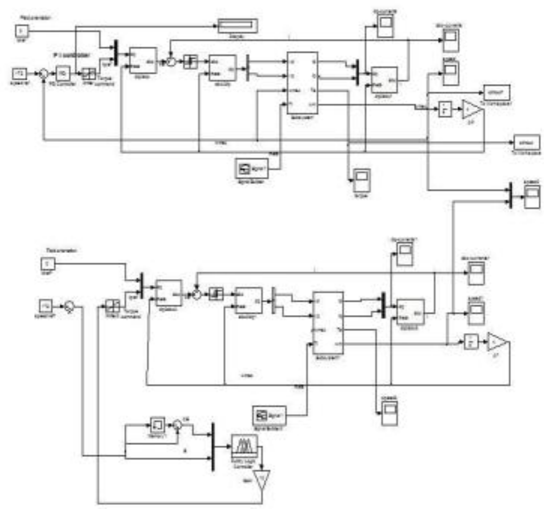


Fig 5 Simulation of PMSM

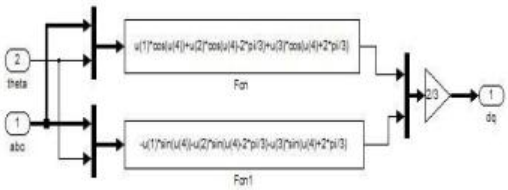


Fig 7 ABC to Dq transformation

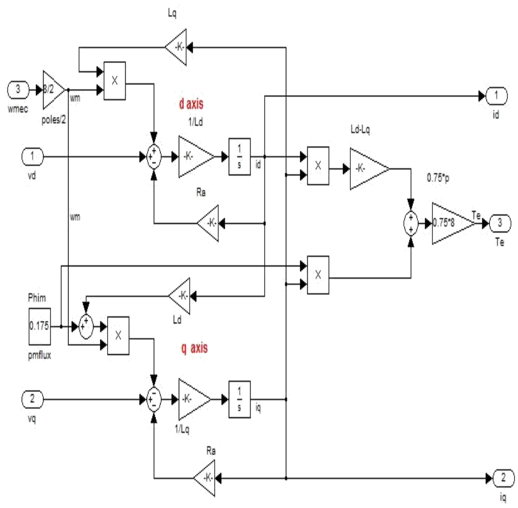


Fig 6 Dq to ABC Transformation

Fig 8 Modelling of PMSM DRIVE

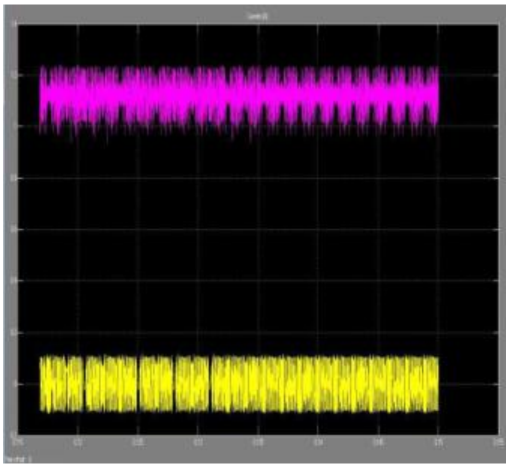


Fig 9 Dq currents

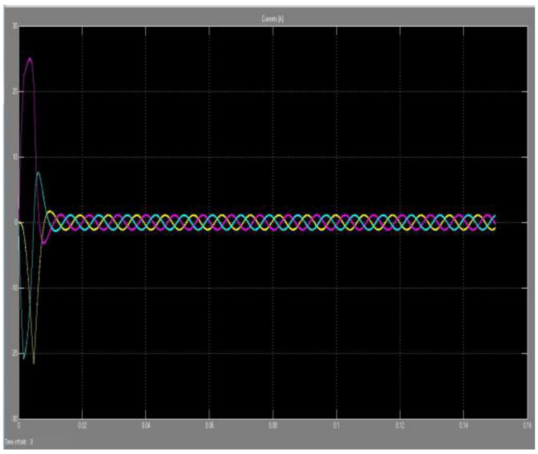


Fig 10 ABC currents

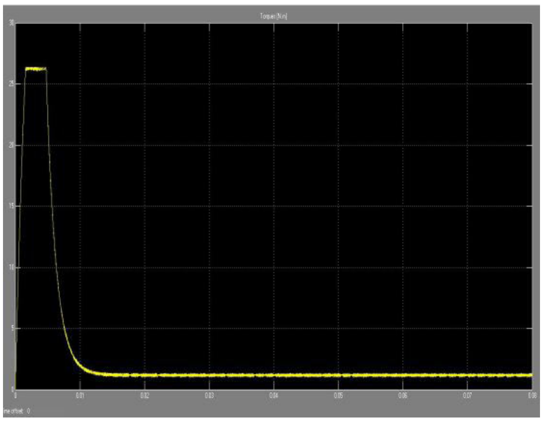
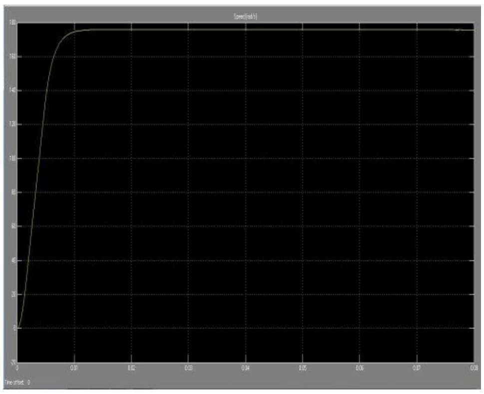


Fig 11 Speed Response



VI CONCLUSION

From the above results we came to know about the performance and characteristics of PI and FUZZY LOGIC CONTROL. Among the rise time of these controllers the rise time of the FUZZY is small, this helps us to know that the response time of FUZZY controller is less when compared to the other two controllers.This can be known from the general concept that as the rise time small speed of response is fast. Then in FUZZY controller the steady state error also small or negligible. We also know that the peak time and settling time of FUZZY is small when compared to that of PI controller.

We know that smaller the peak time and settling time faster is the response of the system. From the above parameters we came to know that for the speed control of PMSM using FUZZY CONTROLLER is suitable and more efficient than the PI controller.

In the above process we made the comparison of output of PI and FUZZY controller and concluded that the FUZZY CONTROLLER performs the best as it has a smaller settling time than compared with the PI controller.

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