DYNAMIC AND STEADY STATE PERFORMANCE OF PMSM MOTOR DRIVE WITH PREDICTIVE FUZZY LOGIC CONTROLLER

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ABSTRACT:
A permanent magnet synchronous motor (PMSM) is a synchronous electric motor whose in place of field consists of permanent magnets. The main difference between a permanent magnet synchronous motor (PMSM) and an induction motor is in the rotor. An electric drive performance is highly influenced by the potential of the controller employed. For high-performance Permanent Magnet Synchronous Motor (PMSM) drive, Vector control techniques are preferred over other methods. Due to the nonlinear dynamics and time-varying parameters of PMSM, its control is a significant issue. This paper investigates the application of a fuzzy logic controller for the speed control of Field oriented PMSM. The Fuzzy Logic is based on the speed error and change of error measured as the difference between the motor speed and the reference speed. The Fuzzy Logic controller performance is also compared to a PI controller. The design analysis and simulation of the proposed system is done using MATLAB and the simulation results of using PI controller and FLC are analyzed. It's been observed that the Fuzzy Logic controller gives better response for speed control of PMSM drive as compared to the PI controller.

Keywords- Permanent Magnet Synchronous Motor (PMSM); Fuzzy Logic; Proportional Integral (PI); Performance Comparision

1. INTRODUCTION:

Permanent Magnet Machines are electromechanical devices using magnets to produce a magnetic flux in the air gap. There are two major classifications of ac motors. The first one is induction motors that are electrically connected to power source through electromagnetic coupling, the rotor and the stator fields interact, creating rotation without any other power source The second is synchronous motors that have fixed stator windings that are electrically connected to the ac supply with a separate source of excitation connected to field windings when the motor is operating at synchronous speed. Among the synchronous motor types the permanent magnet synchronous motor (PMSM) is one possible design of three phase synchronous machines. The stator of a PMSM has conventional three phase windings. In the rotor, PM materials have the same function of the field winding in a conventional synchronous machine. Their development was possible by the introduction of new magnetic materials, like the rare earth materials. The use of a PM to generate substantial air gap magnetic flux makes it possible to design highly efficient PM motors.

2. INVERTER OPERATION:

An inverter refers to a power electronic device that converts power in DC form to AC form at the required frequency and voltage output. In this drive system, three-phase inverter which converts a DC input into a three-phase AC output. Its three arms are normally delayed by an angle of 120° so as to generate a three-phase AC supply. The inverter switches each has a ratio of 50% and switching occurs after every T/6 of the time T at 60° angle interval. The switches S1 and S4, the switches S2 and S5 and switches S3 and S6 complement each other. It mainly has two modes of conduction- 120° and 180°.

