ADANA ALPARSLAN TÜRKEŞ
SCIENCE AND TECHNOLOGY UNIVERSITY

EEE407 - Renewable Energy
Midterm Exam
Prepared by Dr Kasım Zor

Announcement: 4th May 2020, 11:00
Deadline: 8th May 2020, 17:00

Full Name : ____________________ Student ID: ________________

Grade Table (for Lecturer use only)

Question	Points	Score
1	2	
2	4	
3	6	
4	8	
Total:	20	

Instructions for Take-Home Exam

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

- You have exactly 4 days and 6 hours to solve the exam. It has to be received by me at 17:00 on 8 May 2020. ABSOLUTELY NO EXTENSIONS. Late submission will be severely penalised.
- The only option for submission is by e-mail with scanned and signed images by your own handwriting in one PDF file.
- E-mail problems will not be accepted as an excuse for late submissions. It is your responsibility to make sure that your e-mail works properly and that I receive the submission on time.
- This exam is âopen bookâ which means you are permitted to use any materials handed out in class, your own notes from the course, the text book, and anything on the EEE407 - Renewable Energy course website.
- The exam must be taken completely alone. Showing it or discussing it with anybody is forbidden, including (but not limited to) the other students in the course in current or previous years. It is also forbidden to use any solutions to similar problems from previous years as reference material.
- You may not consult any external resources. This means no internet searches, materials from other classes or books or any notes you have taken in other classes etc. You may not use Google or any other search engines for any reason. You may not use any shared Google documents. (You are NOT allowed to submit questions to internet discussion groups, though!).
- Make an effort to make your submission clear and readable. Severe readability issues may be penalised by grade.
- Submit your code separately (or integrated into the solution) with comments and explanations. Even if the final result is wrong, the code may allow us to find the bug and award partial credit.
- Please sign the below Honour Code statement.

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 12 MW turbine with a rotor diameter of 220 m.

   (a) **(1 point)** 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) **(1 point)** Assume that if this turbine has a capacity factor of 52%, calculate the annual energy production in TWh.

   Answer: ____________________

2. Answer the following questions.

   (a) **(1 point)** An ideal nuclear power plant has a capacity factor of around 90%, while the capacity factor for a PV power plant is around 15%. Why is the difference in capacity factor between these two types of energy so large?

   Answer:______________________________

   (b) **(1 point)** 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:______________________________

(c) **(2 points)** Calculate electrical energy generation unit cost of a 20 MW CSP plant with a unit equipment cost of 3,500 USD/kW (including thermal energy storage), a power plant lifetime (ℓ) of 20 years, a capacity factor of 45%, a land price of 10 USD/m^2, and a valuation ratio (ξ) of 10% 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 2,000 kWh/m^2.

Answer: ____________________

3. 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) **(1 point)** Draw a block diagram that illustrates the methodology of your design.

Answer:______________________________

(b) **(2 points)** Calculate how many panels are required to supply the demand and determine the connection configuration of panels.

Answer:____

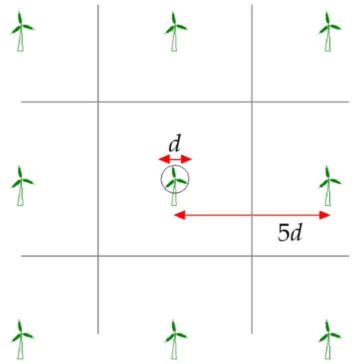
(c) **(2 points)** Calculate how many batteries are necessary for your design and determine the connection configuration of batteries.

Answer:____

(d) **(1 point)** Calculate size of the stand-alone inverter for your design.

Answer:____

4. Answer the following questions by clarifying each step in your solutions.

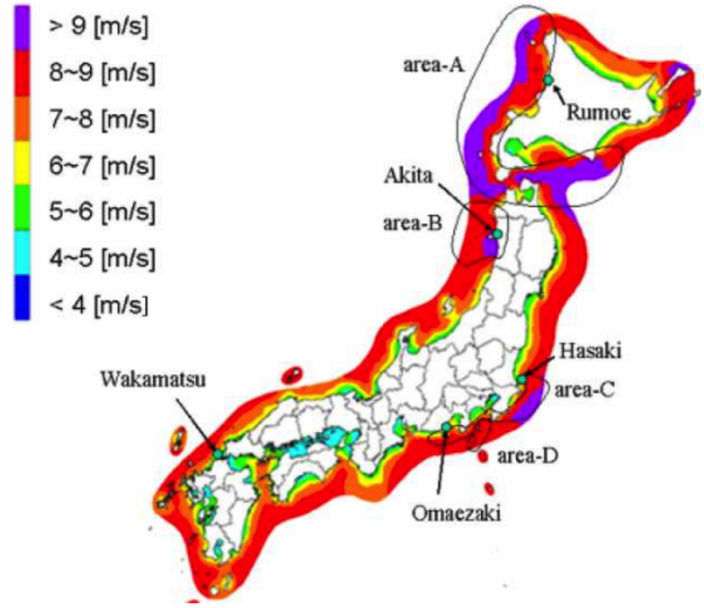


(a) **(2 points)** Consider a wind park with a layout as shown in the above figure in which d corresponds to the rotor diameter of each wind turbine. Prove that,

$$P = \frac{\pi}{100}\eta_c\frac{1}{2}\rho v^3$$

where P is the power per area, ρ is the mass density of the air ($\rho = 1.3$ kg/m^3), η_c is the conversion efficiency of the wind turbine, and v is the average wind speed.

Answer:____



(b) **(6 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 126.5×10^6.

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

Answer:________________________________