Loughborough University

INTEGRATION OF RENEWABLES (DL)

23WSP632

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.

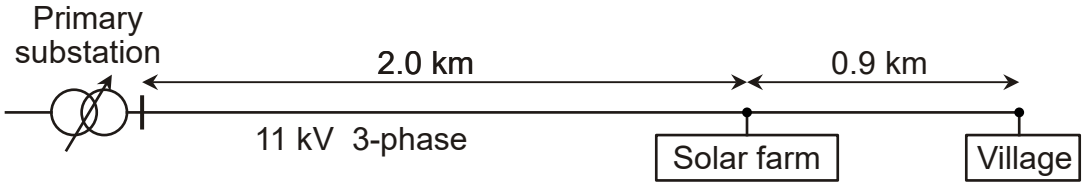
Write your answers in the spaces provided below each question part.
The spaces are generous. You do not have to fill them.

Do all rough work in this book.

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

/continued

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 100AAAC and has an impedance of 0.2769 + j0.3507 Ω/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]

/continued

Continue your answer if you need to.

b) In summer daytime, the village demand reduces to 40% of the peak.
Assume it has the same power factor.
Estimate the voltage at the village, in summer daytime, still without the solar farm. [3 marks]

/continued

c) Estimate the voltage at the village, in summer daytime, with the 4 MW solar farm connected 2 km from the substation. [5 marks]

/continued

d) Considering these voltages, discuss if the proposed solar farm is likely to be acceptable. [4 marks]

/continued

2. Most electric vehicles have a large battery that is charged from the national grid via a power-electronic converter. They are, or could be, plugged in for most of the time, except when the vehicle is being driven.

a) By default, the battery will simply start charging as soon as the driver plugs it in and stop charging once it is full. Explain the challenges this may cause for the electricity supply system. [5 marks]

/continued

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]

/continued

Continue your answer if you need to.

/continued

3.

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

/continued

Continue your answer if you need to.

b) Describe one disadvantage of DFIG wind turbines, compared to other types of modern large-scale commercial wind turbines. [4 marks]

/continued

4.

a) Describe what is meant by “fault ride through”. Explain what is required *during the fault* **and** *immediately afterwards*. [5 marks]

/continued

b) Discuss how fault-ride-through requirements can be met by a hydro-powered fixed-speed synchronous generator that is directly connected to the grid, and mention any challenges. (Look at part c) before answering this part.) [4 marks]

/continued

c) Discuss how fault-ride-through requirements can be met by a solar farm, and mention any challenges. [5 marks]

/continued

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]

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]

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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]

/continued

Continue your answer if you need to.

/continued

b) Discuss the motivations for and challenges of **locational pricing** (where the price of electricity varies according to geographic location). [8 marks]

/continued

Continue your answer if you need to.

End of questions

Murray Thomson
Andrew Urquhart

/continued

If you write any answers on this page, please indicate the question numbers clearly.

/continued

If you write any answers on this page, please indicate the question numbers clearly.