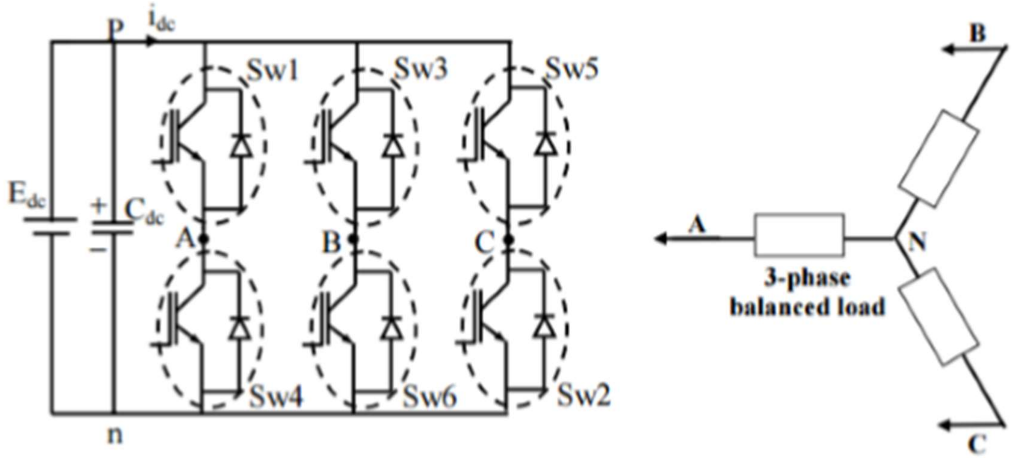

Figure 1 Circuit for three-phase inverter

Here 120° mode of conduction is used to eliminate even and triplen harmonics. In this mode of conduction, each electronic device is in a conduction state for 120°. It is most suitable for a delta connection in a load because it results in a six-step type of waveform across any of its phases. Therefore, at any instant only two devices are conducting because each device conducts at only 120°, unlike that observed in 180° mode of conduction. Rotor position information is very crucial for field oriented (Vector) control. The coordinate transformation uses the value of the rotor position in order to handle the stator current vector projection in a rotating frame. The electrical position is not directly used in this transform but the sine and cosine values of it are used. Whether the control scheme is sensor based or sensorless, position of the rotor is required. Control of PMSM can be categorized as sensor based and sensor-less control. Sensor based control: in this control method, sensors are used to indicate the position of the rotor, for instance incremental encoder, absolute encoder, resolver etc. By using mechanical sensors, it is simple to measure speed and position for feedback to the controller.

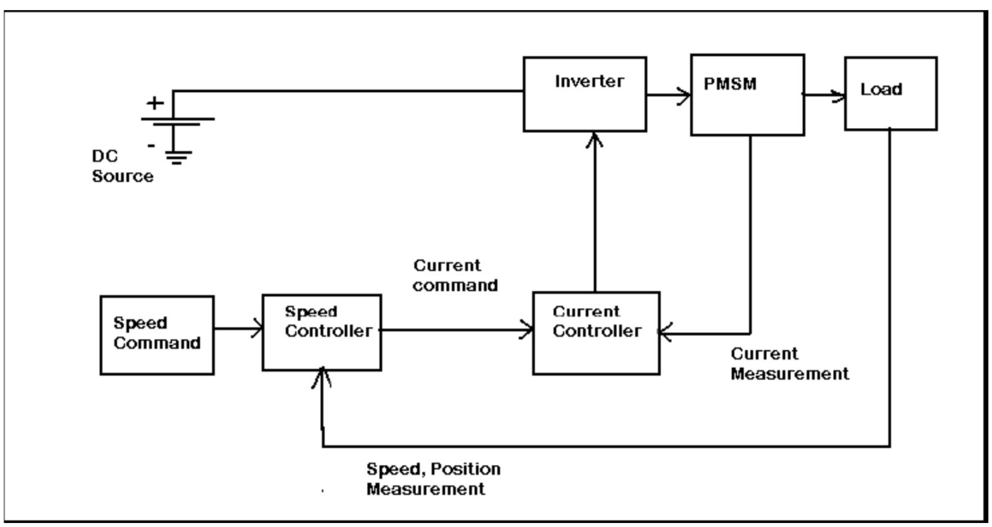

Figure 2 Block Diagram of PMSM Drive system

3. MODELING OF PMSM DRIVE:

The design of PMSM is similar to the standard wound rotor synchronous machine without damper winding and excitation given by the permanent magnet. Hence, by neglecting the equations of damper winding and field current dynamics the *d* - *q* model of PMSM can be derived from the model of Synchronous machine. The model of PMSM had been derived using the following assumptions:

- Saturation is neglected.
- The induced EMF is sinusoidal.
- Eddy currents and hysteresis losses are negligible.
- There are no field current dynamics.

$$V_d = R_s i_d + L_d i_d - L_q \omega_r i_q \qquad (1)$$

$$V_q = R_s i_q + L_q i_q + L_d \omega_r i_d + \Psi_f \omega_r \qquad (2)$$

$$\Psi_d = L_d i_d + \Psi_f \qquad (3)$$

$$\Psi_q = L_q i_q \qquad (4)$$

$$\omega_m = \omega_r \left(\frac{\mathbf{2}}{\boldsymbol{p}}\right)$$

The equation of motor dynamics is;

$$\mathrm{T_e} - \mathrm{T_m} = \mathrm{J}\frac{\mathrm{dw}}{\mathrm{dt}} + \mathrm{Bw} \qquad (5)$$

The torque produced by the PMSM can be expressed as,

$$\mathrm{T_e} = \frac{3}{2}\mathrm{P}\left[\varnothing_\mathrm{M} + (\mathrm{L_d} - \mathrm{L_q})\mathrm{i_d}\right]\mathrm{i_q} \qquad (6)$$

The net-torque produced can be considered to be split into two parts. The component developed by the Permanent magnet flux is called Reactance Torque or Magnetic Torque;

$$\mathrm{T_{magnetic}} = \frac{3}{2}\mathrm{P}\varnothing_\mathrm{M}\mathrm{i_q} \qquad (7)$$

