ADANA ALPARSLAN TÜRKEŞ
SCIENCE AND TECHNOLOGY UNIVERSITY

EEE7196 - Sustainable Energy
Midterm Exam
Prepared by Dr Kasım Zor

3rd Dec 2021, 13:15–15:15

Full Name : _____ Student ID: _____

Grade Table (for Lecturer use only)

Question	Points	Score
1	50	
2	50	
Total:	100	

Instructions for Midterm Exam

Welcome to the midterm exam of EEE7196 - Sustainable Energy and good luck!

Please read the following rules and confirm by signing that you have read and understood the rules before you receive your exam:

- The midterm exam shall be conducted between 13:15 and 15:15. Exam duration is 120 minutes. Students must finalise the exam by delivering it before 15:15. Students are not allowed to leave the exam in the first 30 minutes.
- Student ID cards shall visibly be on the edge of desks till the end of the exam. Students without the student ID cards or Turkish identity cards shall not be participated into the exam.
- This is a closed-book exam which means that students are not allowed to take notes, books, or any other reference material into the exam. Throughout the exam, students shall not possess mobile phones and electronic devices that are capable of storing, receiving or transmitting information or electronic signals, such as computerised watches.
- Students are not allowed to take a glance at the exam questions until told to do so. Students shall not communicate with any other student under any circumstances during the exam period. A student, who cheats, tries to cheat during the exam, or is identified to be cheating after investigating exam documents, is given 0 (zero) for that exam and a disciplinary investigation is opened against the student.
- An incorrect answer to a question is awarded no marks with no consideration of any partial credit. Therefore, no partial credit will be given.

In recognition of and in the spirit of the above rules which constitute Adana Alparslan Türkeş Science and Technology University Honour Code, I certify that I will neither give nor receive unpermitted aid on this examination.

Signature: _____

1. The largest wind turbine in the world is the GE's Haliade-X 14 MW turbine with a rotor diameter of 220 m.

   (a) **(5 points)** Calculate the power of the wind moving with a speed of 10 m/s incident on this wind turbine. Assume that density of air is 1.2 kg/m^3.

   Answer:_____

   (b) **(5 points)** Assume that if this turbine has a capacity factor of 60%, calculate the annual energy production in TWh.

   Answer:_____

   (c) **(10 points)** What is the the Betz limit and why does it equal to 59.3%? Draw a typical power curve for a wind turbine along with emphasising the following terms:

   - Cut-in speed,
   - Cut-out speed,
   - Rated speed.

   Answer:_____

- OWEZ
  - 108 MW
  - 10 km
- Prinses Amalia
  - 120 MW
  - 23 km
- Bard Offshore 1
  - 400 MW
  - 90 km

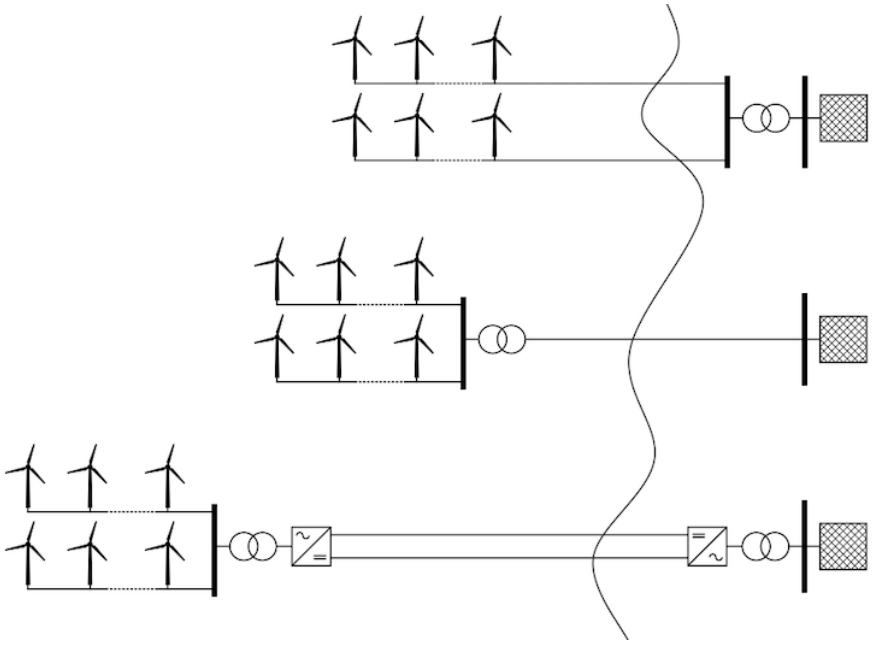
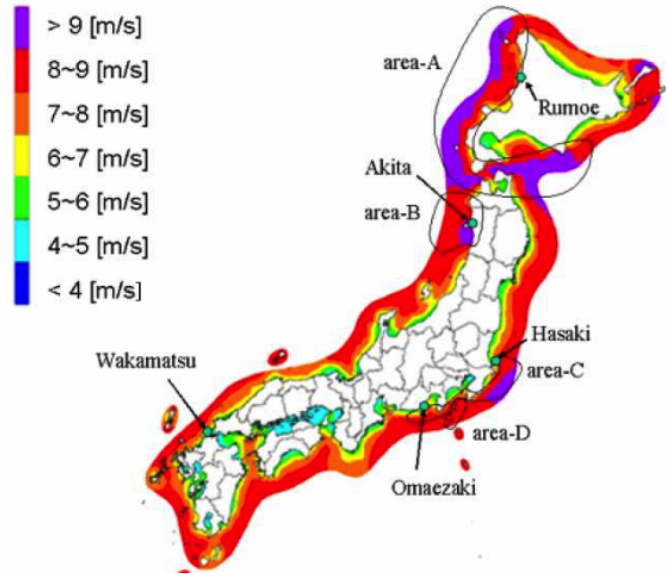


