MODELING AND VECTOR CONTROL OF THREE-PHASE INDUCTION MOTOR WHEN TWO PHASES OF THE STATOR ARE OPEN CIRCUIT

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To my beloved family and specially my dears father and mother

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ABSTRACT

Variable Frequency Drives (VFDs) are used to provide reliable dynamic systems and significant reduction in usage of energy and costs of the induction motors. Over the past decades, many control techniques have been proposed for induction motors drive system. One of the most well-known control method for controlling the speed and torque of the induction motor is Field-Oriented Control (FOC) technique. Modeling and control of faulty or an unbalanced three-phase induction motor (two stator phases open-circuit) is obviously different from healthy three-phase induction motor. Using conventional FOC for faulty three-phase induction motor, results in a significant torque and speed oscillation under fault conditions. Modeling and vector control of a faulty three-phase induction motor is extremely important in some critical applications, such as traction drive in military and space explorations, to ensure fault-tolerant operations. This research presented a new method for modeling and control of three-phase induction motor under fault condition (two-phase open circuit fault). The proposed method for modeling and vector control of faulty induction motor are based on d-q and Rotor FOC (RFOC) methods. It is shown the d-q model of faulty three-phase induction motor has the same structure of equations as the balanced three-phase induction motor. Therefore, by using some modifications to the conventional controller such as FOC, a novel technique for three-phase induction motor with two stator phases open-circuit (faulty three-phase induction motor) has been developed. A comparison between conventional and modified controller showed that the modified controller has been significantly reduced the torque and speed oscillations.

ABSTRAK

Pemacu frekuensi boleh-ubah digunakan untuk memberi sambutan dinamik yang mantap serta mengurangkan penggunaan tenaga dalam motor aruhan. Untuk beberapa dekad yang lepas, banyak kaedah kawalan motor aruhan telah diperkenalkan. Salah satu kaedah yang paling popular untuk pengawalan laju dan dayakilas ialah kawalan medan-berorientasi (Field-oriented Control (FOC)). Kawalan dan permodelan untuk motor rosak (dua fasa terputus) atau motor 3-fasa yang tidak seimbang sudah pastinya berlainan dari kaedah kawalan dan permodelan untuk motor 3-fasa yang sihat. Menggunakan kaedah kawalan FOC sedia ada untuk motor-motor ini akan menyebabkan ayunan yang tinggi dalam sambutan dayakilas dan laju motor. Permodelan dan kawalan untuk motor rosak adalah penting untuk aplikasi tertentu seperti dalam ketenteraan dan eksplorasi angkasa lepas di mana operasi harus diteruskan walaupun kerosakan telah berlaku pada motor. Penyelidikan dalam tesis ini membentangkan kaedah baru dalam permodelan dan kawalan FOC untuk motor aruhan 3-fasa yang mana dua dari fasanya adalah terbuka. Kaedah yang digunakan adalah berasaskan kepada permodelan d-q dan fluks rotor FOC. Ditunjukkan dalam tesis ini permodelan d-q untuk motor rosak mempunyai bentuk persamaan yang sama dengan motor yang sihat. Dengan membuat sedikit ubah suai keatas FOC sedia ada, kawalan untuk motor rosak (dua fasa terbuka) telah dapat dihasilkan. Perbandinagn di antara kawalan kaedah lama dan baru menunjukkan kaedah baru dapat mengurangkan ayunan pada dayakilas dan laju dengan baik.

