Robust Virtual Power Plant Investment Planning Considering a Nonconvex Operational Model: Test Data

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TABLE I
NUMBER OF DAYS GROUPED IN REPRESENTATIVE DAYS

t	1	2	3	4	5
N_t [days]	140	158	28	34	5

TABLE II
DATA FOR CONVENTIONAL GENERATING UNITS (GENERATION)

Unit	$\underline{P}_c^{\mathrm{C}}$ [MW]	$\overline{P}_c^{\mathrm{C}}$ [MW]
Existing unit	15	60
Candidate 1	15	55
Candidate 2	10	45
Candidate 3	10	40
Candidate 4	8	30
Candidate 5	5	20
Candidate 6	12	48
Candidate 7	12	44
Candidate 8	10	38
Candidate 9	5	18
Candidate 10	4	16
Candidate 11	20	73
Candidate 12	17	61
Candidate 13	12	47
Candidate 14	8	33
Candidate 15	6	23

TABLE III
DATA FOR CONVENTIONAL GENERATING UNITS (COSTS)

Unit	$\hat{C}_c^{\mathrm{C,F}}$ [\$]	$\hat{C}_c^{\mathrm{C,SD}}$ [\$]	$\hat{C}_c^{\mathrm{C,SU}}$ [\$]	$\hat{C}_c^{\mathrm{C,V}}$ [\$/MWh]	$C_c^{\mathrm{C,I}}$ [10^6 \$]
Existing unit	50	40	100	100	–
Candidate 1	35	25	70	70	56
Candidate 2	40	30	80	80	36
Candidate 3	45	35	90	90	24
Candidate 4	20	10	40	40	96
Candidate 5	25	15	50	50	76
Candidate 6	33	66	66	26	60
Candidate 7	38	76	76	28	50
Candidate 8	44	88	88	38	45
Candidate 9	18	36	36	8	90
Candidate 10	22	44	44	12	70
Candidate 11	46	96	96	36	85
Candidate 12	50	100	100	40	75
Candidate 13	55	110	110	40	65
Candidate 14	25	50	50	15	105
Candidate 15	28	56	56	18	95

I. DATA FOR THE CASE STUDIES

Based on historical data, we group the 365 days of the year into five representative days using a modified version of the K-means clustering technique proposed in [1]. The number of days grouped in representative days are shown in Table I.

Table **??**

Data for existing and candidate conventional generating units are displayed in Tables II and III. We consider two generation technologies, namely, a peak and a base technology. The peak technology features higher forecast production cost coefficients but lower investment cost coefficients. On the other hand, the base technology is characterized by lower forecast production cost coefficients but higher investment cost coefficients. Moreover, for each unit, all ramp rates are equal to 30% of the corresponding capacity. Upper and lower bounds result from considering a $\pm 20\%$ variation about the corresponding forecast values.

Capacity factor data of photovoltaic solar units for each representative day are obtained from version 2017.1.17 of the System Advisor Model [2], based on weather data from the National Solar Radiation Data Base [3]. Photovoltaic power production data represent the average production over 12 different locations, thereby avoiding the effect of extremely favorable/disadvantageous solar conditions. For the sake of simplicity, we assume that all existing and prospective photovoltaic solar units have the same capacity factors. Fig. 1 shows the hourly capacity factors for every representative day. Capacities and investment cost coefficients for photovoltaic solar units are listed in Table IV.

The initial level of stored energy of the existing storage unit is 80 MWh, whereas candidate storage units are initially discharged. The lower bounds for the levels of stored energy of the existing and candidate storage units are 0 MWh across the

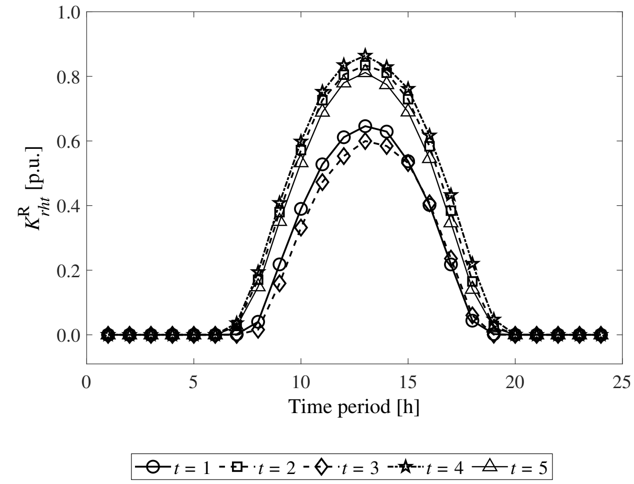

Fig. 1. Hourly capacity factors of photovoltaic solar units.

TABLE IV
DATA FOR PHOTOVOLTAIC SOLAR UNITS

Unit	$\overline{P}^{\mathrm{R}}_r$ [MW]	$C^{\mathrm{R,I}}_r$ [\$$10^6$]
Existing unit	80	–
Candidate 1	70	120
Candidate 2	65	100
Candidate 3	50	80
Candidate 4	35	60
Candidate 5	27	40
Candidate 6	66	91
Candidate 7	54	75
Candidate 8	44	62
Candidate 9	34	42
Candidate 10	20	20
Candidate 11	73	115
Candidate 12	61	82
Candidate 13	53	72
Candidate 14	32	38
Candidate 15	23	25

time span except for the last hourly period of each representative day for the existing storage unit. In this case, for $h = |\mathcal{H}|$, the lower bounds are set equal to the corresponding initial level. Furthermore, the charging and discharging efficiency rates of all storage units are both equal to 0.9 p.u. The remaining data of the storage units, i.e., the rated charging and discharging power capacities, the upper bounds for the level of stored energy, and the investment cost coefficients, are provided in Table V.

