学位論文内容の要旨

This thesis deals with the high performance speed control with efficiency optimization of voltage source space vector modulated PWM inverter-fed induction motor taking core loss into account. Fast and accurate speed response, quick recovery of speed from any disturbances, and insensitivity to parameter variations are some of the important criteria of the high performance electrical drive. In order to achieve high performance the field oriented control of induction motor is employed. However, the accurate performance of torque as well as speed control of IM is affected due the effects of core loss. Therefore, the core loss is taken into account for the design of speed controller of induction motor.

The desired speed of IM can be achieved by varying the voltage and frequency of stator. The space vector modulated PWM voltage source inverter is used because it can easily be implemented in digital signal processor or microprocessor of a personal computer and it allows reducing commutation loss and the harmonic current of output voltage.

The field oriented control theory of IM has been derived by keeping constant rotor flux. The efficiency is very poor even though implementing the field orientation at light load and low speed. Therefore, an efficiency optimization algorithm is developed in terms of slip frequency in order to achieve maximum efficiency for different operating speeds and torque conditions. The conventional PI controller with high performance controller of induction motor has been used in industrial applications. The overshoot and steady state error problems occur where the constant gains of PI controller are chosen by trial and error.

Moreover, the conventional PI controller becomes unstable because the decoupling characteristics of the field oriented control strategies are adversely affected by the parameter changes in the motor. To surmount such a drawback of PI controller, this thesis demonstrates MIMO optimal regulator, discrete-time sliding mode controller, full order and reduced order observers, fuzzy controller and self-tuning PI controller based on fuzzy logic for the high performance speed control of induction motor.

In the design of MIMO optimal regulator and discrete-time sliding mode controller, the magnetizing current components are added in the state space model to compensate the effects of core loss. An augmented system is developed from the state space model of induction motor. The error and the first difference of motor state variables are used as the state variables of the augmented system. Using the augmented system, the feedback gains of these controllers are calculated. The stability of these controllers is confirmed by using the Lyapunov stability theorem.

In order to implement the optimal regulator and sliding mode controller, the bilinear full order and reduced order observers of induction motor taking core loss into account are designed. The gains of these observers are calculated by using the pole placement technique and Lyapunov stability theorem. So, these observers are stable at both constant and variable speeds of induction motor. Fuzzy logic controller is designed to regulate the imaginary component of magnetizing current to achieve the desired speed. The compensation technique, due to the effects of core loss, is taken into account in order to achieve precise and high performance desired speed.

In order to overcome the complexity of design technique of optimal regulator, sliding mode controller and fuzzy logic controller, this thesis presents a new self-tuning PI controller based on fuzzy logic. For the tuning of PI controller gains, the fuzzy adaptation technique is developed according to the knowledge of pole placement technique. In order to update the gains of PI controller, only three fuzzy rules are needed. So, it takes less time to calculate the output of fuzzy adaptation system.

In this thesis, the simulation is implemented by using Matlab and Simulink software. Simulations are carried out by considering the step changes of reference speed, load torque, rotor resistance and damping factor. In order to investigate the controller performance, the simulation is also performed by assuming that the rotor resistance and the inertia are unknown at the starting of induction motor. For all of the controllers, the simulations are carried out for the above mentioned operating points, and for both field orientation and efficiency optimization strategies.

According to the simulation results, the desired speed can be achieved for the step change of speed without any overshoot and steady state error by using the optimal regulator, discrete-time sliding mode controller, fuzzy logic controller and self-tuning PI controller. These controllers are also stable and robust under the variations of parameters and load torque. From the viewpoint of design technique and gains calculation time, the self-tuning PI controller based on fuzzy is superior to other three controllers.

論文審査結果の要旨

高性能ドライブの幾つかの重要な領域は高速、正確な速度応答、外乱からの速度の速やかな回復、パラメータ変動に対する不感である。高性能を達成するために、誘導電動機の速度制御と同じくトルクの正確な性能は鉄損の効果に影響する。それ故、鉄損は誘導電動機の速度コントローラの設計に考慮される。

ファジイ論理コントローラは目標速度を達成するために磁化電流の虚軸成分を調整するように設計される。鉄損の影響による補償に関して、セルフチューニング PI 制御コントローラを提案している。PI 制御コントローラのゲインの調整に関して、ファジイ適応技術が極配置の知識により展開される。 シミュレーション結果に従い、速度のステップ変化に対して、最適レギュレータ、離散時間スライディングモードコントローラ、ファジイ制御器、セルフチューニング PI 制御コントローラを用いることで、オーバーシュートや定常誤差のない望ましい速度応答が得られており、これらの制御アルゴリズムの実装は、産業ドライブの制御系設計の分野に対して貢献するところ大である。

よって、申請者は北見工業大学博士(工学)の学位を授与される資格があるものと認める。