The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6201 ADVANCED CONTROL OF ELECTRIC DRIVES

Credits: 15

Course Description including Aims

This module explores advanced modelling and modern control strategies of electric drive systems with a focus on induction (IM) and permanent magnet synchronous machines (PMSM). The main aims of the unit are:

1. To understand the components of modern drive systems including power electronics, sensors and real-time controllers.
2. To analyse the dynamics of IM and PMSM and understand their transient behaviour.
3. To analyse in details the design, operational constraints and dynamic performance of vector and direct torque control strategies for electric drives.
4. To develop an understanding of advanced control methodologies and open research issues including sensor-less drive operation.
5. To effectively understand and use computer modelling for dynamic simulation of electrical drives and design of control algorithms.

Outline Syllabus

Introduction to the control of electric drive systems: Components of a drive systems, sensors and real time control. **Dynamic modelling of AC machines**: Review of reference frame transformations, dynamic models of induction and permanent magnet brushless DC and AC machines. **Vector control of AC machines**. Speed and current control loop design. Operating regions of AC drives, voltage and current limitations, flux weakening control. **Direct torque and flux control of AC machines. Speed and position sensorless control of IM and PM machines. Computer modelling and simulation of electrical drives and control systems.**

Time Allocation

36 lectures plus 12 hours of support material.

Recommended Previous Courses

E6203 “Motion Control an servo drives”

Assessment

3-hour examination, answer 4 questions from 6.

Recommended Books

R. Krishnan	*Electric Motor Drives Modeling, Analysis and Control*	Prentice Hall
S.K. Sul	*Control of Electric Machine Drive System*	IEEE Press
H. Abu-Rub, A. Iqbal, J. Guzinski	*High Performance Control of AC drives With MATLAB/Simulink Models*	Wiley
Bose, B.K.	*Modern Power Electronics and AC Drives*	Prentice Hall

Objectives

By the end of this module successful students will be able to:

1. describe and select components for an electric drive system.
2. demonstrate detailed understanding of the dynamic behaviour of IM and PMSM.
3. use computer modelling for drive system analysis and control design.
4. display in-depth knowledge of vector and direct torque control strategies used in modern drive systems.
5. display a knowledge of advanced and open research topics in electrical drives systems.

Detailed Syllabus

1	Introduction and outline of the course. Review of variable speed drives. Overview of applications in industrial, transportation and renewable energy.
2,3	Components of a drive systems: power electronics (overview of voltage source converters); current sensors (resistive shunts, hall-effect current transducers), position/speed sensors (encoders, resolvers), signal conditioning
4,5	Review of reference frame transformations. DQ models of three-phase passive networks.
6-8	Dynamic models of IM and PMSM in stationary and rotating reference frames. Torque production.
9,10	Current control in single and three-phase AC systems. Hysteresis control. Linear control with PWM. Proportional + Integral (PI) control tuning. Anti-windup. 11,12 Current control in synchronous reference frame. Feed-forward compensation of cross-coupling. Speed control.
13	Torque production in PMSM. Saliency and reluctance torque. Control strategies in PMSM. Maximum torque per current (MTPA) and voltage (MTPV) control.
14-16	Current and voltage limitations in inverter-fed PMSM drives. Operating regions of a PMSM drive. Flux weakening control.
17,18	Introduction to the problem of position sensorless control of PMSM. Back-EMF based estimation. Open-loop estimation
19-20	Closed-loop model reference adaptive (MRSA) estimation of back-EMF for salient and non-salient machines.
21-23	Limitation of back-EMF estimation at zero and low speed. Signal injection methods for sensorless control at zero speed. Pulsating and rotating high-frequency current injection schemes.
24-25	Introduction to Field Oriented Control (FOC) for IM. Direct FOC. Estimation of rotor flux.
26-27	Indirect FOC of IM. Sensorless control of IM.
28	Operating regions and field weakening control of IM.
29-30	Introduction to Direct Torque Control (DTC). Torque production in IM and PMSM.
31-32	Space vector model of 2-level voltage-source inverter (VSI). Hysteresis flux and torque control. Switching tables for DTC.
33-34	Computer modelling and simulation of electric drive systems (Matlab/Simulink). Simulation of a sensorless vector controller.
35, 36	Contingency and reading week.

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1m	The principles of operation of electrical drives for AC machines and the methodologies for feedback design of modern servo drive systems are introduced. The main advantages/disadvantages of alternative control strategies are discussed. Assessed by formal exam.
SM1fl	Comprehensive analysis of dynamic modelling for AC rotating machines and methodologies for feedback design of modern drive systems are presented and thoroughly analysed. Assessed with formal exam.
SM2fl	Development of control methodologies from basic to state-of-the-art high performance electric drives are presented and discussed. Assessed with formal exam
SM2m	The mathematical tools for modelling and design of feedback control of electric machines and drives are addressed in detail. The importance of simulation in assessing the performance of feedback control systems for Induction and Synchronous Permanent magnet motor drives is highlighted and Matlab/Simulink is employed for numerical analyses of electric drive control systems. Assessed with formal exam
SM5m	Comprehensive knowledge and understanding of mathematical and computational models for modelling and control of electrical drives are developed. Limitations of models due to non-idealities, non-linearity etc. are highlighted.
EA1m	The course covers the development of control algorithms of electric drives starting from the modelling of electrical machines and associated power electronics based on fundamental electromagnetic and circuit theory. Assessed with formal exam.
EA2m	Analytical and computer simulation models are employed for the description and performance analysis of drive systems. The course is underpinned by modelling technique, quantitative analysis and design against specific criteria such as control bandwidth, performance, etc. Assessed with formal exam Assessed with formal exam
EA3m	Problems are presented to the students for simulation study of the performance of several control strategies for induction and synchronous permanent magnet motor drives in Matlab/Simulink environment. Assessed with formal exam
EA3m	Formal design approach based on the mathematical modelling and analysis is presented for drive systems with due consideration of constraints on the feasible operating regions and non-linearity. Assessed with formal exam
EA5m	Well established control principles for modern AC drive, as well as detailed discussion of more recent advances in the field will allow students to investigate new and emerging technologies in electric drives Assessed with formal exam
EA1fl	The course develops analytical and numerical methods for the analysis of performance and limitations of modern drive control systems. Assessed with formal exam.
EA2fl	Analytical and computer simulation models are used to investigate performance and implementation of novel and emerging control schemes. Assessed with formal exam

D3m	Methods for modelling and quantification of measurement errors on drive performance are presented. Assessed with formal exam
EP2m	Characteristics of drive components and their interaction in the system are presented and analysed. Assessed with formal exam
EP9m	Current state-of-the-art of drive systems and recent technology developments are outlined
EP1fl	Characteristics of drive components and their interaction in the system are presented and analysed. Assessed with formal exam
EP2fl	Current state-of-the-art of drive systems and recent technology developments are outlined