SPEED CONTROL OF SENSORLESS ROTOR FIELD ORIENTED FOR FAULTY THREE-PHASE INDUCTION MOTOR BY USING EXTENDED KALMAN FILTER

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To my father and mother for their enormous financial and emotional support throughout my study patiently.

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ABSTRACT

This research discusses d-q model and Rotor Flux Oriented Control (RFOC) method for faulty three-phase induction motor (three-phase induction motor when one of the stator phases is opened). In the controlling method, two transformation matrixes are applied to the equations of faulty three-phase induction motor. As a result, the equations of faulty three-phase induction motor become similar to the balanced mode. By employing some modifications in the conventional block diagram of balanced induction motor, controlling of faulty three-phase induction motor is possible. Additionally, Extended Kalman Filter (EKF) is used for rotor speed estimation. The main advantage of the proposed method is it can be employed for asymmetrical single-phase induction motor. Simulation and Experemental results demonstrate the validity and applicability of the method to improve performance of faulty three-phase induction motor.

ABSTRAK

Kajian ini membincangkan model dq dan kaedah Kawalan Berorientasikan Flux pemutar (RFOC) untuk motor aruhan tiga fasa yang rosak (motor aruhan tiga fasa apabila salah satu daripada fasa pemegun dibuka). Dalam kaedah kawalan ini, dua matriks transformasi digunakan untuk persamaan motor aruhan tiga fasa yang rosak. Hasilnya, persamaan motor aruhan tiga fasa yang rosak menjadi serupa dengan mod seimbang. Dengan menggunakan beberapa pengubahsuaian dalam gambarajah blok konvensional motor induksi seimbang, mengawal motor aruhan tiga fasa yang rosak adalah mungkin. Selain itu, Penapis Kalman Lanjutan (EKF) digunakan untuk anggaran kelajuan pemutar. Kelebihan utama kaedah yang dicadangkan ialah ia boleh digunakan untuk motor aruhan satu fasa tak simetri. keputusan Simulasi dan eksperimen menunjukkan kesahihan dan kesesuaian kaedah untuk meningkatkan prestasi motor aruhan tiga fasa yang rosak.

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CHAPTER 1

INTRODUCTION TO THE RESEARCH

1.1 Background of research

The AC motor drives are widely used in industry. In these drives AC motors like induction motors and permanent magnet synchronous motors are used. These drives are used in some applications such as Heating, Ventilation and Air Conditioning (HVAC), fans, mixers, robots and etc.

Squirrel cage induction motor has many advantages toward DC motor. The main problem of DC motor is commutators and brushes maintenance. These problems causes this type of motor cannot operate in the dirty environments. In the recent years, the DC motors are replaced by induction motors. There are many methods for controlling of induction motors. A general classification of these methods is shown in Figure1.1[1]. Single Phase Induction Motors (SPIM), are widely applied in home applications. In these applications the motor is fed from AC grid in constant frequency and without any controlling strategy. The single phase induction motor has two main and auxiliary winding and its operation needs capacitors (run or start capacitor).

In the recent years, many researchers have been done by researchers on single phase induction motor variable speed drives. In generally, there are three power electronic converters which are used for supplying SPIM: two-leg, three-leg, and four-leg inverters. One of the most popular methods for controlling the speed and

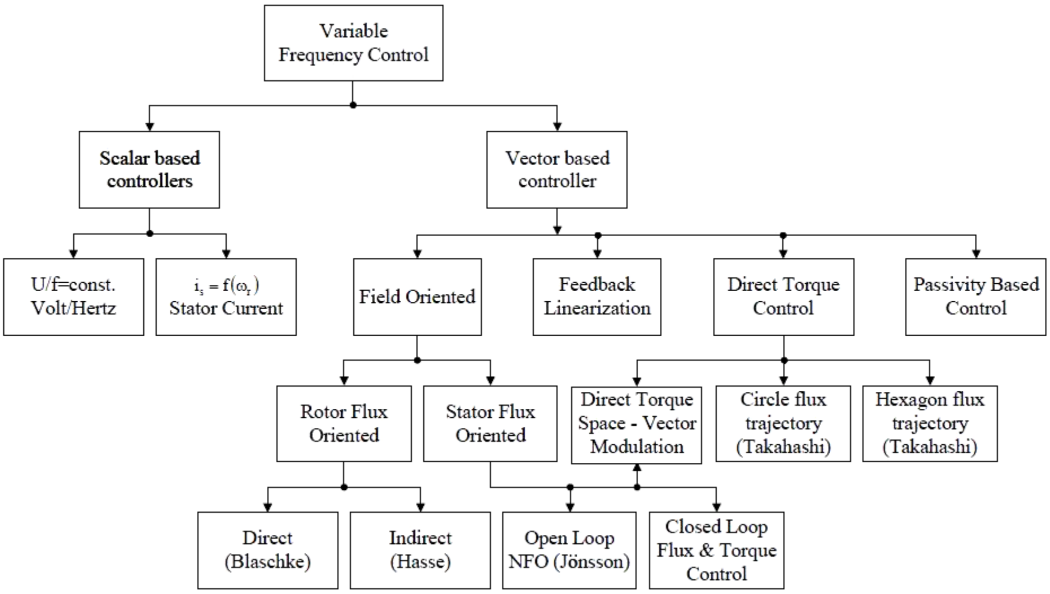

Figure 1.1: General classification of controlling methods for induction motors

torque of the induction motor is Field Oriented Control (FOC). Indirect Field Oriented Control (IFOC) has been presented in [2] and. Direct Field Oriented Control (DFOC) has been discussed in [3]. In this method, motor current separates into field and torque components. In last four decades this method was investigated by many researchers.

