Data Documentation for "Generation Expansion Planning with Revenue Sufficiency Constraints"

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1 California Dataset from Zhao et al. (2018)

For data related to the power network and part of the data for thermal generators, we use the California-based dataset in Chapter 5 of Zhao et al. (2018).

Notice that this dataset has a ten nodes network. Nodes one to four correspond to southern California (CA) balancing authorities including Southern California Edison (SCE), Los Angeles Department of Water and Power (LADWP), San Diego Gas and Electric (SDC&E), and Imperial Irrigation District (IID). Nodes five to seven, which are described as northern CA (Pacific Gas and Electric) in Bining's thesis, are the Bay Area, the region north to the Bay Area, and the region east to the Bay Area. Nodes eight to ten correspond to balancing authorities outside CA including Oregon (OR) and Washington (WA), Arizona (AZ), and Nevada (NV). We only use the nodes that are based on California, i.e. nodes one to seven, in our experiments.

In Zhao et al. (2018), thermal generators are divided into natural gas (NG) and no-NG generators. Since the NG and no-NG generators respectively fit the characteristics of natural gas combine cycle (NGCC) and coal generators, we call them NGCC and coal generators in our paper. Also, their dataset does not include the marginal costs of NG generators, but provides the fuel costs per MMBtu instead. In order to obtain the marginal costs, we do the following calculations:

$$\begin{aligned}\text{Marginal cost / MW} =& \text{variable operational and management cost(OM) / MW} \\ &+ \text{fuel cost / MMBtu} \times \text{heat rate}\end{aligned}$$

Notice that in Zhao et al. (2018) the capacities of thermal generators are scaled up to match the load. We therefore scale down those capacities by dividing all capacities with 2.42. This number is obtained by dividing the total thermal generation capacity with the product of peak load and the planning reserve margin. The detailed information of the marginal cost, capacity and ramping limit for existing thermal generators are listed in Tables 5 and 6 of Section 6

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2 Load

We obtain the hourly load data of California in 2017 from the California Independent Operator (CAISO) website: http://www.caiso.com/market/Pages/ReportsBulletins/RenewablesReporting.aspx. The information we use from the dataset includes thermal output, wind output, and solar PV output. We calculate the total load from those outputs. Also, considering we solve the planning model for a future target year, we assume that the load has an annual growth rate of 1.7%.

Additionally, we assume the planning reserve margin $\Gamma = 0.135$, the cost of unmet load, spinning reserve and quick-start reserve are respectively \$10000/MW, \$7500/MW, and \$5000/MW. The fraction to be met by spinning/total reserves, F^{Spin} and F^{Op}, are respectively 0.015 and 0.06.

3 Other Thermal Data

In addition to the parameters from Zhao et al. (2018), we assume the existing thermal generators have parameters listed in Table 1.

Parameter	NGCC	Coal
C_g^{V} [\$/MW]	159694.92	79448.22
C_g^{FOMG}[\$/KW]	26.87	13.96
C_g^{CV}	1	1
C_g^{Startup} [\$/MW]	140.94	86.31
F_g^{Spin}	0.1	0.1
F_g^{QS}	0	1
Δ_g^{MinUp}	24	6
Minimum generation fraction	0.48	0.32

Table 1: Additional parameters of existing thermal generators

For candidate new thermal generators, we assume that there are 10 generators of each type. The values of C_g^{V}, C_g^{CV}, C_g^{Startup}, F_g^{Spin}, F_g^{QS}, and minimum generation fraction are the same as for existing ones. For other parameters, they assume the values in Table 2.

Parameter	NGCC	Coal
C_g^{FOMG}[\$/KW]	62	10
Fuel cost [\$/MMBtu]	5.57	2.26
Minimum generation fraction	0.3	0.4
P_g^{max} [MW]	1500	1500
R_g^{Up} [MW/h]	1200	800

Table 2: Additional parameters of new thermal generators

4 Capacity Factors of Wind and Solar Generators

In order to calculate the hourly capacity factors of wind generators in different locations of California, we need to know the hourly output of a wind generator, its capacity, and its location. Those data can be obtained from the NREL Wind Prospector (https://maps.nrel.gov/wind-prospector/). This website provides access to the Western Wind dataset, which contains simulated 10-minute wind generator output from 2004 to 2007 and the capacity and location of the corresponding generators. We pick use the data of year 2007, and calculate the hourly wind capacity factor by dividing the hourly generator output with the corresponding capacity.

Similar to wind generators, we need the hourly output of solar generators, its capacity, and its location to calculate the capacity factors of solar generators. The Solar Power Data for Integration Studies webpage from NERL (https://www.nrel.gov/grid/solar-power-data.html) contains the data mentioned above for solar photovoltaic plants in year 2006 including states CA, OR, WA, AZ, and NV.

