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PI CONTROL AND FUZZY LOGIC COMBINED IN A HYBRID APPROACH, SPECIFICALLY DESIGNED FOR INTERIOR PERMANENT MAGNET SYNCHRONOUS MOTORS (IPMSMS) SPEED CONTROLLER

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Abstract

Interior permanent magnet synchronous motors, or IPMSMs, are designed to increase machine efficiency and offer rapid torque response. IPMSMs are used in low- and mid-power applications such as servo applications, electric cars, computer peripherals, robots, and adjustable speed drives. The necessity for simulation tools capable of handling motor drive simulations has arisen from the growing use of PM motor drives. The capacity of simulation tools to execute motor drive dynamic simulations in a visual environment reduces development time and costs. In this thesis, a simulation model for improving the speed control and performance of a closed loop vector controlled IPMSM drive—which employs two loops for improved speed tracking—has been developed. The hybrid PI fuzzy logic controller is used in the outer loop. The fixed gain (Kp) and integral time constant (Ki) of the proportional plus integral (PI) controller make it a popular choice for speed control. However, the PI controller's performance is affected by parameter variations, speed shifts, and load disturbances in PMSM, which results in subpar operation in transient scenarios. The drawbacks of PI controllers are lessened by fuzzy logic controllers, or FLCs. A fuzzy control technique has been created. Another aspect of PI-FLC's design is its ability to control speed effectively in both steady state and transient circumstances. In this thesis, an extensive Simulink model of the inner permanent magnet synchronous motor driving system is created. Simulation results are displayed to help with the analysis of the system performance and the effect of the PI controller parameters on the system performance. Fuzzy logic controllers have also been used in the analysis. In order to display the results, a hybrid PI fuzzy logic controller (PI-FLC) has finally performed analysis under no load, variable speed condition, and variable load condition independently.

Keywords: *Pi-Fuzzy, Speed Controller, Permanent Magnet, Synchronous Motor.*

Introduction

Induction motors and permanent magnet synchronous motors (PMSM) are two types of AC machine drives that are growing in popularity. However, for high performance applications, PMSM drives are more suitable due to their quick dynamic response, high power factor, and broad working speed range. High efficiency, compact size, high power density, quick dynamics, a high torque to inertia ratio, and cheap maintenance are a few benefits of PMSMs. Their uses can be found in electric vehicles, textile machinery, servo and robotic systems, and machine tools, among other things.

The model of PMSM is however non-linear. This paper applies the concept of vector control that has been extensively applied to derive a linear model of the PMSM for the controller design purposes. The speed and current controllers are then designed. The nonlinear equations of the PMSM, current and speed controller equations and real time model of the inverter switches and vector control are used in the simulation. The switches are assumed to be ideal.

PM electric machines are classified into two groups: PMDC machines and PMAC machines. The PMDC machines are similar with the DC commutator machines; the only difference is that the field winding is replaced by the permanent magnets while in case of PMAC the field is generated by the permanent magnets placed on the rotor and the slip rings, the brushes and the commutator does not exist in this type of machine.

The main objective of this research is to improve the performance of an IPMSM drive system by achieving more precise speed tracking and smooth torque response by implementing a Hybrid PI-FLC and an adaptive hysteresis band

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current controller respectively by employing their superior performance.

- To design the equivalent d-q model of IPMSM for its vector control analysis and closed loop operation of drive system.
- Analysis and implementation of PI, Fuzzy and Hybrid PI-Fuzzy logic controller separately as outer speed loop in steady state and transient condition (step change in load and speed) in MATLAB/Simulink environment.
- Analysis and implementation of conventional hysteresis current controller and adaptive hysteresis band current controller as inner current controller in MATLAB/Simulink environment to compare their performances so as to consider better controller for our system application.
- Comparison of system performance using PI, Fuzzy and Hybrid PI-FLC separately as speed controller and adaptive hysteresis current controller as controller during steady state and transient condition in MATLAB/Simulink environment.

Results and Discussion

The performance of drive system using PI, Fuzzy and Hybrid PI-FLC as different speed controller has been demonstrated at no-load, variable load & variable speed conditions. For all condition operation Adaptive hysteresis band current controller has been integrated as inner current controller. The MATLAB/Simulation is focused on minimization of the ripple contents of stator current, torque and improving the motor speed response under transient and steady state operating conditions.

