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OPTIMIZATION FOR PMSM BY USING PARTICLE SWARM OPTIMIZATION

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I hereby declare that I have read this thesis entitled *"Optimization for PMSM Drive Using Particle Swarm Optimization"* and in my opinion this thesis is sufficient in terms of scope and quality for awarding the degree of Bachelor in Electrical Engineering (Control, Instrumentation and Automation)

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OPTIMIZATION FOR PSMS DRIVES USING PARTICLE SWARM OPTIMIZATION

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A report submitted in partial fulfilment of the requirements for the Bachelor of Electrical Engineering

Faculty of Electrical Engineering
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I declare that this thesis entitled *"Optimization for PMSM Drive using Particle Swarm Optimization"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: ………………………………………………………...

Name : …………………………………………………………

Date : …………………………………………………………

To my beloved mother and father

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ABSTRACT

This report shows a modern method for speed control of a PMSM utilizing the Particle Swarm Optimization (PSO) algorithm to improve PI- Controller parameter such as Kp and Ki. This project promotes the software which can perform the result and performance of PMSM drive. There are three objectives to be achieves in this project which are to design a model of PMSM base on vector control approached, to apply PSO technique to improve PMSM drive, to verify the effectiveness of the proposed PSO technique through experiment analysis. The usage of PSO as an optimization algorithm creates the drive tough, with advance dynamic response, progressive accurateness and sensitive to load deviation. Contrast amid different controllers is accomplished, utilizing a PI controller which is tuned by two techniques, firstly conventional and secondly utilizing the PSO method. The performance of PMSM will be evaluated based on the speed response produced by different tuning methods. The rise time, overshoot and settling time will be recorded for making comparison. The result show by applying PSO method for tuning the PI parameters, the overshoot and settling time is decrease compare with trial and error method. But, the rise time for PSO method is more than trial and error method.

ABSTRAK

Laporan ini menunjukkan kaedah moden untuk mengawal kelajuan PMSM menggunakan algoritma Pengoptimuman Swarm Partikel (PSO) untuk memperbaiki parameter PI-Pengawal seperti Kp dan Ki. Projek ini mempromosikan perisian yang dapat melaksanakan hasil dan prestasi pemacu PMSM. Terdapat tiga matlamat yang dapat dicapai dalam projek ini iaitu untuk merekabentuk model PMSM berdasarkan kawalan vektor mendekati, untuk menggunakan teknik PSO untuk meningkatkan pemanduan PMSM, untuk mengetahui keberkesanan teknik PSO yang dicadangkan melalui analisis eksperimen. Penggunaan PSO sebagai algoritma pengoptimuman menghasilkan pemacu yang sukar, dengan tindak balas dinamik yang maju, ketepatan progresif dan sensitif terhadap sisihan beban. P pengawal yang berbeza telah dicapai, menggunakan pengawal PI yang ditala oleh dua teknik, pertama konvensional dan kedua menggunakan kaedah PSO. Prestasi PMSM akan dinilai berdasarkan respon laju yang dihasilkan oleh kaedah penalaan yang berbeza. Masa kenaikan, masa pelarasan dan masa penyelesaian akan direkodkan untuk membuat perbandingan. Hasilnya menunjukkan dengan menggunakan kaedah PSO untuk menala parameter PI, masa overshoot dan penyelesaian adalah berkurang berbanding dengan kaedah percubaan dan ralat. Tetapi, masa kenaikan untuk kaedah PSO adalah lebih daripada kaedah percubaan dan kesilapan.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Permanent Magnet Synchronous Motor (PMSM) is widely used in industries involving motor usage. PMSM is popular due to high power density and large torque according to inertia ratio, high efficiency and speed of the motor can be controlled. The criteria required in the high performance drive system used in robotics, rolling mill, and machine tools are fast and accurate system response, and not sensitive parameters to variation. Not only eliminating the torque and flux that make the system respond quickly, PMSM drives that using the vector control scheme also make control tasks be easy. To fulfil the criteria required to improve drive performance, the speed controller plays a very important role. The usage of controllers such as proportional integral (PI) and proportional integral differential (PID) has been widely used to control DC and AC motors. For controllers like PI and PID, this controllers are difficult to design if the model system is not available. Another weakness for this controller is unknown load dynamics and other factors such as noise, temperature, saturation, etc. affect the performance of these controllers for wide range of speed operations [1]. Some ways have been used to improve PMSM performance such as, Adaptive fuzzy PI, Intelligent technique and genetic algorithm PI controllers. This project using Particle Swarm Optimization (PSO) to tuning PI controllers. The intelligent PI speed controller utilizes the PSO to enhance algorithm the PI-parameters (*Kp* and *Ki*). The entire objective, scope and other will be discussed in the next subchapter

