IE 453 Energy Systems Planning HW1

Due date: March 12th, Sunday 23:55pm

A group of engineers works on a rural electrification project in Sub-Saharan Africa. They aim to build a decentralized electrification system consisting of a wind turbine and a storage system to satisfy electricity demand in a small village. The storage system that will be used in this project has a capacity of 1 MWh, and it works with 85% efficiency. The type of wind turbine these engineers plan to install is General Electric (GE) 1.5-77. A typical (GE) 1.5-77 has a capacity of 1500 kW with a life-time of 25 years, and it costs $2 million.

The power curve for this particular turbine is provided below.

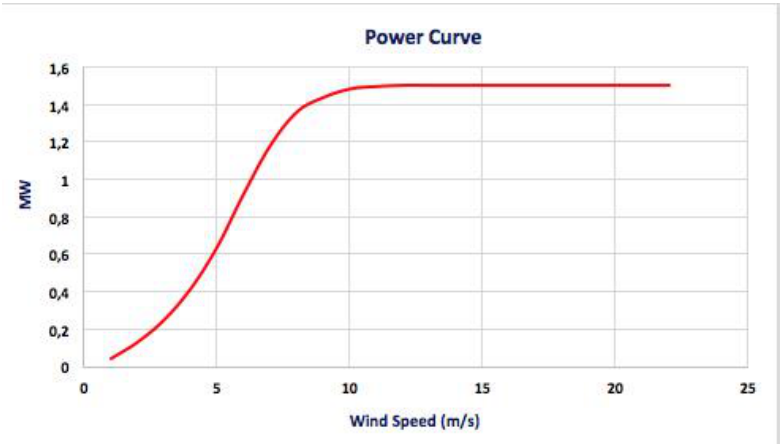

Figure 1: Power Curve

Table 1: Power curve of a single GE 1.5-77 wind turbine.

Speed (m/s)	4	5	6	7	8	9	10	11	12	13	14	15-25
Power (MW)	0.043	0.131	0.25	0.416	0.64	0.924	1.181	1.359	1.436	1.481	1.494	1.5

Assume the weekly interest rate is 0.5%, and the storage system is initially empty. The hourly wind speed and demand data for one week are provided in the file "HW-1 data.xlsx".

Examine the data sets and answer the following questions:

a) Is it possible to meet the hourly demand if there is 10 wind turbine installed in the system with the given storage size? Briefly explain your reasoning. If not, discuss alternative ways to satisfy the unmet demand.

b) Now, assume the storage system that will be used in this project has a capacity of 1.5 MWh and it works with 85% efficiency. What should be the minimum number of turbines installed? Calculate the capacity factor of the wind turbine.

c) Now, assume you have 18 wind turbines. The company has also decided to conduct an analysis on the size of the storage system. However, now, the cost of the storage system is 60 cents/Wh with a life-time of 20 years. Again, assume that the weekly interest rate is 0.5% and the storage system is initially empty. Optimize the size of the storage system so that you can meet the demand while minimizing your total cost.

d) After some time, the company has decided to use a new version of the wind turbines, which are more eco-friendly. You know that the blade length of the new version turbines is twice of the old ones. The version of the turbine has a lifetime of 30 years and it costs $2.5 million. You are required to optimize both the number of turbines and the storage size while satisfying demand. Again, assume that the cost of the storage system is 60 cents/Wh with a life-time of 20 years. (Hint: Power output is directly proportional to the area swept by the blades)