Engineering Tripos Part IIB, 4B19: Renewable Electrical Power, 2018-19

Module Leader

Dr T J Flack [1]

Lecturers

Dr T Flack and Prof G A J Amaratunga

Timing and Structure

Michaelmas term. 16 lectures (including one examples class and one guest lecture). Assessment: 100% exam

Prerequisites

3B3, 3B4, 3B6

Aims

The aims of the course are to:

- introduce the main types of renewable electrical power and the entroduce the main electrical technologies that underpin the generation of renewable electrical power and its integration into the existing electrical transmission and distribution network.
- explain the technologies that enable renewable electricity sources to be integrated into the existing grid at both the transmission and distribution level.
- explain the implications for electrical power systems of the increasing integration of renewable electrical power sources.
- outline the means of quantifying the economic viability of renewable electrical power generation, and show how Government policy can have a significant influence on this.

Objectives

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

- know the various sources of renewable electrical energy and be able to quantify the theoretical energy available from these.
- understand the characteristics of wind turbines and the electromechanical technologies required to match these to generate power to the existing electrical grid.
- understand the theory of asynchronous machines used for large-scale wind generation and why they find widespread use in this application.
- know the theory of permanent magnet and salient pole synchronous machines, and their roles in offshore wind generation and hydroelectric/tidal barrage schemes, respectively.
- understand the operation of a p-n junction diode as PV solar cell, and the means of fabrication of Si solar cells and solar modules.
- know the equivalent circuit for a solar cell.
- understand how the electronic and optical/photonic performance of a solar cell is optimised.
- appreciate the vital role that power electronics plays in renewable electrical power systems with reference to DC links for offshore wind power and solar PV.

- know how electrical power systems are controlled, and appreciate the impact of connecting renewable energy sources at both the transmission and distribution level.
- understand how economics and Government policy affects renewable electricity decision making.

Content

This course is concerned with the electrical technologies that underpin the sources of renewable electricity that make a significant contribution to overall electrical power generation: large-scale wind power; solar PV; hydroelectricity. The theory and operation of these technologies will be explained, with a focus on the electrical aspects. The course will also provide an introduction to some of the enabling technologies that facilitate the connection of renewable electricity sources into the existing 3 phase grid, such as power electronic converters and energy storage equipment. The implications of increasing the proportion of renewable electricity on the operation of the grid will be outlined, as will the economics of renewable energy systems. The effect of Government policy on the uptake of renewable electricity projects will also be briefly considered.

Background to renewable energy (1L, Dr T J Flack)

- Definition, context and arguments for renewable electrical energy.
- Sources of renewable electrical power: hydroelectricity; tidal barrages; wave power; tidal motion; large and small-scale wind power; biomass; solar PV.
- Planning and regulatory issues.

Large-scale wind power (4L, Dr T J Flack)

- Characteristics of wind energy; theoretical power available from the wind (Betz limit and tip-speed ratio); types of wind turbine; control of wind turbines; use of gearboxes; the arguments for fixed and variable speed wind power; options for generator technology.
- Induction generators for large-scale wind power: extension of induction motor theory to generators; generator torque-slip characteristic; speed control by rotor resistance; speed control by slip energy recovery; theory of doubly-fed induction generators; control of reactive power.
- Arguments for offshore wind power, advantages and disadvantages; permanent magnet generators for offshore wind power, theory of permanent magnet generators; connection of offshore wind power into the grid; need for DC links for far-offshore generation.

Introduction to hydroelectric and tidal barrage schemes (1L, Dr T J Flack)

- Quantifying the energy available from hydro and tidal barrage schemes.
- Role within electrical supply system – constant power vs pumped storage operation.
- Turbine design – influence of head of water.
- Salient pole synchronous generators – theory and calculations.

Solar photovoltaics and power electronics for renewables (6L, Prof G A J Amaratunga)

Integration of renewable sources into the grid (1L, Dr T J Flack)

- Overview of UK grid.
- Control of real and reactive power flows.
- Integration of renewable power into existing grid: issues of 'where' and 'when' renewable sources are available.
- Use of energy storage technologies.
- Embedded generation.

Introduction to economics of renewable electricity (1L, Dr T J Flack)

- Introduction to basic economic concepts.
- Simple cost model.

- Inclusion of interest rate/inflation – discounted cash flow analysis.
- Case studies: large hydroelectric plant; small domestic wind turbine vs solar photovoltaics.
- Government incentives and their effects.

Examples Class and Guest lecture (2L, Prof G A J Amaratunga)

There will be one examples class to cover the two examples papers associated with this module.

There will be one guest lecture on an area of topical interest.

Further notes

None.

Examples papers

Two examples papers will be issued.

Coursework

None.

Booklists

Please see the Booklist for Group B Courses [2] for references for this module.

Examination Guidelines

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

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[1] mailto:tjf1000@cam.ac.uk
[2] https://www.vle.cam.ac.uk/mod/book/view.php?id=364101&chapterid=50411
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