The torque can be controlled solely by the torque component of the stator current by maintaining the amplitude of the rotor flux at a constant value. A linear relationship between torque and torque component of stator current is maintained. Another torque component is developed by the saliency of the rotor that is known as, Reluctance torque and is expressed as;

$$\mathrm{T_{reluctance}} = \frac{3}{2}\mathrm{P}(\mathrm{L_d} - \mathrm{L_q})\mathrm{i_d}\mathrm{i_q} \qquad (8)$$

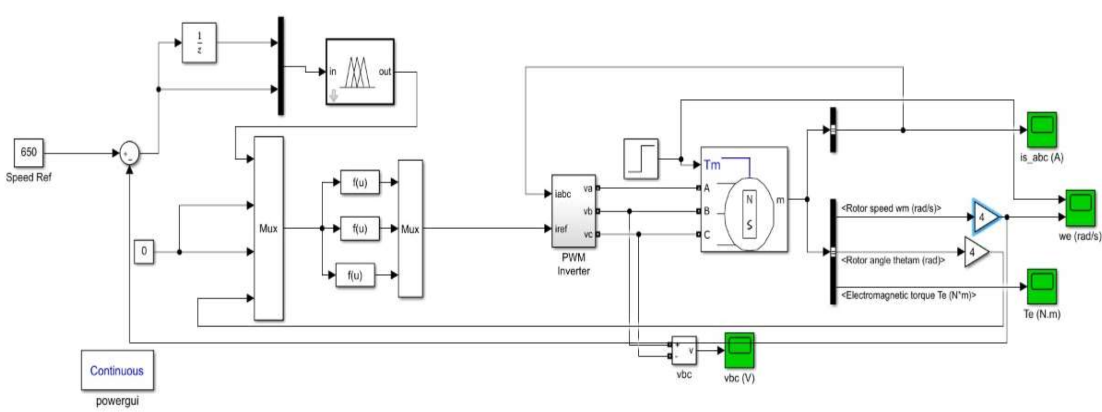

Figure 3 SIMULINK diagram of PMSM Motor System using FLC

4. RESULTS AD ANALYSIS

The main objective of this paper is to compare the performance characteristics i.e. the graphs of Electromagnetic Torque and Rotor Speed with respect to time of a given PMSM motor drive system under a various loading conditions using a both controllers. Our conclusions will be drawn based on how efficient and quick the controller is in ensuring constant speed and smooth operation of the motor. The PMSM motor drive system taken in the simulation is an 8-pole machine which at 500 V and 200 Hz, has a synchronous speed of 3000 rpm. The motor with Unloaded and dynamic loading conditions operating with PI and FL Controller. Simulating both drive system using the simulation diagram using the MATLAB Simulink tool. The simulation will be run for considerable specified time.