Figure 1: Offshore Wind Power Plants

(d) **(15 points)** Three offshore wind power plants are demonstrated in Figure 1. Explain the differences in the grid connection schemes in terms of installed power plant capacity, HV transmission current type, numbers and locations of transformers, power electronic components, and distance to shore.

Answer:



(e) **(15 points)** In this question, only shallow offshore wind will be considered (due to the high Japanese population density). The Japanese coastline is rather steep. For distances larger than 2 km out of the coastline, the average depth of the Pacific and Japanese Sea, is deeper than 25 m. The above figure shows the average wind map around Japan. The Japanese coastline as depicted in the figure has a total length of 5,700 km.

Consider that,

- 35% of the Japanese coastline is deployed with shallow offshore wind farms.
- The wind turbines have a conversion efficiency of 50%.
- The population of Japan is approximately 125.9 million.

According to the aforementioned data, calculate how much energy per day per person can be generated using the wind in the Japanese coastline?

Answer:_____

2. (a) **(10 points)** An ideal nuclear power plant has a capacity factor of around 90%, while the capacity factor for a PV power plant is around 20%. Why is the difference in capacity factor between these two types of energy so large?

Answer:

(b) **(20 points)** Calculate electrical energy generation unit cost of a 15 MW CSP plant with a unit equipment cost of 3,250 USD/kW (including thermal energy storage), a power plant lifetime (ℓ) of 15 years, a capacity factor of 48%, a land price of 10 USD/m^2, and a valuation ratio (ξ) of 20% per year by taking into account the followings:

- In layout planning of the plant,
  - 10 m^2 area is needed for deploying 1 m^2 heliostat,
  - Heliostats will be placed by leaving a margin of 10%,
  - For other equipment, an additional area will be reserved which corresponds to the half of the area occupied by the heliostats.
- Net power capacity of each heliostat is 0.285 kW/m^2.
- Average solar insolation per year is 2,800 kWh/m^2.

Hint: C_{year} and $C_{Investment}$ stand for the costs of annual electrical energy generation and investment respectively.

$$C_{year} = C_{Investment} \times [\frac{\xi \times (1+\xi)^{\ell}}{(1+\xi)^{\ell} - 1}]$$

Answer:

(c) Suppose that you have a small house in the countryside which is not connected to the grid. The place enjoys 4 equivalent sun hours. Therefore, you have decided to install a stand-alone PV system to supply the demand of your house. Electrical needs of the house are summarised in the below table.

Load	Quantity	Power per Item (W)	Time of Use (h)	Type
Incandescent Lamp	4	25	3	DC
TV	1	100	2	AC
Laptop	1	100	1	AC
Refrigerator	1	75	24	AC

Design the system in accordance with the followings:

- Assume that the days of Autonomy is equal to 2, the combined efficiency for the cables, the charge controller, and the battery system is 90%, and the stand-alone inverter efficiency is 95%.
- PV Module Characteristics:

P (W_p)	V_{mpp} (V)	I_{mpp} (A)	V_{oc} (V)	I_{sc} (A)
250	30.78	8.13	37.44	8.90

- MPPT Charge Controller Specifications:

V_{max} (V)	I_{max} (A)	$V_{operational}$ (V)
100	30	12/24

- Battery Features:

Depth of Discharge (%)	$V_{battery}$ (V)	$C_{battery}$ (Ah)
70	12	135

Answer the following questions according to the above instructions.

(a) **(5 points)** Draw a block diagram that illustrates the methodology of your design.

Answer:_____

(b) **(5 points)** Calculate how many panels are required to supply the demand and determine the connection configuration of panels.

Answer:_____

(c) **(5 points)** Calculate how many batteries are necessary for your design and determine the connection configuration of batteries.

Answer:_____

(d) **(5 points)** Calculate size of the stand-alone inverter for your design.

Answer:_____