

Stability-Constrained Microgrid Operation Scheduling Incorporating Frequency Control Reserve – Data Set

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I. DATA OF NUMERICAL EXAMPLES FOR THE MICROGRID SCHEDULING SYSTEM

Table I demonstrates the dispatchable units' power output information inside the Microgrid. Table II shows the reserve output information of dispatchable units. The Table III shows the load expected output standard variance data. The renewable energy (wind and solar) expected output and standard variance per hour can be found in Table IV. Table V provides the main grid interaction data with microgrid. Table VI and Table VII present the different penalty price data sets (Fixed and Market based). Table VIII demonstrates the market price information used for power interaction between microgrid and main grid.

TABLE I. DISPATCHABLE UNIT OUTPUT

Unit No.	Cost (\$/MWh)	Min (MW)	Max (MW)	Min up/down time (h)	Startup cost (\$)	Shut down Cost (\$)
1	21.6	4	15	4	35	10
2	33.8	2.5	12	3	25	10
3	45.4	2	10	2	20	8
4	52.8	1.5	8	2	15	6
5	66.3	0.8	5	2	10	6

TABLE II. DISPATCHABLE UNIT RESERVE OUTPUT

Unit No.	Ramp up (MW/h)	Ramp down (MW/h)	Max UP/DOWN Reserve Max(MW)	Min UP/DOWN Reserve (MW)	ramp up/down reserve cost
1	4	4.5	3	0	15.2
2	3	3.5	2	0	23.6
3	3	3.5	1.5	0	25.8
4	2	2.5	1	0	17.6
5	1.5	2	0.8	0	26.7

TABLE III. HOURLY LOAD DATA

Hour	Expected Load (MWh)	Standard deviation (MWh)
1	26.19	1.5
2	25.95	1.5

3	25.41	1.5
4	27.09	1.5
5	26.37	1.5
6	26.43	1.5
7	30.36	2
8	32.79	2
9	33.57	2
10	35.34	2
11	36.24	2
12	36.39	2
13	41.76	3
14	45.81	3
15	46.08	3
16	47.07	3
17	48.39	3.5
18	48.42	3.5
19	46.68	3.5
20	46.53	3
21	42	3
22	39.09	2
23	29.46	1.5
24	28.35	1.5

TABLE IV. RENEWABLE ENERGY DATA

Hour	Wind		Solar	
	Expected Output (MWh)	Standard Deviation (MWh)	Expected Output (MWh)	Standard Deviation (MWh)
1	15.86	2.5	0	0
2	15.11	2.5	0	0
3	12.36	2	0	0
4	10.23	2	0	0
5	8.85	1	0	0
6	6.48	1	0	0
7	5.92	1	0	0

8	6.02	0.6	2.45	0.1
9	4.13	0.6	6	0.3
10	2.16	0.3	9.1	0.6
11	1.89	0.3	11.25	1
12	2.61	0.3	12.8	1
13	3.39	0.3	13.15	1.3
14	3.70	0.3	13.35	1.3
15	3.50	0.3	11.65	1
16	3.52	0.3	9.95	0.7
17	3.58	0.5	7.85	0.5
18	3.94	0.5	4.9	0.3
19	3.83	0.5	2.05	0.1
20	4.30	0.6	0.05	0
21	5.14	0.6	0	0
22	6.97	1	0	0
23	10.99	1.5	0	0
24	14.88	2	0	0

TABLE V. MAIN GRID DATA

Min Output (MW)	Max Output (MW)	Max Ramp Up Reserve (MW)	Max Ramp Down Reserve (MW)	Min Ramp Up Reserve (MW)	Min Ramp Down Reserve (MW)
-18	18	6	6	0	0

TABLE VI. FIXED PENALTY PRICE

Penalty Type	Load Shedding		Power Curtailment	
	Grid-connected	Islanding	Grid-connected	Islanding
Penalty (\$/MWh)	80	120	40	60

TABLE VII. MARKET-BASED PENALTY PRICE

Time (hour)	Load Shedding		Power Curtailment	
	Grid-connected	Islanding	Grid-connected	Islanding
1	40	60	32	48
2	40	60	32	48
3	40	60	32	48
4	40	60	32	48
5	40	60	32	48
6	40	60	32	48
7	40	60	32	48
8	40	60	32	48

9	40	60	32	48
10	40	60	32	48
11	96	144	80	120
12	96	144	80	120
13	96	144	80	120
14	96	144	80	120
15	96	144	80	120
16	160	240	120	180
17	160	240	120	180
18	160	240	120	180
19	160	240	120	180
20	160	240	120	180
21	160	240	120	180
22	160	240	120	180
23	96	144	80	120
24	96	144	80	120

TABLE VIII. MARKET PRICE

Hour	Power Interaction Cost (\$/MWh)	Ramp Up Reserve Cost (\$/MW)	Ramp Down Reserve Cost (\$/MW)
1	13.53	10.23	10.23
2	9.87	10.46	10.46
3	12.16	11.01	11.01
4	13.82	11.06	11.06
5	16.66	11.84	11.84
6	16.92	12.16	12.16
7	15.57	13.12	13.12
8	20.55	14.88	14.88
9	19.66	14.88	14.88
10	24.38	16.64	16.64
11	33.35	16.32	16.32
12	62.06	20.64	20.64
13	59.21	24.32	24.32
14	59.91	24.96	24.96
15	58.90	26.72	26.72
16	71.81	28.64	28.64
17	103.91	30.47	30.47
18	99.25	35.71	35.71
19	86.45	36.32	36.32
20	81.48	32.56	32.56
21	69.64	30.8	30.8

22	63.86	25.92	25.92
23	53.48	24.56	24.56
24	51.01	22.96	22.96