1.2 Problem Statement

By using a PI controller, there are some problems that have come out. First and foremost, when used the step reaction of Ziegler Nichols method, Root-locus method, and Particle Swarm Optimization technique, the problem has come from the tuning part. This problem will make the tuning section become difficult and take long time to finish it.

PI controller is used to control the speed and current available in axis d and q. However the PI controller has some limitations such as its design depending on the exact machine model and the exact parameters.

In addition, PI controller have some weaknesses such as very sensitive to interference such as parameter variation and load disturbances [2]. This difficulty leads to complicated control design. However, for intelligent controller, the design does not require the exact mathematical model of the system. Intelligent controller is able to solve nonlinear problems through learning, Artificial Neural Network are applied for this area.

In conclusion, in this project, all of the problem that was stated will be trying to overcome. Lastly, the validation results that we get from the simulation are recorded to overcome the problem.

1.3 Objectives

The objectives to be achieved in this project are:

- To design a model of PMSM drives using vector control approached.
- To apply PSO technique to improve PMSM drive
- To verify the effectiveness of the proposed PSO technique through simulation analysis.

1.4 Scope of Project

There are several scopes that should be achieved in this project:

- To design the PMSM drive system by using MATLAB/ Simulink.
- To find the value parameter PI controllerKp, Ki and from trial and error method, and Particle Swarm Optimization method.
- To compare, the better system response by using different method of tuning the PI controller.

1.5 Motivation

The motivation to run this project are to make easy work for tuning PI parameters (Kp and Ki) by using optimization technique. As world know, nowadays technology grows up very fast. All of the work should be done in very faster to reduce of working time. In conclusion of this project, it can help of industries to minimize of their problem in tuning of controller for PMSM drive.

1.6 Summary

From this chapter, the general task is presented in details. From the objective and the scope of the project, some ideas of this project is explained. In the next chapter, the literature review will be discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses some conclusion about several projects that has been carried out by others researcher in this world. To complete this "Optimization for PMSM Drives using Particle Swarm Optimization (PSO)", a lot of research papers were used as a reference.

2.2 Types of Synchronous AC Motors

There are several types of AC Synchronous Motor, each types of AC motor have a difference characteristic such as construction and working principle. The following are the types of synchronous motors.

- Salient pole
- Non salient pole (round or cylindrical rotor)
- Permanent magnet (surface, inset, buried/interior, imprecated
- rotor)
- Reluctance motor (synchronous reluctance, switched reluctance)
- Stepping motor (variable reluctance, permanent magnet, hybrid)

