Performance of Stator Resistance Compensator in Direct Torque Control of Induction Motor Drive

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Abstract:
Control of induction motor is most precisely required in many high performance applications. With the development in power electronic field various control methods for control of induction motor have been developed. Among these Direct torque control (DTC) seems to be particularly interesting, being independent of machine rotor parameters and requiring no speed or position sensors. In addition to the simple structure it also allows a good torque control in transient and steady state conditions. The disadvantage of using DTC is that it results in high torque and flux ripple and variable switching frequency of voltage source inverter, owing to the use of hysteretic controllers for torque and flux loop. In order to overcome these problems, various methods have been proposed by several researchers like variable hysteretic band comparators, space vector modulation, predictive control schemes and intelligent control techniques. However these methods have diminished the main feature of DTC that is simple control structure. This report presents constant switching frequency based torque and flux controllers to replace conventional hysteretic based controllers where almost fixed switching frequency with reduced torque and flux ripple is obtained by comparing the triangular waveforms with the compensated error signals. Controller is carried out under the fault conditions, disturbances and simulation will be done on MATLAB.

Keywords: Direct torque, induction motor, resistance estimator, resistance compensator

I. INTRODUCTION

(1) Direct Torque and Flux Control (DTFC) scheme of an induction motor operating with a stator resistance PI estimator. The variation of stator resistance due to changes in temperature or frequency degrades the performance of this control strategy. (2) Stator resistance PI compensator is one of the simplest methods proposed to estimate stator resistance. This method is based on the real time stator resistance correction regarding the variations of the stator current magnitude, which must be a constant value when the stator flux and motor torque are constant. This reference value can be calculated using the flux and torque commands and motor parameters. (3) Direct torque control (DTC) uses the stator resistance of the machine for the estimation of stator flux. The variation of stator resistance due to temperature changes in the machine makes the operations difficult at low speeds. A method for the estimation of changes in stator resistance during the operation of the machine is presented.

A. Necessity of resistance compensator

System becomes unstable if the stator resistance value used in controller is higher than that of machine resistance the stator resistance may be lower than its controller set point nominal value is externally housed drive system in colder climates the operated temperature may be different from the motor temperature at starting if drive system has parameter adaption and its performance is poor then the estimated resistance may be higher than the actual motor resistance

Resistance compensator

On the basis of the reference paper, and on the basis of industrial training problem occurring are as followed

- Mismatch of stator resistance
- Gain error
- Offset error

This type of control is based on the directly determination of the sequence of control applied to the switches of inverter. This choice is generally based on the use of hysteretic regulators, whose function is to control the state of the system, and to modify the amplitude of the stator flux and torque. The variation of stator resistance due changes in temperature or frequency degrades the performance of this control strategy, and therefore is a big issue of DTFC. Stator resistance using DTC controller is equal to its real value motor develop its reference flux and torque When digital controller finite sampling frequency. The magnitude of stator current vector is not precisely equal to its reference value and there is an error that changes with motor and controller operation and PI estimator are considered the incremental value of stator resistance for correction is obtained through PI controller and limiter. The current error goes through low pass filter which has very low pass cut off frequency in order to remove high frequency Components contained feedback current. This low pass filter does not generate any adverse effect on stator resistance. Adaptation if the filter time constant chosen to be smaller than that of adaptation time constant the final estimated value is obtained as the output of another low pass filter and limiter. This low pass filter is necessary is necessary for smooth Variation of estimated resistance value this final signal is update stator resistance and can be used directly in controller Induction motor torque control has traditionally been achieved using Field Oriented Control (FOC). This involves the transformation of stator currents into asynchronously rotating d-q reference frame that is typically aligned to the Rotor flux. In this reference frame, the torque
and flux producing components of the stator current are decoupled. It is then used to regulate the output voltage to achieve the required stator current and therefore torque. This controller API controller limits the transient response of the torque controller. Direct Torque Control (DTC) uses an induction motor model to achieve a desired output torque. By using only current and voltage measurements, it is possible to estimate the instantaneous stator flux and output torque and the

**Abbreviations and Acronyms**

Direct torque control (DTC), Direct Torque and Flux Control (DTFC), PI estimator proportional integrator, Lp filter low pass filter, Field Oriented Control (FOC).

**B. Equations**

**I. MOTOR SPECIFICATION FOR DIRECT TORQUE CONTROL OF INDUCTION MOTOR DRIVE**

<table>
<thead>
<tr>
<th>P</th>
<th>V</th>
<th>F</th>
<th>R</th>
<th>L</th>
<th>L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 kW</td>
<td>415 V</td>
<td>50 Hz</td>
<td>6.03Ω</td>
<td>6.085Ω</td>
<td>29.9 mH</td>
</tr>
</tbody>
</table>

**II. MATHEMATICAL EQUATION**

condition. In this figure, V and I denote voltage vector and current vector, respectively.

