ECT-2 Individual or Group of 2 Bonus Assignment (2020-2021)
Date due: Monday Feb. 1, @17:00 hrs.

The goal of this bonus assignment is to test your analytical design skills in relation to the two most mature intermittent renewable energy technologies: solar and wind energy, and get you to think about storage utilization. The assignment will be graded with a pass/fail and in the case of a pass you will receive 0.5 points on your final grade for this course.

In line with the renewable energy developments taking place in Europe and the Netherlands, a new project is currently under construction by Vattenfall. See press release at link below:
https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2019/vattenfall-combines-wind-solar-and-batteries-in-new-hybrid-energy-park

The hybrid energy park will be located in the north of Goeree-Overflakkee Island between Middelharnis and Stad aan 't Haringvliet. It consists of 22-24 MW of wind turbines and a solar farm of 36-38 MW peak power. Assume the project will supply all electricity to an island microgrid which serves a number of customers with the aggregated demand profile given in the *.txt file provided on Bb. Hourly weather data can be downloaded from here:
https://projects.knmi.nl/klimatologie/uurgegevens/selectie.cgi

Use the wind speed at 10m. and global irradiance data from the nearby KNMI station ***Wilhelminadorp 2018***; watch out for converting to correct units!

1) Design the hybrid energy park specifying the number of wind turbines and PV solar panels that need to be installed to arrive at a total of around 60 MW peak power. You may select data sheets of your choice that are available online, for example for PV: *http://www.firstsolar.com/-/media/First-Solar/Technical-Documents/Series-6-Datasheets/Series-6-Datasheet.ashx* and for wind: the data sheets of the Enercon or Vestas turbines provided in the wind energy lectures/tutorials. Reference all your on-line or literature resources. Further, make all necessary assumptions e.g. regarding hub height for wind turbines, tilt and orientation for PV panels etc. (and clearly justify them) in addition to the following:
   - The wind turbines can have a maximum tip height (hub + half diameter) of 150m.
   - Assume air density at sea level.
   - Assume roughness length of 0.03, corresponding to class 1 terrain (see slides 40-41 of lecture 5).

2) Plot the empirical distributions (histograms) and calculate the minimum, maximum, average and standard deviation of the hourly wind and solar energy production separately, and for the hybrid energy park as a whole. Express these values in both MW and % of installed capacity. Comment on the degree of correlation or (lack thereof) between wind and solar energy production.

3) Calculate the capacity factors and full load hours for the solar and wind farms, separately, and also for the hybrid energy park as a whole.

4) Estimate the spatial requirements for the hybrid energy park (with the design as in 1).

5) Using the given 1-year, hourly demand profile in kWh ***(Demand_Data_in_kW.txt)***, how much total annual renewable energy produced will be curtailed and how much annual demand would be unserved? Assume in this case that the microgrid is isolated.

6) If you were to add storage within the hybrid energy park to store the excess energy and later partially supply the excess demand, what would you choose for the size of the storage in terms of power rating and energy rating? What type of storage technology would you opt for? Justify your answer.

7) Assuming the investment cost of 61 million euros disclosed by the project developer Vattenfall is correct, and the project is fully grid-connected, how many years will it take for this investment in the hybrid energy park to be recovered? Assume all years have similar wind and solar regimes as 2018. Neglect the use of storage in the revenue calculation and disregard curtailment. Make reasonable assumptions regarding the operation & maintenance costs, and reduction in operating hours due to maintenance. Reflect on the economic feasibility of the project in case the producer receives a fixed price of 58 euro/MWh (according to the SDE++ 2020 subsidy proposal) and compare it to the case when the producer is exposed to wholesale market prices. For information on average day-ahead market price trends, use e.g.: *https://www.tennet.eu/fileadmin/user_upload/Company/Publications/Technical_Publications/Dutch/Annual_Market_Update_2018_-_Final.pdf*

What to submit: Report in Word or PDF of min. 5 and max. 10 pages detailing your methods and findings. You may use either Excel or a script language such as MATLAB, Python or R for your calculations. Turn in your code as well, together with a short explanation how to run it, in case it is not self-explanatory. *If working in groups of 2: please add to your report an Appendix with a short statement indicating how each group member contributed.*
Optional: Short feedback paragraph regarding the degree of difficulty of this assignment and what we can do to make it more interesting for future students.