- Result during No-load Condition for Conventional PI Controller:

For this case the gain constants are set as Kp= 5 & Ki= 100 and the reference speed to be track is 1350 rad/sec. Fig.4.2 shows the 3-phase stator current which does not contains any disturbances, smooth response of electromagnetic torque and rotor speed where the ripple contents of the rotor speed are 200 and settling time is 0.5 sec. The response of the PI controller is under No-load condition.

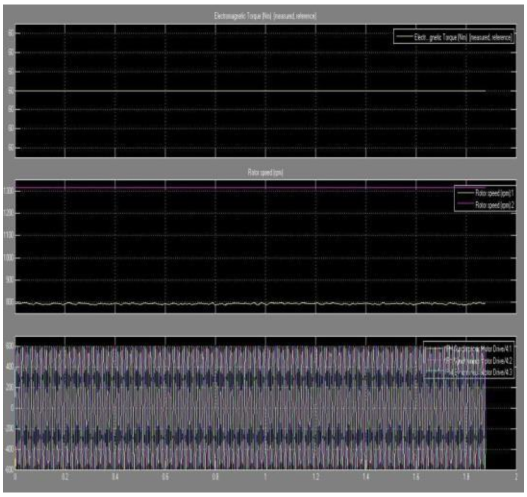

Figure 1: PI controller response under No Load condition

- Result during No-load Condition for Fuzzy Logic Controller:

For this case a 5×5 triangular MF for both inputs as well as output variables of FLC, Fuzzy implication using Mamdani's min operators and Defuzzification using Centroid method has been implemented for designed FLC. Fig.5.3 shows the Fuzzy Logic Control Block diagram. Figure
5.4 shows the 3-phase stator current, shows response of electromagnetic torque and rotor speed where the ripple content is 200 and the rotor speed are 1350 rad/sec.

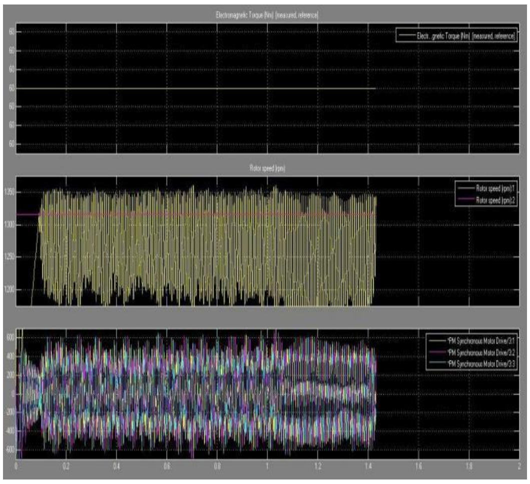

Fig 2:- Electromagnetic Torque, Rotor speed and response of fuzzy logic controller

- Result during No-load Condition for Hybrid PI-FLC:

The Hybrid PI-Fuzzy Logic Controller, Figure shows the 3- phase stator current, response of electromagnetic torque and rotor speed where the ripple contents are 100 and the rotor speed is 1350 rad/sec and settling time is 0.1 sec. So the responses obtained in this case are little improved as compared to Conventional PI and FLC.

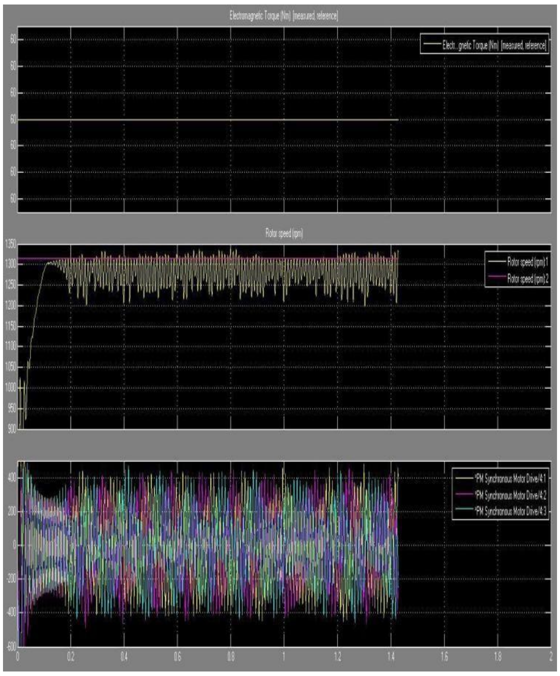

Figure 3: Hybrid Torque, Rotor Speed and ripple factor response at No Load

- Result during Variable Speed Condition for Hybrid PI-FLC:

