Engineering Tripos Part IB, 2P8: Mechanical Engineering, 2025-26

Course Leader

Prof M Sutcliffe [1]

Lecturers

Prof H Hunt, Prof M Sutcliffe, Dr S Mandre, Dr S Goetz, Prof J Cullen

Timing and Structure

Lent Term: 14 lectures + 2 examples classes, 4 lectures/week. Lectures will be recorded.

Aims

The aims of the course are to:

- Describe systematic methods for assessing the sustainability of wind energy and other renewable energy systems.
- Analyse the aerodynamics and structural loading of wind turbine blades, the choice of materials, and the effect of scale.
- Analyse the mechanical and electrical aspects of wind turbine machinery.

Objectives

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

- Summarise the technical, social, environmental and economic challenges to consider in assessment of the sustainability of renewable energy systems.
- Make quantitative estimates relating to materials, energy and environmental aspects of a renewable energy technology.
- Analyse the aerodynamic loads on a wind turbine blade.
- Calculate the energy capture potential of a wind turbine.
- Follow an appropriate methodology for preliminary structural design and material selection for wind turbine blades.
- Make a realistic fatigue lifetime prediction for blade structures.
- Select materials and perform structural optimisation for towers and turbine blades.
- Analyse epicyclic and parallel gearboxes as applied to wind turbine generators.
- Undertake a simple modal analysis of a wind turbine.
- Outline principle sources of noise generation in wind turbines.
- Understand how the electrical power generator rating is chosen and the implication for turbine/generator control,annual energy production and system payback period.
- Know the main electrical technologies that are used, their advantages and disadvantages, with reference to the implications for the need for a gearbox, fixed vs variable speed operation and power electronic convertors for interfacing to the 3-phase grid.
- Understand how the induction motor theory taught in the Lent Term may be extended to induction generators.

Content

Overview of renewable energy systems (1L, Prof HEM Hunt)

- Renewable energy technologies: wind, hydro, solar, tidal; development status in UK, EU, worldwide. *(2) Chap. 5*

Sustainable development: materials and renewable energy systems (1L, Prof J Cullen)

- Five-step methodology for assessment of sustainability of a technological development
- Application to wind turbines, focussing on materials supply, energy payback and environmental issues.

Fundamentals of wind turbine design (1L, Prof HEM Hunt)

- Fundamental fluid mechanics limits to energy generating potential, including derivation of Betz limit, influence of size and height, estimates of wind loading, capacity factor.

Wind turbine loading (3L, Dr S D Mandre)

- Aerofoil aerodynamics
- Blade element momentum theory
- Centrifugal loading
- Self weight loading

Structural design and material selection for wind turbines (3L, Prof MPF Sutcliffe)

- Scaling effects
- Material performance indices
- Shape optimization
- Composite blades

Mechanics of wind turbines (2L, Prof MPF Sutcliffe)

- Gearbox design: epicyclic and parallel drives, velocity ratios and tooth force calculations
- Vibration modelling and modal analysis.
- Noise and vibration.

Power generation in wind turbines (2L, Dr S Goetz)

- Electrical challenges of generating electricity from wind energy- contrast with conventional fossil fuel generation met in the Lent Term
- Generator rating in terms of volume and rotational speed.
- Need for gearbox - the electrical perspective.
- Choice of generator rating by considering output electrical power vs wind speed, annual energy production, payback period.
- Generator technologies and their advantages and disadvantages
- (i) Implications for gearbox.
- (ii) Implications for fixed or variable speed operation.(iii) Implications for power electronic convertors and interfacing to the 3-phase grid.
- Extension of induction motor theory met in the Lent Term to induction generators.
- Simple output power and reactive power calculations.
- Slip energy recovery and variable speed operation.

Guest lecture (1L, Prof Shaun Fitzgerald)

- Climate repair

Examples papers

1. Global warming and carbon footprints. Sustainability of wind energy. Wind power fundamentals. Wind

turbine aerodynamics and loading.
2. Manufacturing. Materials. Fatigue. Mechanics. Electrical Power

Booklists

Please refer to the Booklist for Part IB 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 [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] 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.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

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.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

D2

Understand customer and user needs and the importance of considerations such as aesthetics.

D3

Identify and manage cost drivers.

S1

The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

S3

Understanding of the requirement for engineering activities to promote sustainable development.

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).

P5

Awareness of nature of intellectual property and contractual issues.

US1

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

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.

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