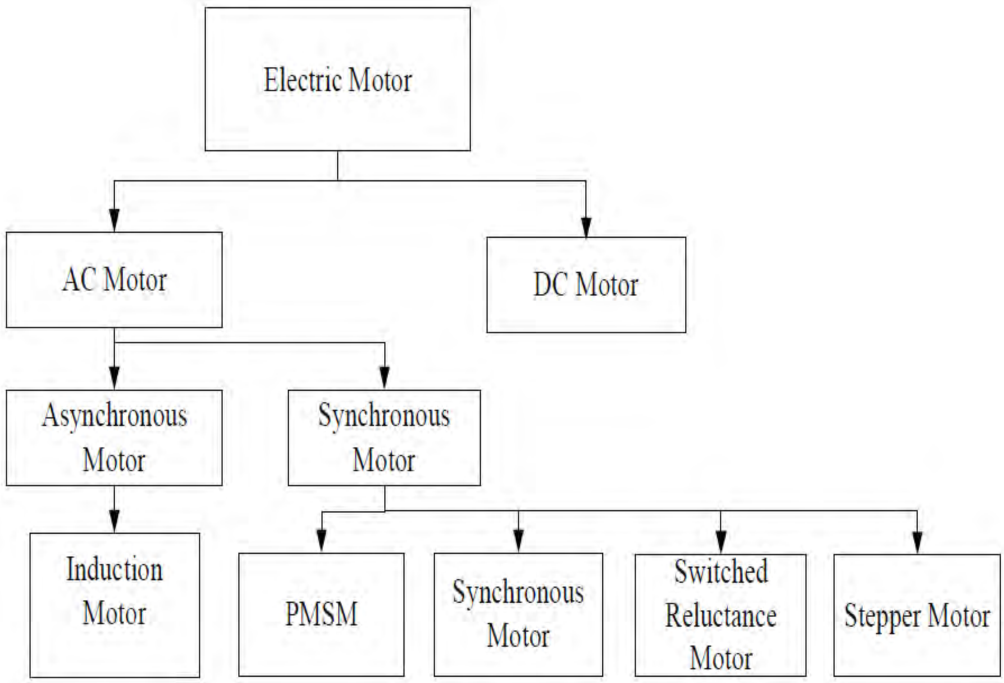


Figure 2.0: Types of Electric Motor

Figure 2.0 shows the type of electric motors. It can be divided into two groups, which are AC motor and DC motor. AC motor can be classified into two types which are asynchronous motor and synchronous motor. Induction motors in the Asynchronous motor category, while Synchronous motors comprise of PMSM, Switched Reluctance Motor, and Stepper Motor.

2.3 Advantage of PMSM over than other Motors

1) Permanent Magnet Synchronous Motor (PMSM) has a lower inertia compared to Induction Motor because of no rotor cage in the construction of PMSM. This cause the reaction to the electric torque faster. This means the torque to inertia ratio of this PMSM is higher.

2) Efficiency for PMSM is higher than Induction Motor. This is because the rotor losses for Permanent magnet machines is ignored. This theory applies to continuous flux operations.

3) To achieve excitation, IM require a source of magnetization. However, the excitation for PM machines is in the form of rotary magnet.

4) For the same capacity, the PM machine has a smaller size than IM machine. This is very useful if the area is limited.

2.4 Field oriented control of PMSM

Field oriented control (FOC) is one of the important variations in controlling PMSM in term of vector control methods [3]. FOC play a role in controlling the magnetic field and torque through control the component of d and q of stator current or relative flux.

By using FOC technique, motor torque and flux can be controlled very effectively through the information obtained from the stator current and the rotor angle. One of the advantages of FOC is the fast response and small torque ripple [4].

The FOC technique is implemented using two current regulators such as direct-axis component, quadrature-axis component, and one speed regulator.

2.5 Direct Torque Constant of PMSM

In 1980, I. Takahashi and T. Noguchi introduced the direct torque control technique for induction motors as an alternative to controlling flux and torque [5]. The DTC control the state of inverter directly, by comparing the error between the reference and the approximate value of torque and flux. One of the six voltage vectors produced from the voltage source inverter is selected for storing and supplying at the limits of two hysterical bands. The advantages of DTC are dynamic torque feedback, low complexity, and robustness [6]. Figure 2.1 shows the basic block diagram of the conventional DTC PMSM. The components that found in the diagram are current transform, flux estimators for torque and stator, hysteresis comparators for flux and torque, a switching table, and a voltage source inverter.

