EG2040 Wind Power Systems
Assignment 5 – Small Scale Wind Turbine Systems

Deadline for full credits: Thursday 25 April, 17.00

The assignments should be completed individually and the report containing all solutions should be submitted in the blue box marked EG2040, outside the student room at Teknikringen 33. If Matlab is used for completing the assignment the code should be included with the report.

Solutions to the assignments should be well motivated and explained in detail. All equations used should be written clearly and all variables clarified. Figures and tables should be properly scaled and have captions. Write your name and student number on the front page of the assignment.

The teaching assistant will be available to answer questions during the scheduled course assistance hours.

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1 Hybrid System Design Rules

An isolated power system serving the community of Cantgettherefromhere uses a 100 kW diesel generator. The community plans to add 50 kW of wind power. The hourly average load and power from the wind turbine over a 24 hour period is detailed in the table below. The diesel generator (when in operation) has a no-load fuel usage of 3.5 liter per hour, an additional incremental fuel use of 0.20 liter per kilowatt-hour plus a fixed start up cost of 1 liter.

Hour	Load [kW]	Wind [kW]	Hour	Load [kW]	Wind [kW]
0	22	32	12	82	46
1	23	31	13	95	45
2	14	42	14	90	50
3	14	49	15	99	45
4	17	45	16	80	40
5	22	35	17	73	43
6	31	5	18	60	42
7	40	7	19	68	50
8	45	12	20	76	49
9	73	20	21	65	31
10	77	25	22	29	30
11	90	40	23	25	50

1. Describe the design rules which the given hybrid system should follow to operate optimally:
   (a) Which power source should be used first? Motivate why.
   (b) Assume that you have an energy storage in this hybrid system (e.g. a battery). How would the design rules change then?
2. For the day in question, using the hybrid system design rules, determine:
   (a) The maximum renewable energy that can be used in the system without any storage.
   (b) The maximum renewable energy that can be used in the system with sufficiently enough storage possibility.

(c) The maximum fuel savings (in liters of diesel), that can be achieved with intelligent use of controls, sufficiently large energy storage and renewables, compared to the case with only the diesel generator. Motivate the use of the diesel generator.

The numbers are given for each hour in the table, but each digit concerning load and wind power production cannot be assumed to be known before the specific hour.

2 Wind/Diesel/Battery System Operation

Based on the previous analysis and other input, the community of Cantgettherefromhere has upgraded its power system. The hybrid power system now includes a 100 kW diesel generator, 100 kW of installed load, 50 kW of wind power, a 100 kW dump load, and an energy storage with 100 kWh capacity. The hourly average load and power from the wind over a 24 hour period have remained the same and are listed in the table above.

Assume that the mean hourly data accurately describe the load and power from the wind and that fluctuations about the mean load are handled by the energy storage. Determine the hourly energy flows (i.e. power production of diesel generator each hour, production of wind turbine each hour, storage fill up each hour) for the following system control and operating approaches.

3 Diesel-only system - In this baseline system, the diesel provides all of the power to the load.

- The diesel provides power down to 0 kW.

4 Minimum diesel - In this system minimizing diesel power takes priority, except that the diesel may not be shut off and must run at a minimum of 25 kW to ensure long diesel engine life, and the battery is limited to be used between 10 and 80 kWh. Thus, the system operates by the rules:

- The minimum diesel power is 25 kW.
- Only the minimum diesel power that is needed above 25 kW is used (no power above 25 kW is used to fill up the storage).
- The storage can only be used between 10 and 80 kWh of capacity, to maximize storage efficiency and battery life.
- Storage is filled to 20 kWh to start with.
- The sum of the energy from the power sources in the system (diesel, wind, battery) must equal the sum of the energy. into the power sinks in the system (the load, dump load, and battery).
- If there is excess energy in the system it is first stored, if possible, and dumped only if necessary.

5 Diesel shut off - In this system a rotary inverter between the batteries and the grid provides reactive power and the diesel can be shut off. It shuts off whenever possible, but when running, needs to be at a minimum load of 25 kW. When running it is also used to fill up the storage to use the fuel most efficiently. The battery level is maintained between 10 and 80 kWh. This ensures that there is adequate capacity to handle fluctuating loads when there is no diesel in the system. Thus, the system operates by the rules:

- The diesel can be shut off.
- The minimum diesel power is 25 kW when the diesel is running.
- When the diesel is running, the storage is also filled up if possible to improve diesel fuel efficiency.
- Storage can only be used between 10 and 80 kWh of capacity, to maximize storage efficiency and battery life.

- Storage is filled to 20 kWh to start with.
- The sum of the energy into the power sources in the system (diesel, wind, battery) must equal the sum of the energy into the power sinks in the system (the load, dump load, and battery).
- If there is excess energy in the system it is first stored, if possible, and dumped only if necessary.

Specifically, for each operating approach, determine how much energy is supplied by the diesel over the 24 hour period and the reduction in diesel power compared to the diesel only case, including the fuel savings for task 4 and 5.