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LIST OF ABREVIATIONS

FOC	-	Field-Oriented Control
RFOC	-	Rotor Field-Oriented Control
SFOC	-	Stator Field-Oriented Control
IRFOC	-	Indirect Rotor Field-Oriented Control
DRFOC	-	Direct Rotor Field-Oriented Control
DTC	-	Direct Torque Control
HVAC	-	Heating Ventilation and Air Conditioning
VFCD	-	Variable Frequency Control Drives
MEMF	-	Motional Electromotive Force
SNR	-	Signal to Noise Ratio
GA	-	Genetic Algorithm
MRAS	-	Model Reference Adaptive System
RMRAS	-	Robust Model Reference Adaptive System
KF	-	Kalman Filter
EKF	-	Extended Kalman Filter
RLS	-	Recursive Least Square
VHFIM	-	Virtual High Frequency Injection Method

CHAPTER 1

INTRODUCTION

1.1 Background of Study:

Three-phase induction motors are utilized in wide range of applications as a means of transforming electric power to mechanical power [1]. The alternating current is provided to the stator winding directly whereas supply the voltage to the rotor winding is by induction; consequently it is named induction machine. The induction machine has the ability to function as a motor and as a generator. Nevertheless, it is rarely employed as a generator providing electrical power to a load. The overall performance features as a generator are not good enough for most usage. The induction machine is broadly applied as a motor in many applications. The induction motor is employed in different sizes. Small single-phase induction motors are applied in many domestic appliances, such as lawn mowers, juice mixers, blenders, washing machines, stereo turntables, and refrigerators. Large three-phase induction motors (in 10's or 100's of horsepower) are applied in fans, compressors, pumps, textile mills, paper mills and so forth. The linear type of the induction machine has been created mainly in order to use in transportation systems [2].

1.2 Problem Statement:

The AC motor drives are broadly used in industry. In these drives, AC motors like permanent magnet synchronous motors and induction motors are widely used. Common applications of AC drive systems are Heating, Ventilation and Air Conditioning (HVAC), mixers, fans, robots, etc. [3]. Over the past decades, many control techniques have been proposed for induction motors drive system. One of the most well-known control method for controlling the speed and torque of the induction motor is Field-Oriented Control (FOC). From the energy conversions point of view, practically almost all electrical machines including induction motor, can be modeled by an equivalent two-phase machine model (d-q model) [4]. Under healthy operating condition, this two-phase machine has a balanced structure and is used to derive the well-known Rotor FOC (RFOC) scheme. In the same manner, a faulty three-phase induction motor such as two of the phases are cut-off, can also be modeled by an equivalent two-phase machine however, with an unbalanced structure (in this research, only stator two phase cut-off faulty, which is a typical faulty condition in three-phase induction motor, will be considered). Modeling and control of faulty induction motor, is obviously different from the conventional balanced three-phase induction motor. As such, new modeling and control approaches have to be applied at the instance the faulty is detected. By applying the conventional balanced three-phase induction motor control strategy, such FOC to faulty induction motor, 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 induction motor.

1.3 Research Objective

This research presented a new method for modeling and control of three-phase induction motor under fault condition. Main objectives of this research are as follows:

- To review the control technique for faulty three-phase and single-phase induction motor drive.
- To develop a model of a faulty three-phase induction motor when two-phases of the stator are open circuit, which can be controlled using FOC technique.
- To modify a conventional FOC of induction motor, so that it can be applied for unbalanced three-phase induction motor (while two-phase of stator are open circuit).
- To verify the developed model and FOC technique via simulations.

1.4 Scope of Study:

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

- The fault condition will be limited to two-phase open circuit.
- Study on FOC will be focused mainly on Indirect RFOC (IRFOC).
- The effectiveness of the proposed method will be evaluated using MATLAB software.
- Comparison between the conventional FOC and the proposed modified FOC for three-phase induction motor under fault condition.

1.5 Significance of Study:

Modeling of a three phase induction motor during two phase open circuit faulted condition (faulty or an unbalanced three phase induction motor) is extremely important in some critical applications, such as traction drive in military and space explorations, to ensure fault-tolerant operations. In some critical applications, such as in space exploration, electric vehicle and military, the control of faulty three-phase induction motor 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. It is also interesting to note that the model of the unbalanced three-phase induction motor (with two phase cut-off) is in principle, similar to the single-phase induction motor model. In other words, a single-phase induction motor can also be classified and considered as an unbalanced three-phase induction motor.

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