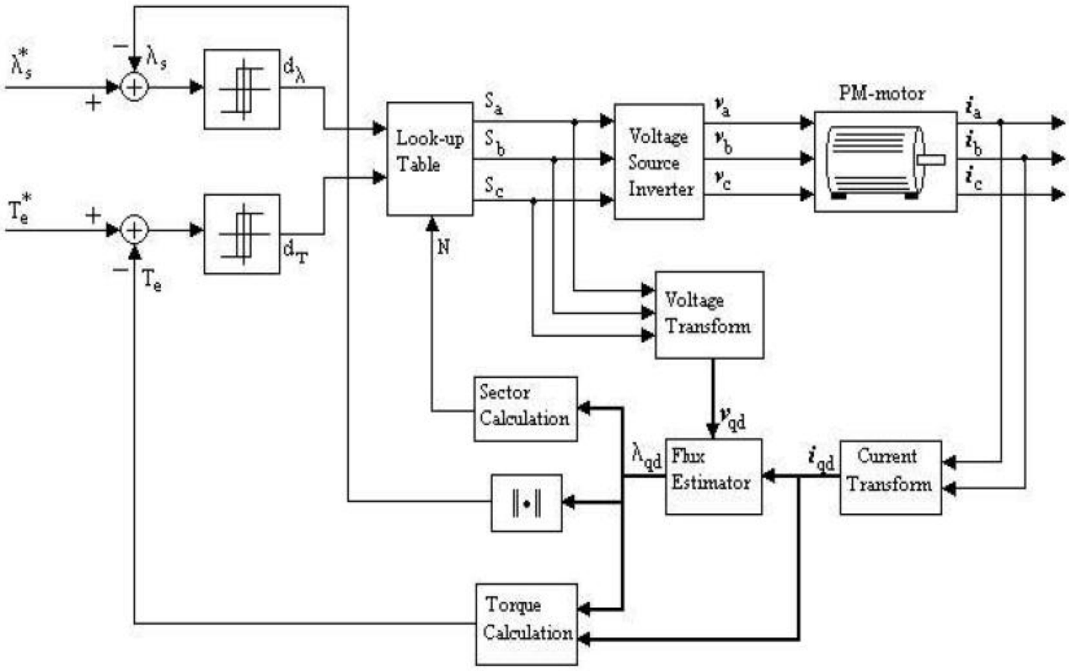


Figure 2.1: Block Diagram of the conventional DTC

2.6 Comparison of Static and Dynamic Performance

This journal explain the differences between DTC and FOC. The authors made studies related to static and dynamic performances of FOC and DTC [7]. Every information obtained from simulation by using the MATLAB / Simulink Power System Block.

The objective of this project is to compare the control strategies, by using the same power section.

This journal presents the advantages and disadvantages of each type of command. This command is very important to meet the need to know:

- Static and dynamic performance of a system (FOC and DTC).
- Control with best prosecution guidelines
- Best releases disturbance.
- Not sensitive to changes in parameters.

2.6.1 Comparison at the level of regulation speed

Diagram 2.2 shows the results of the simulation for FOC hysteresis and DTC technique by applying torque load equal to 5N.m at t = 0.1s and a reference speed equal to 100 rad /s. The result of the simulation shows the peak torque at start up for FOC is greater than the DTC, since the application of the load at t = 0.1s, so the torque reacts quickly, which causes rapid rejection of the disturbance.

The advantages of DTC compared with FOC hysteresis is the speed of DTC has high dynamic without start-up, overshoot, and the response time is also reduced.

For stator flux, DTC can achieve its reference value without overrun, contrast with FOC hysteresis there is an overrun during start-up.

