Engineering Tripos Part IB, 2P8: Mechanical Engineering, 2018-19

Lecturers

Prof M Sutcliffe, Dr TBC, Dr T Flack, Dr H Shercliff and Dr H Hunt [1]

Timing and Structure

Lent Term: 14 lectures + 2 examples classes, 4 lectures/week

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, Dr 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, Dr HR Shercliff)

- 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, Dr 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. TBC)

- 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 T Flack)

- 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, Mike Wastling,Evance Wind)

- Small-scale wind energy or Large-scale wind energy

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 see the Booklist for Part IB Courses [2] for references for this module.

Examination Guidelines

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

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [5] which sets out the standard for degree accreditation.

The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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