The IEEE Reliability Test System

1 System Description

The 24 bus system [1] is illustrated in Figure 1. The slack bus of the system is node 13.

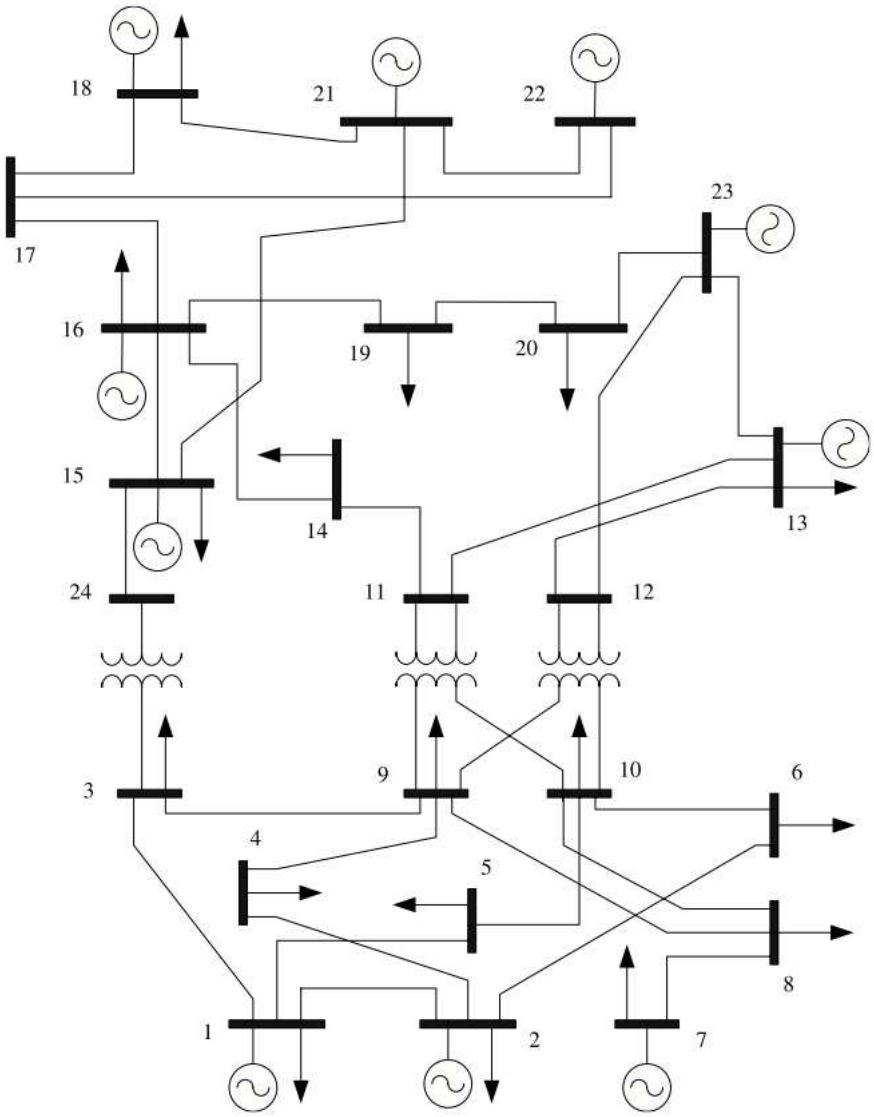

Figure 1: 24-bus power system – IEEE One Area RTS-96

1.1 Unit Data

Tables 1-3 present the generating units' data of the power system. The generating units offer a single block of energy, up and down reserve capacity. Table 1 provides the technical data of generating units, Table 2 categorizes the units in different types and Table 3 provides the costs and initial state of the generating units at the beginning of the scheduling horizon. The data is based on [1], [2], [3].