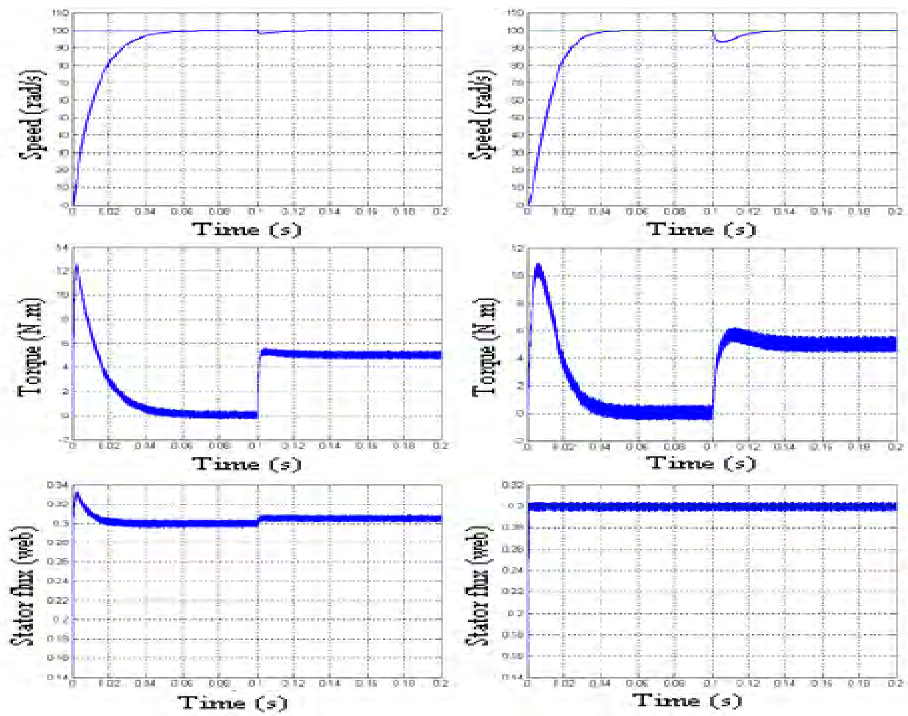
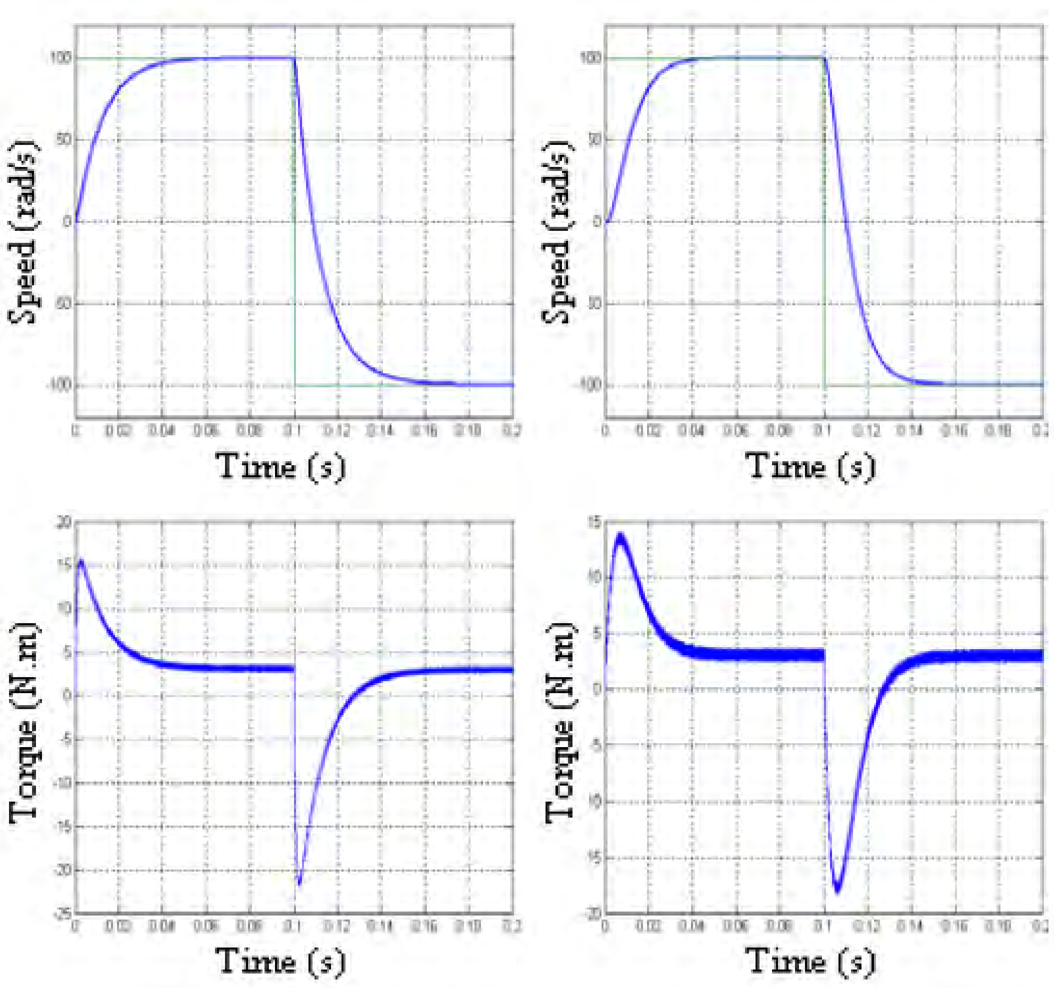


Figure 2.2: Regulation of speed followed by an application of torque load at the t = 0.1 s [7]

2.6.2 Test of Strength for Reversing Rotation of the Machine

The speed reference is changed from +100 rad/s to -100 rad/s aimed for testing the strength of the both technical command for the reverse direction at time, t = 0.1s when the torque load is 3Nm. Figure 2.3 shows that continuity in speed is normal and there is no overrun for DTC and FOC. In addition, the difference between both technical command is FOC hysteresis present the peak torque than DTC.