The Hybrid model variable speed fuzzy rule viewer and the figure 4.10 shows the 3-phase stator current, response of electromagnetic torque and rotor speed responses with lesser ripple and notches in the stator current and torque response than the PI & FLC. The ripple content in torque under load condition is 0.05 Nm.

The comprehending results and responses of proposed IPMSM drive system using two integrated control strategy has been presented which is modeled and verified in the MATLAB/ Simulink environment. From the given responses of speed control of IPMSM drive system using a current controller and different speed controller techniques, we come to the conclusion that the hysteresis band current controller reduces the torque ripple, minimizes the current error and maintains the switching frequency. While among different speed controller, Hybrid PI-FLC is giving better response than others during both steady state and transient Conditions.

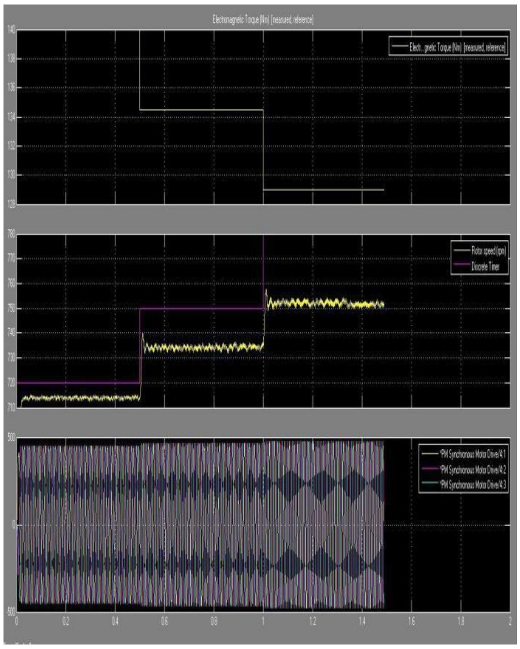

Figure 4: Hybrid Model Variable Speed Results

Conclusion

This dissertation is mainly emphasized on the study of performance of IPMSM drive system using different current controllers in inner loop and speed controllers in outer loop. In order to run IPM motor at the desired speed, a closed loop with vector control IPMSM drive was successfully designed and operated in constant torque mode. The feasibility of the above mentioned integrated control strategy is modeled and verified in the MATLAB/Simulink environment for effectiveness of the study.

From the obtained results we observed that, during both steady-state and transient conditions hysteresis current controller reduces the torque ripple, minimize the current error and maintain the switching frequency. While comparing with the PI controller, the FLC and hybrid PI- FLC techniques, it is proved that PI-FLC controller has superior performance. The ripple contents of stator current, flux and torque are minimized considerably and the dynamic speed response is also improved with the proposed control technique under transient and steady state operating conditions. The simulation results are presented in forward motoring under no-load, load and sudden change in speed operating conditions.

So the proposed model with Hybrid PI- FLC as speed controller and fixed band hysteresis current controller has been used as a current controller which is providing smooth and improved performances as compared to other controllers that have been taken in consideration in this Thesis.

Future Scope

Here the focused has been made on the performance enhancement of IPMSM drives and simulation work has been done for its thorough analysis. However, due to equipment limitations these methods could not tested practically for all purposes. So in the future work the results obtained for proposed control techniques from simulation environment may be validated with experimental results. In addition to that, the analysis of performance of PMSM drive implementing further advanced and intelligent controller like Adaptive fuzzy controller, Adaptive Hysteresis controller and implementation of such controller in both speed and current loop can be carried out. The analysis also can be extended to the above rated speed operation i.e. Flux weakening region also.

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