SEF 01: Sustainable Energy

Wind Energy
Revision Guide

I list here some of the key points in each of the eight sets of presentation slides I presented. The intention is that these points are a basic checklist in revising for the examination. Being able to deal with these points will be good preparation but you should treat them as a framework of main points to which further detail can be attached.

1 Background

Nothing in this section is specific to the exam.

2 Energy Yield

You should be able to:

- Explain why power is proportional to the cube of wind velocity.
- Define the power coefficient C_P of a turbine in the equation $P = ½\ C_P\ \rho A\ V^3$.
- Use the equation $P = ½\ C_P\ \rho A\ V^3$ to calculate, for instance, power yield from a turbine of a given size in a given wind speed.
- Describe a typical annual distribution of wind speeds and explain how this leads to decisions in turbine design on where to place the cut-in speed, base-speed and cut-out speed.
- Calculate the load factor of a turbine from a simple set of wind speed data.
- Describe how hub height and ground surface roughness affect wind speed and therefore energy yield.

3 Blade Aerodynamics

You should be able to

- Identify the two components of airflow over the blade (due to wind and due to blade rotation through the air) and explain how these combine to form a relative flow over the blade at some angle-of-attack.
- Explain how the lift and drag forces that arise from the airflow over the blade aerofoil can be resolved into a force that acts to rotate the blades and a force that acts as a thrust on the the blade/tower.
- Explain how pitching of a blade can be used to reduce the lift force.
- Explain the term tip-speed ratio and define it with the equation $\lambda = {\omega R}/{V}$.
- Explain the importance of tip-speed ratio to maintaining operation at the maximum power coefficient, C_P of the turbine and how this relates to angle-of-attack.
- Justify the fact that the most common form of turbine is a 3-bladed horizontal axis turbine.

4 The Betz Limit

You do not need to be able to reproduce the proof of the Betz limit.
You should be able to:

- Explain why it is not possible to extract all of the kinetic energy in a moving air-mass by, for instance, reference to $P = \bar{F} \cdot \bar{V}$ and the dependence of V on F.

- Quote $C_P^{Max} = {}^{16}/_{27} \approx 59\%$

5 Turbine Control

You should be able to:

- Explain why variable speed operation of a turbine is important.
- Explain, with refence to wind speed distribution, why two modes operation (power maximisation and constant power operation) are employed
- For each mode of operation, explain which variables are maintained constant and which are varied and in particular which variable is used to effect control (generator reaction torque for power optimisation and blade pitch for constant power). There is no need to learn the equation for optimal torque in the power maximisation regime, but you need to know that such an equation exists.

6 Generators

You should be able to:

- Recognise that a simple generator rotating at variable speed cannot be connected directly to a standard AC grid.
- Explain in outline how a pair of DC/AC power converters can be used in a full-converter format to interface a wind turbine to a gird.
- Explain in outline how a DFIG can interface a wind turbine to a grid.
- Describe the advantages and disadvantages of DFIG with respect to a full-converter interface.

You do not need to know the detail of DC/AC converter circuits here or in section 8.

7 Wind Farm Layout

You should be able to:

- Give a qualitive description of the impact of the wake of a turbine on turbines elsewhere in a wind farm.
- Explain the importance of wind direction relative to the wind farm layout in determining the effect of wakes on power yield.
- Recommend separation distances between rows of turbines and between turbines within a row based on rules-of-thumb.

8 Offshore Wind

You should be able to:

- Explain why offshore wind farms have advantages over onshore wind farms and what disadvantages may exist.
- Explain in outline why DC is used for long subsea connections.