4.1 PI CONTROLLER WITHOUT LOAD

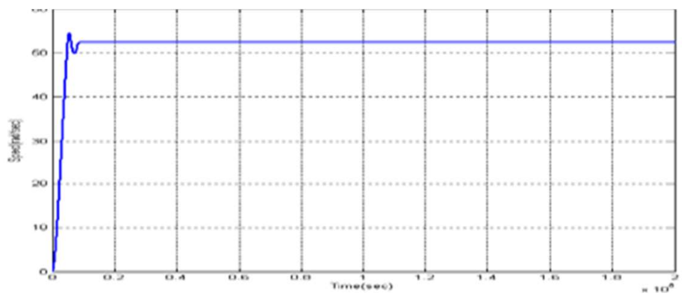

Figure 4 Speed Vs time

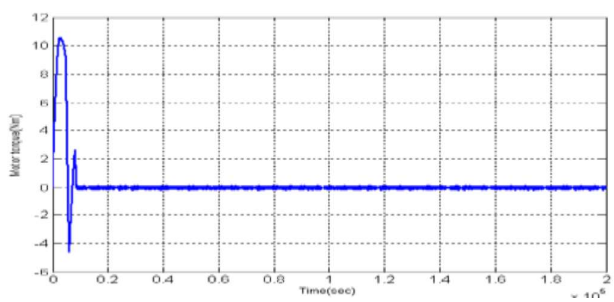

Figure 5 Torque vs Time

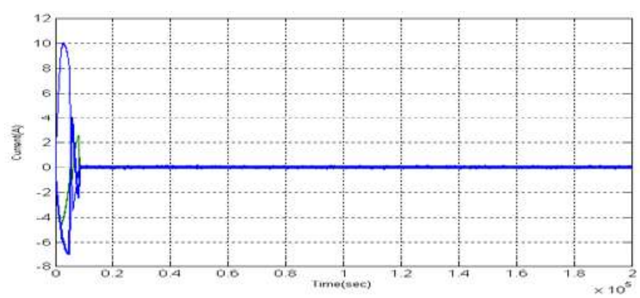

Figure 6 current vs time

4.2 FUZZY LOGIC CCONTROLLER WITHOUT LOAD

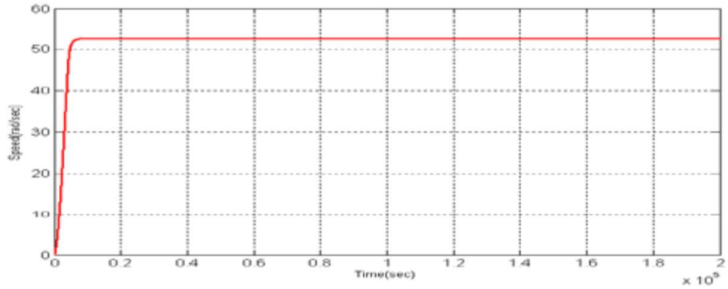

Figure 7 Speed Vs time

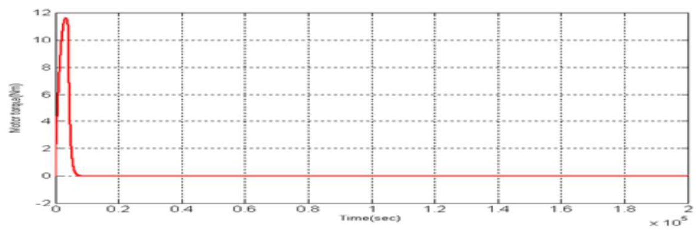

Figure 8 Torque vs Time

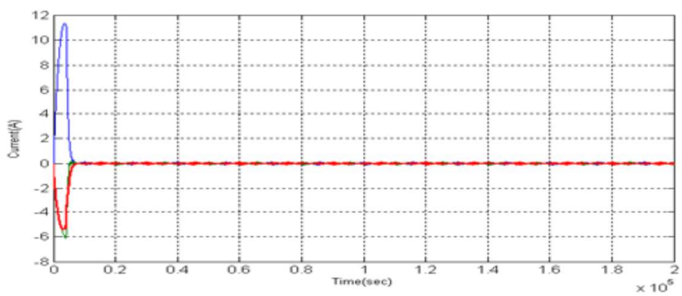

Figure 9 current vs time

4.3 PI CONTROLLER WITH DYNAMIC LOAD OF 10 Nm:

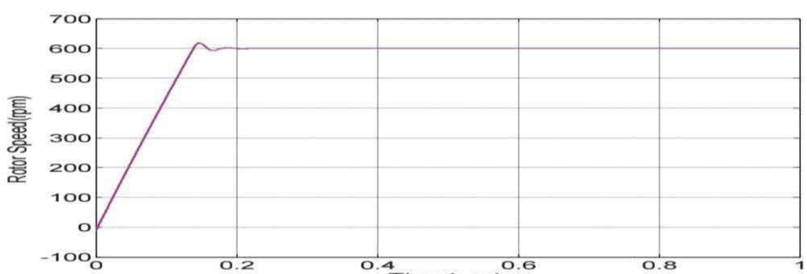

Figure 10 Speed vs Time

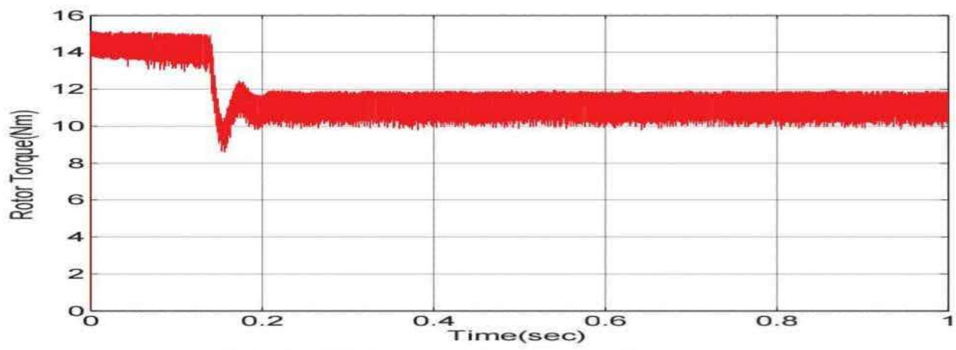

Figure 11 Torque vs Time

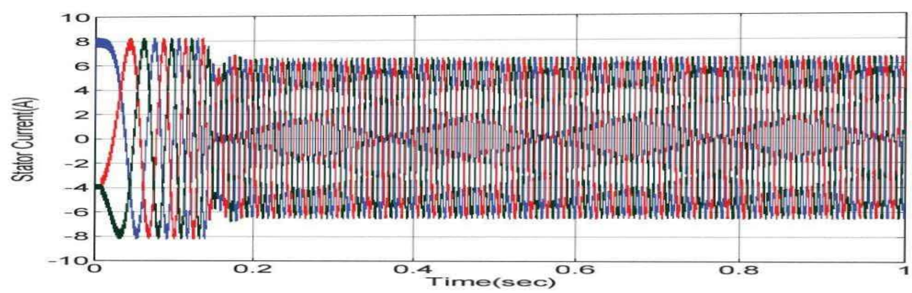

Figure 12 Current vs Time

4.4 FUZZY LOGIC CONTROLLER WITH DYNAMIC LOAD OF 10 Nm:

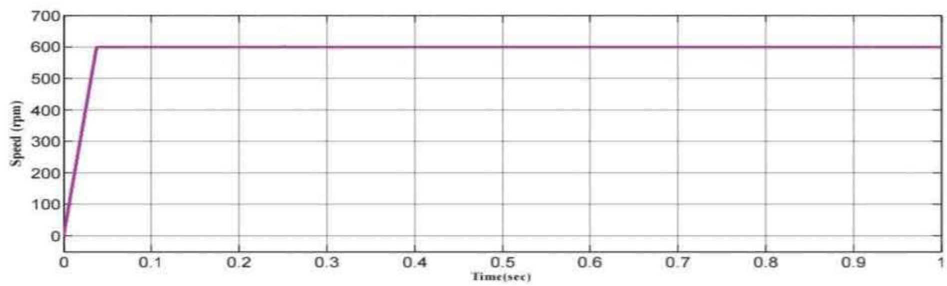

Figure 13 Speed vs Time

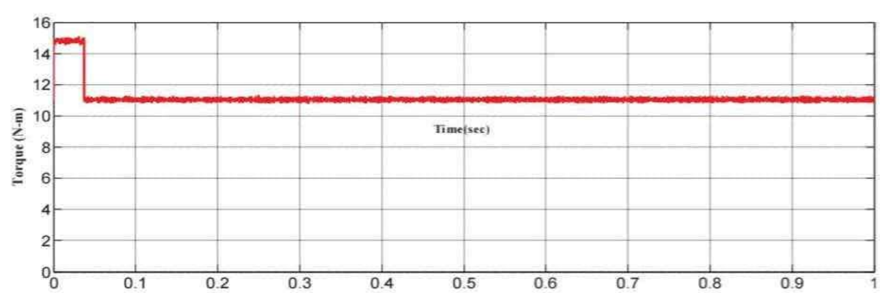

Figure 14 Torque vs Time

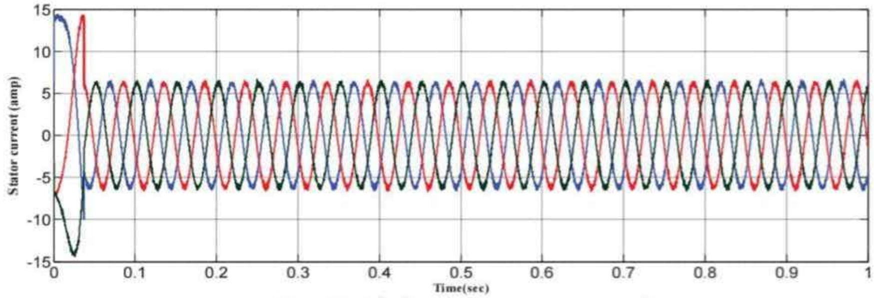

Figure 15 Current vs Time

5. CONCLUSION:

Therefore, it is successfully simulated the speed control of a PMSM drive system using both a Proportional-Integral controller and Fuzzy Logic Controller. The performance analysis of a PMSM along with its subsystems is explained in brief. Furthermore, a comparative study has been discussed between the PI controller and Fuzzy Logic controller using the MATLAB SIMULINK tool for the speed control of a PMSM. The results obtained using both the controllers separately are then compared and analyzed to evaluate the speed controllers' performance. The inference which can be concluded after comparison is that speed control of PMSM using Fuzzy Logic Controller has better performance when step response characteristics are measured from the Rotor Speed vs Time curves, as shown. Across all loading conditions, the FLC driven PMSM motor had lower step response characteristics, showing faster and more efficient speed control.

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