NOVEL SPEED CONTROL TECHNIQUES FOR THE VECTOR-CONTROLLED PMSM DRIVE

by

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CERTIFICATE

This is to certify that the dissertation titled **"Novel Speed Control Techniques for the Vector-Controlled PMSM Drive,"** being submitted by **Mr. Sant Amit Vilas** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under my guidance and supervision.

Mr. Sant Amit Vilas has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The results obtained herein have not been submitted in part or in full to any other University or Institute for the award of any degree.

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ABSTRACT

Permanent magnet synchronous motors (PMSM) are employed in a variety of applications owing to its higher efficiency and high power density. For the control of PMSM, vector control is a standard technique in which the outer speed loop provides the reference value of the current for the inner current loop and any disturbance in the speed controller output would cause erroneous currents and degrade the system performance. Traditionally, proportional-integral (PI) controllers are preferred as speed controllers. But, as a result of the constant proportional and integral gains, PI controllers suffer from performance degradation due to parameter variation and system disturbances. Speed controllers based on fuzzy logic, artificial neural network (ANN), and sliding mode control (SMC) have been reported in a number of literatures. However, these controllers suffer from computational complexity, need of rule base, learning or compensation requirements.

A comprehensive literature survey on these speed controllers for PMSM drives lead to the opportunities for developing better speed controllers which are either free or pose reduced tuning requirements and computationally simpler. The speed controllers proposed in this thesis can be classified as hybrid controllers, individual controllers and online tuned controllers.

Hybrid controllers combine the features of two different controllers and assign weights for the two controller output to determine the output of the hybrid controllers. The proposed hybrid controllers are hybrid fuzzy-PI controller, hybrid PI controller and hybrid bang-bang-PI controllers. The main contributions to these hybrid controllers are the proposed novel noninherent and inherent switching functions for the determination of the weights of

the individual controller outputs. These weight determination algorithms, termed as switching algorithms, are computationally simple and enable the controller to provide good dynamic and steady state response. Another, contribution is the hybrid PI controller where the fuzzy controller of the hybrid fuzzy-PI controller is replaced by the fuzzy equivalent proportional controller which imitates the fuzzy control action under dynamic conditions without the need of rule base or excessive computations associated with the fuzzy logic controller.

The proposed individual controllers comprise of enhanced bang-bang controller, fractional order PI (FO-PI) controllers, multi resolution wavelet PI (MRW-PI) controller and cumulated dopamine neural structure controller. The enhanced bang-bang controller, which combines the features of the bang-bang operation of SMC for good transient response and that of the PI controller to improve the steady-state response, utilizes the conventional bang-bang control action along with computationally simple mathematical functions for the switching gain correction. This research work also presents the investigations on fractional order (FO) controllers. With the main emphasis on real time implementation, FO-PI and MRW-PI speed controller based vector control of PMSM is carried out. Lastly, in the group of individual controllers cumulated dopamine neural structure speed controller is proposed. This controller utilizes the structure of ANN to model the state experienced by the neurons on cocaine consumption due to the dopamine accumulation in synapse. The controller algorithm is simple, computationally less intensive and doesn't necessitate any tuning and retuning, learning or rule base. Moreover, the retuning, generally required with the incorporation of sensorless algorithm in a tuned PMSM drive, is not needed with the cumulated dopamine neural structure controller. This has been demonstrated with sliding mode observer, superposition theory based observer and high frequency signal injection technique where good dynamic and steady state speed response is obtained without any tuning or retuning needs.

To utilize the excellent features of the PI controller and to overcome the problems associated with the fixed gains; this work also analyzes the operation of PMSM drive with the online tuning of PI speed controller gains. This classification is sub-classified as gain scheduled PI (GSPI) controller, fuzzy assisted GSPI controller, and GA and PSO based online tuned PI controllers. The performance of the vector-controlled PMSM drive with proposed gain scheduled PI (GSPI) speed and current controller has been analyzed for three different mathematical functions. However, GSPI controller still requires proper selection of the limits for the gains and hence, GSPI speed controller with fuzzy logic based gain determination is developed for the vector controlled PMSM drive. The online tuning of PI controller with heuristic approach is also investigated. Genetic algorithm (GA) and particle swarm optimization (PSO) have been separately employed for the online tuning, with the population strength limited to six and cost function being evaluated with the help of the cumulated dopamine neural structure controller. Moreover, the proposed online tuning with heuristic methods is also tested for the sensorless vector-controlled PMSM drive. Simulations for the reported speed controllers have been carried out in PSIM for the vector-controlled PMSM. The speed controller and vector control algorithms have been implemented in hardware with TMS320F2812 DSP processor for the PMSM drive.

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