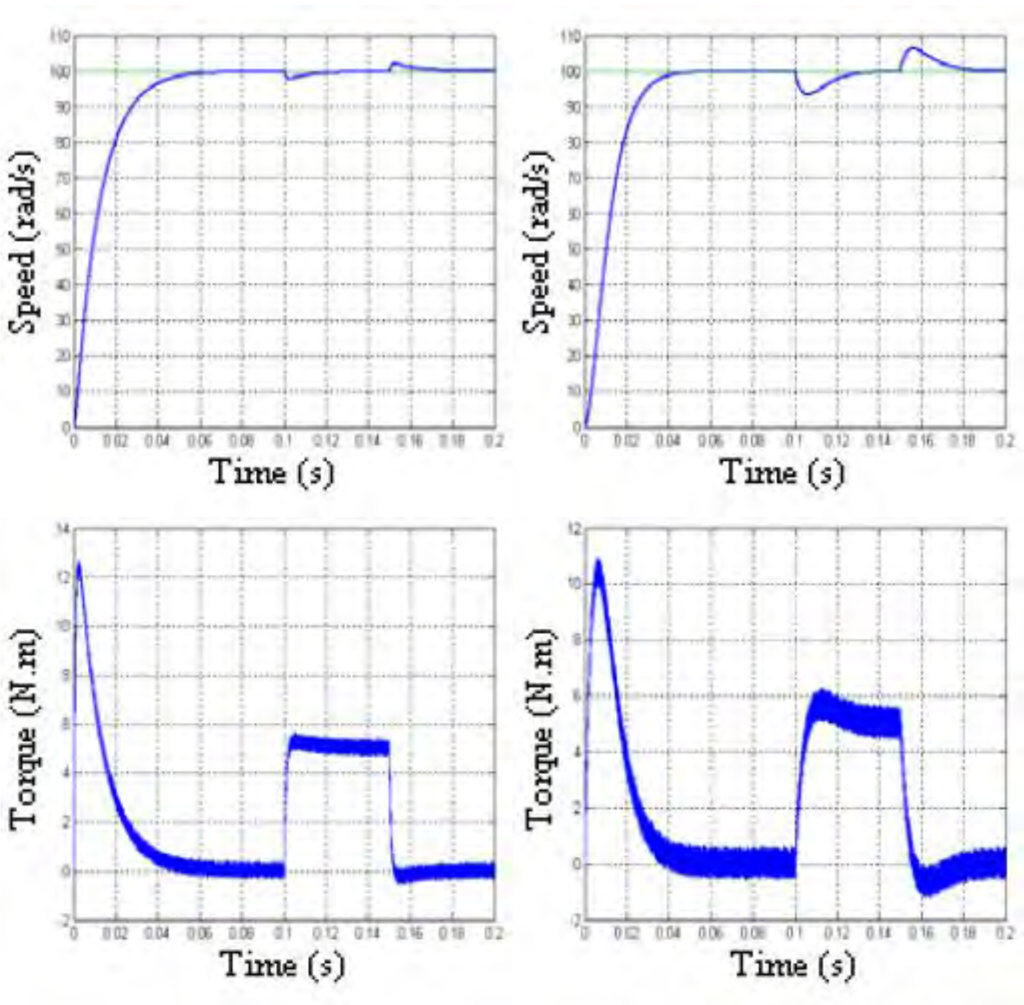


(a) FOC (b) DTC

Figure 2.3: Comparison of inversion speed between 100rad/s to –100 rad/s [7]

2.6.3 Test of Robustness for Load Change

The speed, flux stator, and torque as shown in figure 2.4 are from the machine in case of starter vacuum at speed level is 100rad / s. The load torque that be used is 5N.m at time t = 0.1s, then the load torque is changed to 0N.m at time t = 0.15s. The result shows the torque reacts immediately, and the speed reaches the reference when a minor flaw in the FOC case. In contrast, the speed of DTC reaches its reference after a considerable strain.



(a) FOC (b) DTC

Figure 2.4: Comparison at the variation torque load [7]