Nowadays, estimation of parameters in IMs is spread among researchers. One of the most popular methods for parameters estimation in induction motors is Kalman filter. Kalman filter is one kind of observer that with filtering of the measurement noises and system noises and by considering of nonlinear induction motor model, estimate the state variables.

In this study, a new IRFOC method for faulty IM is presented. In this method by using two new rotational transformation matrixes, the transformed equations of the faulty induction motor to the rotor field oriented reference frame become similar to the equations of a balance motor. The advantage of the presented method is that it can be used for the vector control of all of faulty motors and single-phase IMs. Moreover, in this project, a new method for estimation of rotor speed by using EKF in faulty motors is presented.

1.2 Objectives

This research presented a new method for modeling, control and speed estimation of 3-phase IM under open-phase fault condition. The Objectives of this research are:

1-To develop a model of a faulty 3-phase IM(IM) that can be controlled using a field-oriented control technique

2-To modify a conventional field-oriented control of IMso that it can be used for unbalanced 3-phase IM

3- To develop an Extended Kalman Filter (EKF) for a faulty 3-phase IM

4-To verify the developed model and field-oriented control via simulations

1.3 Scope of study

To achieve the research objectives, the following scopes will be covered:

a. The fault condition will only be limited to an open-phase type.

b. Study on the conventional Field Oriented Control (FOC) method for faulty will be focused mainly on the rotor flux field-oriented (RFOC).

c. Development and modification will be based on the conventional EKF and FOC for a balanced three-phase IM.

d. The effectiveness of the proposed method will be evaluated using Matlab software.

e. Analytical comparison between the conventional FOC and the proposed FOC for 3-phase IM under faulty condition will be performed.

1.4 Problem Statement

Over the past decades, many control methods have been proposed for IMs drive system [1]-[36] and one of the most popular control method for controlling the speed and torque of the IM is the FOC. From the energy conversion point of view, almost all electrical machines including IM, can be modeled by an equivalent two-phase machine model (*d*-*q* model) [2]. Under normal operating condition, this two-phase machine has a balanced structure and is used to derive the well-known Rotor Field Oriented Control (RFOC) scheme. In the same way, a faulty three-phase IM such as one of the phase is cut-off, can also be modeled by an equivalent two-phase machine however, with an unbalanced structure. In some critical applications, such as in space exploration, electric vehicle and military, the control of faulty three-phase IM is very important and critical. These applications require a fault-tolerant control techniques whereby the operation of the drive system cannot be interrupted by a faulty conditions mainly for safety reasons, and the drive systems must sustained its minimum operating performance at least until the faults are rectified. The modeling and control of faulty IM, however, is obviously different from the conventional balanced three-phase IM. As such, new modeling and control approaches have to be applied at the instance the faulty is detected. In this research, only stator phase cut-off faulty, which is a typical faulty condition in three-phase IM, will be considered. By applying the conventional balanced three-phase IM control strategy, such FOC to faulty IM, significant oscillations in the torque output will be presence; this is because of the unequal inductances in the d and q axis of the unbalanced IM. It is also interesting to note that the model of the unbalanced three-phase IM (with one phase cut-off) is in principle, similar to the single-phase IM model. In other words, a single-phase IM can also be classified and considered as an unbalanced three-phase IM.

One of the drawbacks in FOC method is rotor speed measurement. Estimation of rotor speed instead of rotor speed measurement by using speed sensor will reduce the complexity, size and cost of the drive system. Another problem of using speed sensor in harsh and noisy environment is it may fail to find the stable position.

1.5 Arrangement of project report

This project report is organized as follows:

After introduction in chapter 1, in chapter 2, the literature review of the previous works and the d-q model of the balanced 3-phase IM have been presented. Moreover, the RFOC model of balanced 3-phase IM is discussed in this chapter. After that, VSI for feeding of IM is shown. In chapter 3, the d-q model of the faulty 3-phase IM is presented. Furthermore, a new method for RFOC of unbalanced 3-phase IM is presented in this chapter. The equations of vector control for faulty 3-phase IM by using conventional rotational transformation and the main idea of using rotational transformations for faulty 3-phase IM is presented in this chapter. Besides, a brief overview of the EKF algorithm and estimation of rotor speed for 3-phase induction motor under open-phase fault is explained in chapter 3. The performance of the presented methods are analyzed and checked through experiments and Matlab simulations in chapter 4. Finally the paper is concluded in chapter 5. Besides, we suggested some recommendation for the future work in this chapter.

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