Table 1: Technical Data of Generating Units

$Unit$	$Node$	P_{max} MW	P_{min} MW	R^+ MW	R^- MW	RU MW/min	RD MW/min	UT h	DT h
Unit 18	18	400	100	0	0	6.67	6.67	1	1
Unit 21	21	400	100	0	0	6.67	6.67	1	1
Unit 1	1	152	30.4	40	40	2	2	8	4
Unit 2	2	152	30.4	40	40	2	2	8	4
Unit15b	15	155	54.25	30	30	3	3	8	8
Unit 16	16	155	54.25	30	30	3	3	8	8
Unit 23a	23	310	108.5	60	60	3	3	8	8
Unit 23b	23	350	140	40	40	4	4	8	8
Unit 7	7	350	75	70	70	7	7	8	8
Unit 13	13	591	206.85	180	180	3	3	12	10
Unit 15a	15	60	12	60	60	1	1	4	2
Unit 22	22	300	300	0	0	5	5	0	0

Table 2: Unit Type

$Unit\ Type$	$Unit(s)$
Nuclear	18 21
Coal/Stream	1 2 15 16 23a
Coal/3 Stream	23b
Oil/Stream	7 13 15
Hydro	22

Table 3: Costs and Initial State of Generating Units

$Unit$	C \$/MWh	C_u \$/MW	C_d \$/MW	C_{su} \$	P_{ini} MW	U_{ini} 0/1	T_{ini} h
Unit 18	5.47	0	0	0	320	1	50
Unit 21	5.47	0	0	0	320	1	16
Unit 1	13.32	15	14	1430.4	121.6	1	22
Unit 2	13.32	15	14	1430.4	121.6	1	22
Unit15b	10.52	16	14	312	0	0	-2
Unit 16	10.52	16	14	312	124	1	10
Unit 23a	10.52	17	16	624	248	1	10
Unit 23b	10.89	16	14	2298	280	1	50
Unit 7	20.70	10	9	1725	0	0	-2
Unit 13	20.93	8	7	3056.7	0	0	-1
Unit 15a	26.11	7	5	437	0	0	-1
Unit 22	0.00	0	0	0	240	1	24

A positive T_{ini} shows the time periods that the generating unit has been online at the beginning of scheduling horizon. A negative one shows the time periods that the generating unit has been offline at the beginning of scheduling horizon.

1.2 Load Data

In Figure 2, the load profile is illustrated. Table 4 provides the total system demand per hour and Table 5 presents the node location of the loads, as well as load at each node as a percentage of the total system demand. The load data is based on [2].

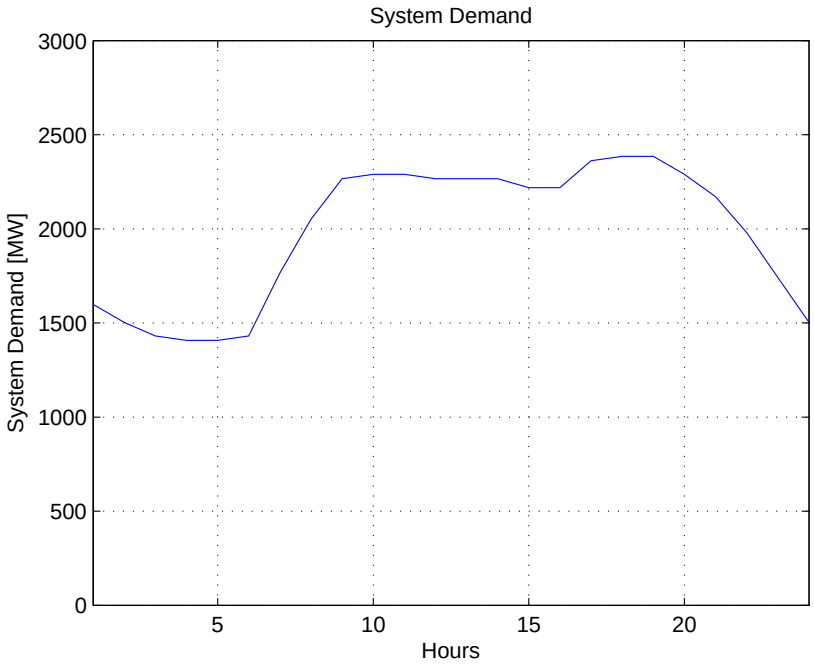

Figure 2: System Demand Profile

Table 4: Load Profile

Hour	*System Demand* MW	*Hour*	*System Demand* MW
1	1598.252	13	2266.178
2	1502.834	14	2266.178
3	1431.270	15	2218.469
4	1407.416	16	2218.469
5	1407.416	17	2361.596
6	1431.270	18	2385.450
7	1765.233	19	2385.450
8	2051.487	20	2290.032
9	2266.178	21	2170.760
10	2290.032	22	1979.924
11	2290.032	23	1741.379
12	2266.178	24	1502.834

