The University Of Sheffield.

Electronic & Electrical Engineering.

EEE223 ELECTRICAL ENERGY MANAGEMENT AND CONVERSION

Credits: 20

Course Description including Aims

An outline of the electrical supply infrastructure, including the plurality of electrical energy generation modalities currently in use, is followed by elementary ideas behind protection, safety and tariff structures. The characteristics of electrical machines are discussed together with the circuit strategies that can be used to control of machine performance. Circuits for more general high efficiency power management are also described. Circuits dealing with power will dissipate energy and that energy must be removed if overheating is to be avoided - elements of thermal management are discussed in the context of audio power amplifiers.

Specific aims of the unit are

1. make students aware of the operation of the UK power grid system
2. give students an understanding of tariff structures and system protection
3. cover sufficient magnetostatics for understanding of machine operation
4. introduce the idea of pulse width modulation (pwm) as energy flow control mechanism
5. apply pwm ideas to motor control and power management problems
6. consider energy dissipation within an electronic device
7. introduce simple thermal modelling and heatsinking strategies

Outline Syllabus

Energy supply system – overview of organisation, generation, protection, tariffs, ***Energy sources***, renewables, efficiency. ***Magnetic fields***, Ampère's Law, Bio-Savart Law, forces, self and mutual inductance. Basic ideas behind ***AC and DC machines*** (brushed and brushless), actuators. ***Switching power controllers***, buck and boost, simple lossless considerations – energy in = energy out equilibrium. ***Thermal issues*** with devices – diodes and transistors – estimating power loss, heatsinking, power amplifiers, classes, B (efficiency, maximum power dissipation and working out of P_{DISS}) and D (outline of components of class D system), advantages and disadvantages.

Time Allocation

48 lectures, 24 problem classes, 125 hours guided independent study

Recommended Previous Courses

Knowledge equivalent to first year modules EEE117 and EEE118.

Assessment

Mid-term examination (10%) plus three hour examination (90%), 3 hour examination (answer 4 from 6)

Recommended Books

Dewan	Power Semiconductor Drives	Wiley
Hindmarsh J	Electrical Machines and their Applications	Pergamon
Hindmarsh J	Worked Examples in Electrical Machines and Drives	Pergamon
Slemon	Electric Machines	Addison-Wesley
Williams B W	Power Electronics	Macmillan

Objectives

By the end of the unit, a candidate will be able to . . .

1 show awareness of various conventional and renewable methods of power generation.
2 describe various method of protection used in power systems
3 make simple estimates of electrical energy costs based on prevailing tariff structures
4 perform basic force calculations related to the magneto-statics
5 compare and contrast the characteristics of several types of electrical machine
6 identify the aspects of a machine characteristic that can be used for performance control
7 design simple pwm control circuits
8 estimate the switching time of a power MOS switch and the consequences for switching losses.
9 design a choke input smoothing filter in the context of a switching regulator.
10 work out first order estimates of buck-boost and boost converter behaviour.
11 estimate the power dissipated in an audio power amplifier output stage
12 choose a heatsink capable of removing heat well enough to keep system temperatures within defined boundaries.

Detailed Syllabus

lecture	**topic**
1 & 2	Introduction to course and outline of contents. Review of phasor and complex notation and of 3-phase, star and delta connections. Overview of components of a power system.
3,4 & 5	Transmission and distribution systems (and typical voltages). Electricity demand by sector, daily variation, annual variation, tv pickups. Fuels used in generation, diversity, implications. Renewable energy; environmental issues, fuel poverty, security of supply, international agreements. Renewable sources, biomass, wind, marine, solar, geothermal, hydro, etc. Overview of UK power generation and future trends.
6 & 7	Safety, fault protection and switching. Fuses, isolators and circuit breakers, protection against lightning surges. Elementary tariff structures.
8 & 9	Ampère's force law. Definition of B field, magnetic field. Biot-Savart law, scalar and vector forms, application to long straight wire.
10 & 11	Field lines, field on axis of a circular loop, field of a solenoid, numerical examples. Magnetic flux. Ampère's law for magnetic fields, application to solenoid.
12 & 13	Review of experimental evidence for magnetic induction. Faraday's law. Lenz's law. Numerical example. Self and mutual inductance, calculation of inductance of solenoid and parallel wire transmission line.
14, 15 & 16	Forces due to magnetic fields. Force between parallel wires. Force on a linear conductor. Linear motor. Comparison of linear motor and generator. Torque on a current loop reversibility of energy flows between electrical and mechanical systems. Comparison with electrostatics and force between 2 plates
17, 18 & 19	Review of magnetic circuits and analysis, B-H loops, examples of basic F=BIL analysis applied to a loudspeaker. Development of an electrical equivalent circuit of a loudspeaker. Discussion of other voice coil like applications.