Regarding the flexible demands, the forecast minimum and maximum consumption levels are shown in Figs. 2 and 3, respectively, whereas the forecast values of minimum daily energy consumption are presented in Table VI. Upper and lower bounds result from considering a $\pm 20\%$ variation about the corresponding forecast values.

TABLE V
DATA FOR STORAGE UNITS

Unit	$\overline{P}^{\mathrm{S,C}}_s$ [MW]	$\overline{P}^{\mathrm{S,D}}_s$ [MW]	$\overline{S}^{\mathrm{S}}_{sht}$ [MWh]	$C^{\mathrm{S,I}}_s$ [\$$10^6$]
Existing unit	80	80	160	–
Candidate 1	70	70	140	20
Candidate 2	60	60	120	18
Candidate 3	55	55	110	16
Candidate 4	40	40	80	14
Candidate 5	25	25	50	12
Candidate 6	58	58	116	22.0
Candidate 7	48	48	96	17.0
Candidate 8	38	38	76	15.0
Candidate 9	28	28	56	14.2
Candidate 10	20	20	40	12.2
Candidate 11	90	90	180	28.0
Candidate 12	72	72	144	26.0
Candidate 13	53	53	106	17.5
Candidate 14	36	36	72	14.5
Candidate 15	18	18	36	10.0

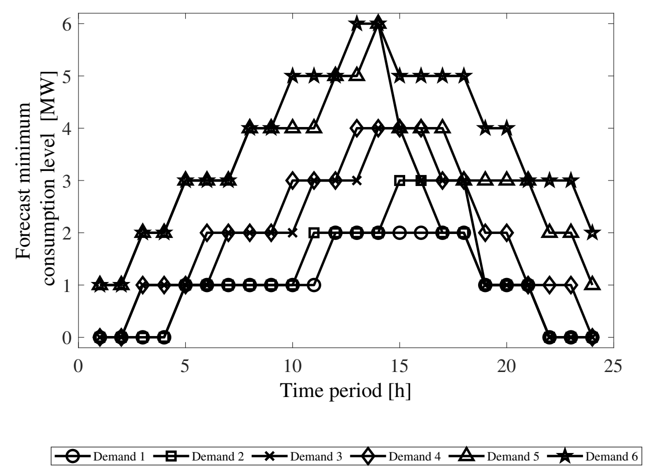

Fig. 2. Forecast minimum power consumption levels of the flexible demands

Finally, forecast energy market prices are obtained from historical energy market prices for the Electric Reliability Council of Texas North Central zone [4]. Fig. 4 shows the forecast hourly energy market prices of every representative day. Upper and lower bounds result from considering a $\pm 20\%$ variation about the corresponding forecast values.

REFERENCES

[1] L. Baringo and A. J. Conejo, “Correlated wind-power production and electric load scenarios for investment decisions,” *Appl. Energy*, vol. 101, pp. 475–482, Jan. 2013.
[2] System Advisor Model, 2022. [Online]. Available: https://sam.nrel.gov/
[3] National Solar Radiation Data Base, 2022. [Online]. Available: https://nsrdb.nrel.gov/

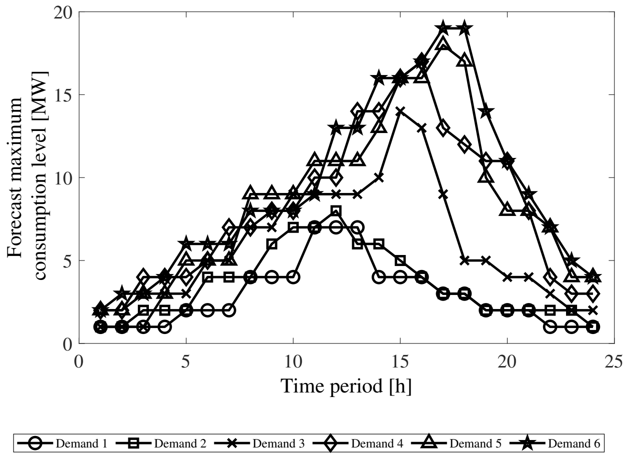

Fig. 3. Forecast maximum power consumption levels of the flexible demands

TABLE VI
FORECAST VALUES FOR THE MINIMUM DAILY ENERGY CONSUMPTION OF THE FLEXIBLE DEMANDS

Demand	$\hat{D}^{\mathrm{D}}_{d}$ [MWh]
1	52.0
2	65.0
3	104.0
4	130.0
5	156.0
6	182.0

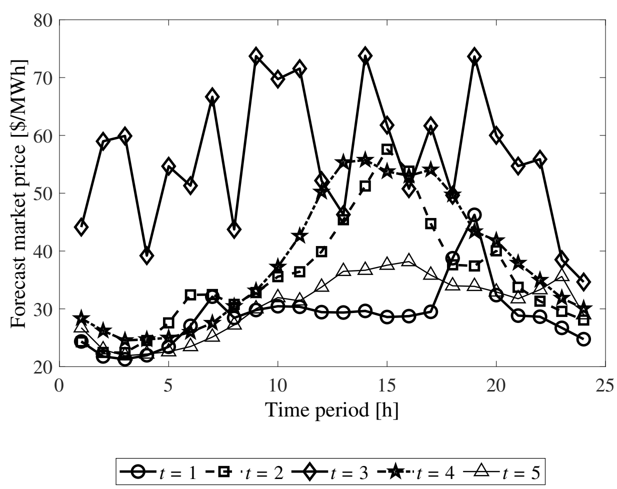

Fig. 4. Forecast hourly energy market prices.

[4] Electric Reliability Council of Texas, 2022. [Online]. Available: https://www.ercot.com