Table 5: Node Location and Distribution of the Total System Demand

Load	*Node*	*% of system load*	*Load*	*Node*	*% of system load*
Load 1	1	3.8	Load 10	10	6.8
Load 2	2	3.4	Load 13	13	9.3
Load 3	3	6.3	Load 14	14	6.8
Load 4	4	2.6	Load 15	15	11.1
Load 5	5	2.5	Load 16	16	3.5
Load 6	6	4.8	Load 18	18	11.7
Load 7	7	4.4	Load 19	19	6.4
Load 8	8	6	Load 20	20	4.5
Load 9	9	6.1			

1.3 Transmission Lines

The transmission lines data is given in Table 6. The lines are characterized by the nodes that are connected, as well as the reactance and the capacity of each line. The data is based on [2].

Table 6: Reactance and Capacity of Transmission Lines

From	*To*	*Reactance* p.u.	*Capacity* MVA	*From*	*To*	*Reactance* p.u.	*Capacity* MVA
1	2	0.0146	175	11	13	0.0488	500
1	3	0.2253	175	11	14	0.0426	500
1	5	0.0907	350	12	13	0.0488	500
2	4	0.1356	175	12	23	0.0985	500
2	6	0.205	175	13	23	0.0884	500
3	9	0.1271	175	14	16	0.0594	500
3	24	0.084	400	15	16	0.0172	500
4	9	0.111	175	15	21	0.0249	1000
5	10	0.094	350	15	24	0.0529	500
6	10	0.0642	175	16	17	0.0263	500
7	8	0.0652	350	16	19	0.0234	500
8	9	0.1762	175	17	18	0.0143	500
8	10	0.1762	175	17	22	0.1069	500
9	11	0.084	400	18	21	0.0132	1000
9	12	0.084	400	19	20	0.0203	1000
10	11	0.084	400	20	23	0.0112	1000
10	12	0.084	400	21	22	0.0692	500

2 Implementation Including Wind Power Production

It is recommended to include six wind farms at different locations throughout the grid. It is proposed to locate the wind farms at 3, 5, 7, 16, 21 and 23 nodes. In this case, the capacity on the transmission lines connecting the node pairs (15,21), (14,16) and (13,23) is reduced to 400 MW, 250 MW and 250 MW, respectively. This is done in order to introduce bottlenecks in the transmission system.

References

[1] C. Grigg, P. Wong, P. Albrecht, R. Allan, M. Bhavaraju, R. Billinton, Q. Chen, C. Fong, S. Haddad, S. Kuruganty, et al. *The IEEE Reliability Test System 1996. A report prepared by the reliability test system task force of the application of probability methods subcommittee*. IEEE Transactions on Power Systems, 14(3): 1010-1020, 1999.

[2] A. J. Conejo, M. Carrion, J. M. Morales. *Decision Making under Uncertainty in Electricity Markets*. Springer US, 2010.

[3] F. Bouffard, F. D. Galiana, A. J. Conejo. *Market-Clearing with Stochastic Security Part II: Case Studies*. IEEE Transactions on Power Systems, 20(4): 1827-1835, 2005.

Nomenclature

C	Production cost
C_d	Downward reserve cost
C_{su}	Start up cost
C_u	Upward reserve cost
DT	Minimum down time of each generating unit
P_{ini}	Power output of each generating unit at time 0
P_{max}	Maximum output power of each generating unit
P_{min}	Minimum output power of each generating unit
R^+	Maximum reserve capacity of up regulation of each generating unit
R^-	Minimum reserve capacity of up regulation of each generating unit
RD	Ramp down rate of each generating unit
RU	Ramp up rate of each generating unit
T_{ini}	Number of hours of which the generating unit was in/out at the beginning of planning horizon
U_{ini}	Stating whether the unit is online/offline at time 0
UT	Minimum up time of each generating unit