POLITECNICO DI MILANO

MASTERS OF SCIENCE IN ENERGY ENGINEERING

LOW-CARBON TECHNOLOGIES – A.A. 2019-20

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Exercise lesson – 22nd April 2020, Dr. Cristina Elsido

Laboratory on Multi-Energy Systems

A Multi-Energy System is composed by (see annex file for data):

- 1 CHP Internal Combustion Engine (ICE) fueled with NG or 1 CHP Organic Rankine Cycle (ORC) fueled with biomass, and producing heat and electricity
- 1 heat pump, using electricity to produce heat
- 2 boilers, fueled with NG and producing heat
- A thermal storage system – cases b, c, d
- An electric storage system (battery) – cases c, d

Considering the given electric and thermal power demands for the 2 given days (see Excel file), write a MILP optimization problem using Pyomo to determine the optimal operating strategy of the MES that minimizes the total operating costs.
For each of the 2 days, determine the objective function value and provide the following plots:

1. Overall electricity balance for each time step of the day (electric demand, electricity produced/consumed by each unit, purchased/sold electricity, electricity charged/discharged from the battery, battery state of charge)
2. Overall thermal energy balance for each time step of the day (heat demand, heat produced by each unit, storage charge/discharge, storage level of charge)

Assumptions:

- Time step $\Delta t = 1h$
- Natural Gas price = 30 €/MWh, biomass price = 25 €/MWh
- Electricity price for selling to/ purchasing from the grid as in Excel file
- Charging/discharging efficiency of battery: $\eta_C = 0.97$
- Heat losses from thermal storage: $\eta_D = 0.5\%$ of the state of charge
- Performance maps, operating range, O&M costs, start-up costs of ICE, ORC and boiler units as in Excel file
- For all units except ORC: no ramp-up limit, no limit on number of daily start-ups
- For ORC unit only: max number of start-ups = 1; ramp-up limit = 50% of maximum input

For each of the following cases, solve the optimization problem and describe the main effects in terms of objective function and operating strategy of the units:

a) No electric and thermal storages available
b) Thermal storage with capacity equal to 2 MWh, no battery
c) Thermal storage with capacity equal to 2 MWh, and battery with capacity equal to 1 MWh
d) Thermal storage with capacity equal to 4 MWh, and battery with capacity equal to 1 MWh