Ain Shams University

Faculty of Engineering

Enhancement of the Performance of a Mechatronic System

A Thesis

By

Noha Yaseen Abdelfattah Mostafa

Submitted in partial fulfillment of the requirements of the degree of M.Sc. in Mechanical Engineering

Supervised by

Prof. Dr. Farid A. Tolba

Prof. Dr. Magdy M. Abdelhameed

Cairo 2012

Statement

This thesis is submitted in the partial fulfillment of master degree in Mechanical Engineering to Ain Shams University.

The author carried out the work included in this thesis, and no part of this thesis has been submitted for a degree or qualification at any other university.

Signature

Noha Yaseen Abdelfattah Mostafa

Examiners Committee

The undersigned certify that they have read and recommend to the Faculty of Engineering – Ain Shams University for acceptance a thesis entitled "Enhancement of the Performance of a Mechatronic System", submitted by Noha Yaseen Abdelfattah Mostafa, in partial fulfillment of requirements for the degree of master in Mechanical Engineering.

Signature

Prof. Dr. Farid Abdel Aziz Tolba
Professor of Automatic Control
Design and Production Engineering Department
Faculty of Engineering - Ain Shams University

Prof. Dr. Fahmy Metwally Bendary
Professor of Automatic Control
Faculty of Engineering- Shoubra - Benha university

Prof. Dr. Taher Jamal Aboelyazyd
Professor of Production Engineering
Faculty of Engineering - Ain Shams University

Pro.f Dr. Magdy Mohamed Abdelhammed
Professor of Automatic Control and Mechatronics
Design and Production Engineering Department
Faculty of Engineering - Ain Shams University

Date: / / 2012

Acknowledgment

First of all, I would like to thank GOD for giving me the strength and health to do this project work until it was done

I am heartily thankful to my supervisors Prof. Dr. Farid A. Tolba and Prof. Dr. Magdy M. Abdelhameed whose motivation, guidance and support from the initial to the final level inspired me to develop an understanding of the subject.

I owe my deepest gratitude to all my family my parents, my sisters Nada and Yasmin , my beloved husband Mahmoud and my dear lovely daughter Malak for their personal support and great patience at all the times.

I am most grateful to Eng. Ahmed Ramadan, Eng. Tamer Ismail, Eng. Hend, Eng. Omar Shehata and all my colleagues for their help and encouragement.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project.

Noha Y. Mostafa

Enhancement of the Performance of a Mechatronic System

Abstract

Saturation happens in different locations in the system which affects the performance negatively. Improvement is considered a very interesting point of research. To overcome the drawbacks of such a phenomena; in this work, a combination of vector control and backstepping control technique is presented and tested on an experimental set. The proposed controller has proved its ability to improve positioning system performance in the presence of saturation. Practical implementation and experiments had been carried out to validate the simulation results.

Keywords: Saturation; Permanent magnet synchronous motor; Backstepping control; Non linear control; PMSM.

Summary of the M.Sc. Thesis

Enhancement of the Performance of a Mechatronic System

There have been great efforts to develop high performance control schemes to enhance the performance of the mechatronic servo systems. They are subjected to a group of serious non-linear problems, such as Dead-zone, backlash, hysteresis and saturation which exist in mechanical, hydraulic, magnetic, and other types of system components.

Saturation is a very common nonlinear phenomenon in engineering systems. It exists in different parts of a control system, such as actuators or sensors, due to the capacity limits of those physical components. Among saturation happening at different locations, of special interest and common occurrence are systems with input saturation.

Hence, input saturation has been widely studied since1950s, and significant advances have been reported over the last decade. However, the number of available results by taking saturation into account in the design is still limited due to the difficulty of the problem.

For linear systems with control effort constraints, many methods have been proposed for control law design, such as stable feedback regulation, anti-windup schemes, error governors, reference governors, and approaches based on exploitation of positively invariant sets. For linear systems with bounded controls and control-rates, a small gain approach is used to obtain a stabilizing control law. For non-linear systems, optimal control approach has been investigated. For a class of nonlinear systems the unforced dynamics of which

are Lyapunov stable, a bounded state control for global stabilization is used. Intelligent compensation of actuator nonlinearities for a class of nonlinear system was considered using neural networks (NN).

This thesis presents position control technique for permanent magnet synchronous motor (PMSM) with saturation problem based on nonlinear backstepping technique. Backstepping Control as an effective non-linear control design methods is used usually associated with Lyapunov-based law, so that the whole closed-loop system can meet the expectations of static and dynamic performance.

The mathematical model of the PMSM is established in the d - q coordinates. For its characteristics; Backstepping Control theory is adopted. An experimental set of PMSM AC Servo System is established. PMSM is as its implementation of components. dSpace system is as control core. Intelligent Power Inverter which is produced by SEW is its power-driven core.

In the process of system design, the adjusted parameters are less in the Backstepping Control design than vector control design. The location tracking only needed four parameters in Backstepping Control design and need seven parameters in vector control design. Therefore the Backstepping Control is more easily to design and to achieve in engineering than the vector control.

As long as the parameters are greater than zero during Backstepping Control design, the system will be stable. The selected system parameters may cause instability in the vector control. So the need of classical control theory such as root locus method and so on to solve the Eigenvalues of the transfer function and ensure that they are in the left-ping.

This thesis aims at the non-linear mathematical model of the permanent magnet synchronous servo motor and proposal of Backstepping Control Strategy. The simulation and experimental results show that Backstepping Control strategy can guarantee the global uniform asymptotic stability of the system. Among The advantages of the proposed control strategy are simplicity of designed structure, the adjusted parameters are relatively less. Easiness of achievement in engineering applications.

Table of Contents