Engineering Tripos Part IIA, 3B4: Electric Drive Systems, 2022-23

Module Leader

Prof T Long [1]

Lecturers

Dr S Goetz, Prof T Long

Lab Leader

Prof F Udrea [2]

Timing and Structure

Lent term. 16 lectures.

Aims

The aims of the course are to:

- Build on the Electrical Power Course given in Part 1B.
- Recognise that electrical motor drives in applications of all kinds are required to perform at high efficiency, controllability and reliability.
- Study electric drives for: medium power applications; precision applications; high power transport and industrial applications; domestic applications.
- Understand permanent magnet motors and their drive systems with a special focus on all-electric vehicles.
- Examine the magnetic design of permanent magnet motors, focusing on soft magnetic and permanent magnetic materials, saturation and iron losses.
- Study stepper motors which are used in robotics, 2-D and 3-D printers.
- Understand the main design principles of large three-phase induction motors.
- Study electric drive systems based on three-phase induction motors.
- Examine mechanisms for heat production and removal in electrical machines, and be able to carry out thermal analysis for duty-cycling operation.
- Study single-phase induction motor drive systems which are dominant in domestic applications such as white goods.

Objectives

As specific objectives, by the end of the course students should be able to:

- Understand the basic principles of operation.
- Be able to apply simple motor design rules.
- Be able to specify diffferent motors for different applications.
- Understand the design contstriants on multiple motor machines.
- Appreciate magnetic and thermal constraints.
- Be aware of different magnet materials and suitability for motor operation.

Content

The subject of electric drive systems is a vast one, and so the syllabus has been designed to give the student an appreciation of this very important area of engineering by focusing on four areas: electric drives for medium power applications such as electric vehicles (drives based on permanent magnet motors); automation drives with applications such as robotics, 3-D printers (based around stepper motors); large drives for transport/industry (based around the three-phase induction motor); domestic drive systems based around the single-phase induction motor. The course illustrates the idea that the engineering of electric drive systems is multidisciplinary, involving an understanding of mechanics, control systems, power electronics, electromagnetics for machine design, electrical materials and thermal design.

Introduction to Electric Drive Systems (1 lecture)

What is an electric drive system? Range of applications. Components of a drive system. Drive based around brushed DC motor: DC motor principles and operating characteristics; sensors; mechanical load; controller; power electronic converter.

Permanent magnet machines (4 lectures)

Brushed permanent magnet machines and drive systems; principles of operation; analysis; transient behaviour and electrical/electromechanical times constants.

Trapezoidal brushless DC motors: construction, theory and operation as an electric drive system; sensored and sensorless operation.

Sinusoidal brushless DC motors: construction, theory and operation; electric drive system and control; application.

All-electric vehicle: an examination of the specificationof the electric drive system of the NissanLeaf. How the main design choices are made. Consequences for range, top speed, acceleration, efficiency and CO2 emissions.

Magnetic design (1 lecture)

Characteristics of soft and permanent magnetic materials. Analysis using magnetic circuits. Iron loss calculations. Designing with permanent magnet materials.

Stepper motors (2 lectures)

Construction, theory of operation and analysis. Position error. Torque-position characteristic and oscillatory behaviour and its avoidance. Operation at speed and when accelerating. Commissioning. Types of excitation: full-stepping, half-stepping, micro-stepping. Drive circuits.

Basic machine design (2 lectures)

Stator structure including winding and core. Electrical and magnetic loadings. Machine ratings and basic requirement specification. Basic machine design procedure and process.

Induction machine operation (2 lectures)

Operatingcharacteristics of induction machine. Maximum torque and starting torque of induction machines. Speed control methods of induction machine: adjusting stator voltage, adjusting rotor resistance, variable voltage variable frequency (VVVF) method.

Thermal duty cycle of electric machines (2 lectures)

Temperature expression and thermal analysis of electric machines. Basic cooling methods and over temperature protection of electric machine.

Single phase induction machine and universal AC machine (2 lectures)

Theory and equivalent circuit of single phase induction machines. Operating characteristics of single phase induction machines. Equivalent circuit of universal AC machines. Typical applications of universal AC machines.

Examples papers

4 examples papers issued at 2 week intervals to coincide with the lecture material.

Coursework

Electric drive for vehicles

Aim: To understand how an electrical drive system based around a brushless DC motor functions, and to investigate its performance.

Learning objectives:

- To characterise the components of the drive system through a series of tests.
- To perform experiments on the drive system under steady-state conditions in order to understand how it works, and to compare experimental results with theory.
- To investigate the transient behaviour of the drive system during typical drive-cycles.

Practical information:

- Sessions will take place in the EIETL during the Lent term.
- It is best to do the lab after lecture 5 so that all of the background material has been covered.
- Prepare for the lab by reading the lab handout and going over lectures 1 - 5.

Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D4

Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering

discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

Last modified: 23/11/2022 08:36

Links
[1] mailto:tl322@cam.ac.uk
[2] mailto:fu10000@cam.ac.uk
[3] https://teaching22-23.eng.cam.ac.uk/content/form-conduct-examinations
[4] https://teaching22-23.eng.cam.ac.uk/content/uk-spec