20, 21 & 22	DC machines; principle of operation including the action of the commutator. Motor and generator equations. Performance characteristics of separately excited (inc. permanent magnet) and series wound machines. Discussion of applications.
23, 24 & 25	Induction machines; production of a rotating field, relationship between speed, frequency and pole number. Development of induction motor equivalent circuit for steady state operation, development of torque power and efficiency
26 & 27	Demonstration of poor efficiency for high slip; implications for speed control strategies; single phase induction motors, starting strategies.
28, 29 & 30	Introduction to the idea of switchmode power supplies, circuit shapes for basic single and double ended dc-dc converters, idea of PWM as a regulating modality, advantages and disadvantages of a switchmode approach. BJT and MOSFET switches - behaviour, advantages and disadvantages, and how the data is presented on datasheets. Inductive energy stores, Boost convertors and buck-boost converters assuming ideal switches.
31 & 32	Switching regulators, choke input filtering, design approach for rectangular waveforms - controller ICs. Linear regulators, available IC versions. Overvoltage and overcurrent protection.
33 & 34	Other power switching technologies - SCR, Triac, GTO, IGBT - behaviour and advantages and disadvantages
35 & 36	Principles behind speed control of dc and induction motors
37 & 38	Audio power amplifiers, classes A, B, C, and D. Crossover effects in class B and how they are minimised. Outline of a class D topology. Choosing a supply voltage given a spec for load resistance and required output power. Average supply current versus peak - importance of time constants in any averaging process
39 & 40	Power dissipation and heat removal. Calculation of dissipation in class B output stage. Thermal structure of an electronic device with junction to case and case to sink thermal resistances. Maximum junction temperatures, environmentally limited temperatures. Determination of required heatsink thermal resistance, generality of approach to all electronic devices that need dissipated power removing

EEE223 UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p/SM1m	This unit teaches basic electromechanical energy conversion principles, which enables the students to understand the basic principles and methodology necessary to underpin their education in electrical and electronic engineering, to enable appreciation of its scientific and engineering context, and to support their understanding of historical, current, and future developments and technologies. This is tested by examination at the end of the module.
SM2p/SM2m	The course includes mathematical notation consistent with the subject, and familiarises the students with the language necessary to progress in this field, which is utilised in the final exam for the subject.
SM3p/SM3m	The use of tutorials within the course allows the students opportunities to apply the knowledge to problems in the subject area, supporting their study in the area of electromechanical energy conversion.
EA1p/EA1m	The course puts across basic engineering principles behind electromechanical energy conversion, electric machines and simple power electronic circuits, and applies them to example systems. This is tested by examination at the end of the module.
EA2p	Through the course, the students gain the ability to identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques, with examples being given where appropriate, and the objective being examined at the end of the course.

EA2m Mathematical models are describe circuit behaviour from which students are expected to be able to determine device voltage/current limits and power dissipation so they are able to ascertain suitability of components and design cooling systems. Assessed in the end of module examination.

EA4p/EA4m The course promotes the use of systems based examples to help the students grasp the systems approach to the analysis of problems, for example the study of a servo system to see the interaction of the drive with the motor requirements. This is tested by examination at the end of the module.

EP1p/ EP1m The examples in the course show how the technology can be applied to various problems and in a number of situations to solve problems. This is re-enforced by the tutorial questions. This is tested by examination at the end of the module.

EP2p/ EP2m The course imparts to the students the basic knowledge and characteristics of materials, for example magnets, and equipment (servo systems) and leads them to an understanding of how the characteristics influence the system design. This is tested by examination at the end of the module.

EP4p/ EP4m The course aims to guide the student to be able to extract relevant information from datasheets where applicable, for example switching characteristics of MOSFET's etc. This will be tested by examination, as data will be presented in a similar way as in a datasheet for the questions.

ET5p/ ET5m Students are informed that the electricity generation network is highly regulated and generators must meet certain standards (inc. technical and safety) to provide their services. Students are also made aware of the need to meet power quality and EMC requirements and the challenges these impose.