The input active power P and reactive power Q are expressed as,

\[ P = VI \cos \phi \]

\[ Q = VI \sin \phi \]

Equations

Where, \( V = \sqrt{V_{d}^2 + V_{q}^2} \), \( I = \sqrt{I_{d}^2 + I_{q}^2} \) and \( \phi \) is the power factor angle. - Forwardly derived as follows:

\[ I_{3d} = \frac{(\alpha_{2}^2 M_{13} M_{24} - \alpha_{2} M_{13} R_{3} I_{d} + \alpha_{3} R_{1} M_{23} I_{2d})}{(R_{3}^2 + \alpha_{3}^2 L_{3}^2)} \]  \( \text{(3)} \)

\[ I_{3q} = \frac{(\alpha_{2}^2 M_{13} M_{24} - \alpha_{2} M_{13} R_{3} I_{q} + \alpha_{3} R_{1} M_{23} I_{2d})}{(R_{3}^2 + \alpha_{3}^2 L_{3}^2)} \]  \( \text{(4)} \)

Substituting (2) and (3) in (1), the order of the voltage equation can be reduced as,

\[ \begin{bmatrix} V_{d} \\ V_{q} \end{bmatrix} = \begin{bmatrix} R_{1} + R_{m} & -\alpha_{2} L_{4} \\ \alpha_{2} L_{4} & R_{1} + R_{m} \end{bmatrix} \begin{bmatrix} I_{d} \\ I_{q} \end{bmatrix} + \begin{bmatrix} M_{32d} \\ M_{32q} \end{bmatrix} \]  \( \text{(5)} \)

Where,

\[ R_{m} = \frac{\alpha_{2}^2 M_{13}^2}{R_{3}^2 + \alpha_{3}^2 L_{3}^2} \]

\[ M_{32d} = \frac{\alpha_{2} M_{13} R_{3}}{R_{3}^2 + \alpha_{3}^2 L_{3}^2} M_{32} \]

\[ M_{32q} = \frac{\alpha_{2} M_{13} R_{3}}{R_{3}^2 + \alpha_{3}^2 L_{3}^2} M_{32} \]

The parameter \( R_{m} \) is referred to as the equivalent iron loss resistance and is connected in series with the armature resistance \( R_{1}, L_{1} \) denotes the armature inductance. Assuming that the mutual inductances \( M_{32d} \) and \( M_{32q} \) are sufficiently small as compared with the mutual inductance \( M_{32} \), these inductances are neglected; as a result, the voltage equation is simplified as,

\[ \begin{bmatrix} V_{d} \\ V_{q} \end{bmatrix} = \begin{bmatrix} R_{1} + R_{m} & -\alpha_{2} L_{4} \\ \alpha_{2} L_{4} & R_{1} + R_{m} \end{bmatrix} \begin{bmatrix} I_{d} \\ I_{q} \end{bmatrix} + \begin{bmatrix} 0 \\ K_{e} \end{bmatrix} \]  \( \text{(6)} \)

Where, \( K_{e} = (M_{32}) \) represents the emf coefficient. The validity of this simplification is confirmed by the experimental result. This type of control is based on the direct determination of the sequence of control applied to the switches of a tension inverter. This choice is generally based on the use of hysteresis regulators, whose function is to control the state of the system, and to modify the amplitude of the stator flux and the electromagnetic torque. The PI resistance estimator performance is investigated. Using simulation more result to achieve more similarly to practical system digital system used that adjustable frequency. When stator resistance using DTC controller is equal to its Real value motor develop its reference flux and torque. When digital controller finite sampling frequency The magnitude of stator current vector is not precisely Equal to its reference value and there is an error that changes with motor and controller operation and PI estimator are considered the incremental value of stator resistance for correction is obtained through PI controller and limiter. The current error goes through low pass filter which has very low pass cut off frequency in order to remove high frequency Components contained feedback current. The PI resistance estimator performance is investigated. Using simulation more result to achieve more similarly to practical system digital system used that adjustable frequency. When stator resistance using DTC controller is equal to its Real value motor develop its reference flux and torque. When digital controller finite sampling frequency. The magnitude of stator current vector is not precisely Equal to its reference value and there is an error that changes with motor and controller operation and PI estimator are considered the incremental value of stator resistance for correction is obtained through PI controller and limiter. The current error goes through low pass filter which has very low pass cut off frequency in order to remove high frequency Components contained feedback current. The PI resistance estimator performance is investigated. Using simulation more result to achieve more similarly to practical system digital system used that adjustable frequency.
steady-state condition, the LP filter estimator will degrade the performance and efficiency of the direct torque control (DTC) drive system since it introduced magnitude and phase errors, thus resulting in an incorrect voltage vector selection. The stator flux steady-state error between the LP filter and a pure integrator estimator technique is derived and its effect on the steady-state DTC drive performance is analyzed. A simple method is proposed to compensate for this error which results in a significant improvement in the steady-state drive performance. Simulation based on this technique is given and it is verified by experimental results Direct Torque Control (DTC). This technique increases the number of voltage vectors beyond the available eight discrete voltage vectors without any increase in the number of speed control to have wide torque-speed characteristics. Optimized value of stator flux based on the maximum reference value of electromagnetic torque is proposed to operate in conjunction with duty ratio control. The performance of the proposed drive system is evaluated through digital simulation using MATLAB.

II. REFERENCES


Semiconductor switches in the inverter. PI controller is proposed for outer speed control loop to achieve swift response, less overshoot and precision.

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