Wind Integration in ISO New England

EAEE 4220 Fall 2021 Project 1

1 Introduction

You take the position of a policy maker to provide policy suggestions to decarbonize ISO New England and is given the attached one-bus system model and. Details about this system model is explained in the attached the paper. Note the model in this paper has 8 buses with no transmission limits, so it is equivalent to a single-bus model (ISO New England has minor congestion issues).

2 Project Objective

Please finish a report summarizing how different wind penetration, in terms of installed wind capacity, would impact the operating cost of the ISO New England system, and how much wind energy can be successively integrated. Specifically, investigate the following criteria as the wind generation capacity increases

- The average daily total operating cost of the ISO-NE system.
- The average daily electricity price.
- The profit received by generators.
- Commitment status of generators by fuel type and ramp speed (slow and fast units).

Besides, investigate how much wind capacity is needed to retire all coal generators (BIT and SUB) from the system.

3 Directions

1. The major effort in this project is to program a unit commitment model. Wind generation should be modeled as a zero marginal cost resource and can be curtailed, i.e., $w_t \leq WA_t$, where W is installed wind capacity, A_t is the time-variant capacity factor given in the data, and w_t is the actually wind power integrated into the grid. w should be included in the nodal power balance as a generator. The rest please refer to the complete unit commitment formulation in the attachment.
2. There are 90 scenarios each with 4 days of duration, please run unit commitment over a 4-day duration to capture the impact of on/off status of coal generators.
3. You can assume all generators are off at the start of each scenario.
4. You don't need to go through all 90 scenarios and can pick 5 or 10 representative ones depending on the shape of demand or wind power factor.

5. After you have implemented a functional unit commitment model, please adjust the installed wind power capacity and observe the result from each scenario, then finish summarizing results in your report.

4 Appendix - Unit Commitment Formulation

Indexes

- t: Time period index $t \in \{1, 2, \ldots, T\}$, a total of T time periods.
- b: Bus index $b \in \{1, 2, \ldots, B\}$, a total of B buses.
- i: Generator index $g \in \{1, 2, \ldots, I\}$, a total of G generators.
- l: Line index $l \in \{1, 2, \ldots, L\}$, a total of L lines.

Cost parameters

- MRC_i: the marginal generation cost for generator i.
- NLC_i: no load cost for generator i.
- SUC_i: start-up cost for generator i.

Unit constraints parameters

- Gmax_i: maximum generation of generator i
- Gmin_i: minimum generation of generator i
- Tup_i: minimum up time of generator i
- Tdn_i: minimum down time of generator i
- RR_i: ramp rate of generator i

Demand and renewable parameters

- W: installed wind capacity
- α_t: wind capacity factor during time period t
- D_t: system demand during time period t

Continuous decision variables

- $g_{i,t}$: production of generator i during time period t
- $r_{i,t}$: hourly reserve generator i could provide during time period t
- w_t: wind power generation during time period t

Binary decision variables

- $u_{i,t}$: 1 if generator i is on during time period t, otherwise zero
- $v_{i,t}$: 1 if generator i is turned on at the start of period t, otherwise zero
- $z_{i,t}$: 1 if generator i is turned off at the start of period t, otherwise zero

Objective function

$$\min \sum_t \sum_i (\mathrm{MRC}_i g_{i,t} + \mathrm{NLC}_i u_{i,t} + \mathrm{SUC}_i v_{i,t}) \tag{1}$$

Generation limit constraint

$$\text{Gmin}_i u_{i,t} \leq g_{i,t} \leq \text{Gmax}_i u_{i,t} \tag{2}$$

Generation ramp constraint (the minimum generation limit adds to the ramp up limit when the generator is turned on)

$$-\text{RR}_i \leq g_{i,t} - g_{i,t-1} \leq \text{RR}_i + \text{Gmin}_i v_{i,t} \tag{3}$$

Generator start-up and shut-down logic

$$v_{i,t} - z_{i,t} = u_{i,t} - u_{i,t-1} \tag{4}$$

$$v_{i,t} + z_{i,t} \leq 1 \tag{5}$$

Generator minimum up time constraint (note the use of the alternative time index τ)

$$\sum_{\tau=\max\{t-\text{Tup}_i+1,1\}}^{t} v_{i,\tau} \leq u_{i,t} \tag{6}$$

$$\sum_{\tau=\max\{t-\text{Tdn}_i+1,1\}}^{t} z_{i,\tau} \leq 1 - u_{i,t} \tag{7}$$

Power balance, the dual variable λ_t associated with this constraint is the system price

$$\sum_i g_{i,t} + w_t = D_t : \lambda_t \tag{8}$$

System reserve (3+5 rule: hourly reserve amount must equal to 3% of demand and 5% of integrated wind)

$$\sum_i r_{i,t} \geq (3\%)D_t + (5\%)w_t \tag{9}$$

$$r_{i,t} \leq \text{Gmax}_i u_{i,t} - g_{i,t} \tag{10}$$

$$r_{i,t} \leq RR_i \tag{11}$$

Wind generation limit

$$w_t \leq \alpha_t W \tag{12}$$