In figure 1 we present the average wind and solar capacity factors of the two representative days.

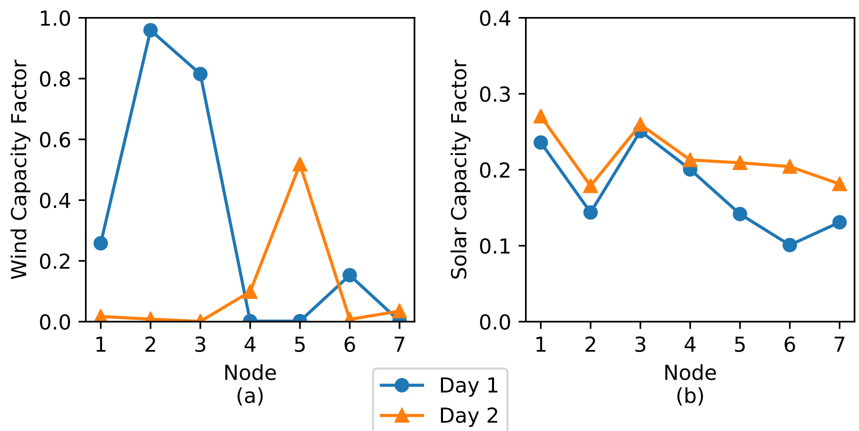

Figure 1: Capacity factors at each node for: (a) wind generators, (b) solar generators.

5 Other Renewable Data

The total wind and solar capacities in California are obtained from the CAISO monthly stats report: https://www.caiso.com/Documents/MonthlyStats-Feb2018.pdf. The data is as of March 6th, 2018.

The capacities of existing renewable generators at each node are assigned proportionally to the ratio of

$$\frac{\text{Average capacity factor at a node}}{\text{Total average capacity factors over all nodes}}.$$

In table 3 we list the renewable generation capacities at each node.

Node	Wind [MW]	Solar [MW]
1	1417	2189
2	816	1378
3	558	2027
4	945	1459
5	1159	1378
6	816	1378
7	601	1378

Table 3: Existing renewable capacities at each node

In addition, we assume the parameters in table 4 for renewable generators.

Parameter	Wind	Solar
C_g^{V} [$/MW]	136139.92	119771.19
C_g^{FOMG}[$/KW](existing)	30.82	42.48
C_g^{FOMG}[$/KW](new)	29	24
C_g^{CV}	0.15	0.6
Minimum generation fraction	0.3	0.4

Table 4: Additional parameters of renewable generators

6 Tables

Unit	Marginal Cost [$/MW]	Capacity [MW]	Ramping Limit [MW/h]
1	44.68	620	496
2	44.68	620	496
3	44.68	620	496
4	44.68	620	496
5	44.68	620	496
6	44.68	620	496
7	44.68	620	496
8	44.68	620	496
9	45.60	496	397
10	46.51	413	331
11	46.51	413	331
12	46.51	413	331
13	46.51	413	331
14	46.51	413	331
15	46.51	413	331
16	46.51	413	331
17	46.51	413	331
18	45.60	496	397

19	46.51	413	331
20	46.51	413	331
21	46.97	372	298
22	44.68	620	496
23	45.60	496	397
24	44.68	620	496
25	44.68	620	496
26	44.68	620	496
27	44.68	620	496
28	44.68	620	496
29	44.68	620	496
30	44.68	620	496
31	44.68	620	496
32	45.60	496	397
33	45.60	496	397
34	46.51	413	331

Table 5: Marginal cost, capacity, and ramping limit of existing NGCC generators

Unit	MarginalCost [$/MW]	Capacity [MW]	RampingLimit [MW/h]
1	25	620	331
2	25.5	496	248
3	26	413	207
4	26	413	207
5	26	413	207
6	26	413	207
7	26	413	207
8	26	413	207
9	26	413	207
10	26	413	207
11	25.5	496	248
12	26	413	207
13	25	620	331
14	25	620	331
15	25	620	331
16	25.5	496	248
17	25.5	496	248
18	26	413	207
19	26	413	207
20	26	413	207
21	26	413	207
22	26	413	207

23	26	413	207
24	26	413	207
25	26	413	207
26	26	413	207
27	26	413	207
28	28	165	83

Table 6: Marginal cost, capacity, and ramping limit of existing coal generators

References

[1] Bining Zhao et al. *Electricity-Gas Systems: Operations and Expansion Planning Under Uncertainty*. PhD thesis, The Ohio State University, 2018.