

INTEGRATION OF RENEWABLES

23WSP032

Semester 2 23/24

In-Person Exam Paper

Student ID
Number:

Desk Number:

The standard length of time for this paper is **3 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam.
Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper.
Instead, please make a note of your query in your answer script
to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

Use of a calculator is permitted - It must comply with the University's Calculator Policy
for In-Person exams, in particular that it must not be able to transmit or receive information
(e.g. mobile devices and smart watches are not allowed).

Answer **ALL FIVE** questions.

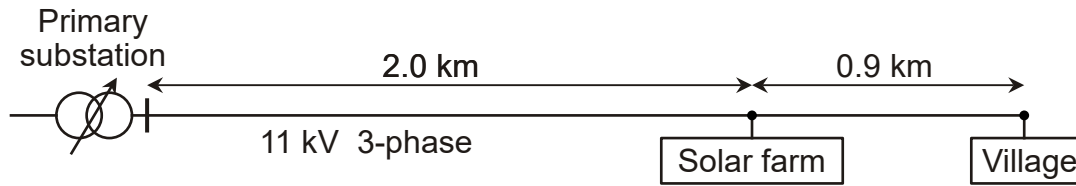
Each question carries a total of 20 marks.

Write your answers in the spaces provided below each question part.
The spaces are generous. You do not have to fill them.

Do all rough work in this book.

Additional space is provided at the back of this book if you need it.

1. A 4 MW solar farm is proposed in the following diagram.



The tap changer at the primary substation is set to keep the voltage at the substation busbar at 11.0 kV.

The overhead line from the primary substation to the village is 2.9 km long of 100AAC and has an impedance of $0.2769 + j0.3507 \Omega/\text{km}$.

The peak demand of the village is 3 MW, with transformers and water pumps (induction motors) bringing the power factor to 0.96

The following equations may be used to make the **estimates** requested below.

$$\Delta V \approx \frac{PR + QX}{V} \qquad \cos \phi = \frac{P}{S} \qquad S = \sqrt{P^2 + Q^2}$$

You do **not** need to perform exact calculations.

- a) Estimate the voltage at the village, at the time of peak demand and **without** the solar farm.

[8 marks]

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[illegible]

- [3 marks]

[illegible]

- c) Estimate the voltage at the village, in summer daytime, with the 4 MW solar farm connected 2 km from the substation.

[5 marks]

[illegible]

- d) Considering these voltages, discuss if the proposed solar farm is likely to be acceptable.

[4 marks]

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- [5 marks]

[illegible]

- b) More helpfully, the power-electronic converter could be programmed to reduce these challenges and even to provide valuable services to the electricity supply system, either nationally or locally, in pursuit of decarbonisation. List these possible benefits and describe how the converter can be controlled to achieve them.

[15 marks]

[illegible]

[illegible]

3.

- a) List and explain the benefits of DFIG wind turbines, compared to other types of modern large-scale commercial wind turbines. [16 marks]

[illegible]

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4.

- a) Describe what is meant by “fault ride through”. Explain what is required *during the fault and immediately afterwards*.

[5 marks]

[illegible]

- [4 marks]

[illegible]

- c) Discuss how fault-ride-through requirements can be met by a solar farm, and mention any challenges.

[5 marks]

[illegible]

- d) A concern with the solar farm is that its response may be slow in comparison to the synchronous generator. Suggest why it may be slow and why this may be a concern for the grid operator.

[3 marks]

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- e) The response can be divided into “reactive fault current contribution” and “real fault current contribution”. Explain why the size of the synchronous area can affect the relative requirements for these two contributions.

[3 marks]

[illegible]

5. Electricity is commonly bought and sold at a **fixed price** per kWh in consumer markets and similarly per MWh in generation markets. We can call this **flat pricing**.

To help decarbonisation, there are calls to use more **dynamic pricing**, in which the price can vary depending on various factors.

- a) Discuss the motivations for and challenges of **temporal pricing** (where the price of electricity varies throughout the day and from day to day etc.). [12 marks]

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[illegible]

- b) Discuss the motivations for and challenges of **locational pricing** (where the price of electricity varies according to geographic location).

[8 marks]

[illegible]

[illegible]

End of questions

Murray Thomson
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[illegible]

[illegible]