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APPENDICES

Appendix A: A modified IEEE-24 bus system

This test system is derived form [80]. Table A.1 presents the parameters of the original polynomial cost functions and Table A.2 shows the parameters of the piecewise-linear cost functions for the 26-units system. Table A.3 presents the demand considered for this system and graphically is shown in Figure A.4.

Table A.1 Original polynomial cost functions of a modified IEEE-24 bus system

No	Bus	$/MWh^2	$/MWh	$
1	15	0.0253	25.5472	24.3891
2	15	0.0265	25.6753	24.4110
3	15	0.0280	25.8027	24.6382
4	15	0.0284	25.9312	24.7605
5	15	0.0286	26.0611	24.8882
6	1	0.0120	37.5510	117.7551
7	1	0.0126	37.6637	118.1083
8	2	0.0136	37.7770	118.4576
9	2	0.0143	37.8896	118.8206
10	1	0.0088	13.3272	81.1364
11	1	0.0090	13.3538	81.2980
12	2	0.0091	13.3805	81.4641
13	2	0.0093	13.4073	81.6259
14	7	0.0062	18.0000	217.8952
15	7	0.0061	18.1000	218.3350
16	7	0.0060	18.2000	218.7752
17	15	0.0046	10.6940	142.7348
18	16	0.0047	10.7154	143.0288
19	23	0.0048	10.7367	143.3179
20	23	0.0049	10.7583	143.5972
21	13	0.0026	23.0000	259.1310
22	13	0.0026	23.1000	259.6490
23	13	0.0026	23.2000	260.1760
24	23	0.0015	10.8616	177.0575
25	18	0.0019	7.4921	310.0021
26	21	0.0020	7.5031	311.9102

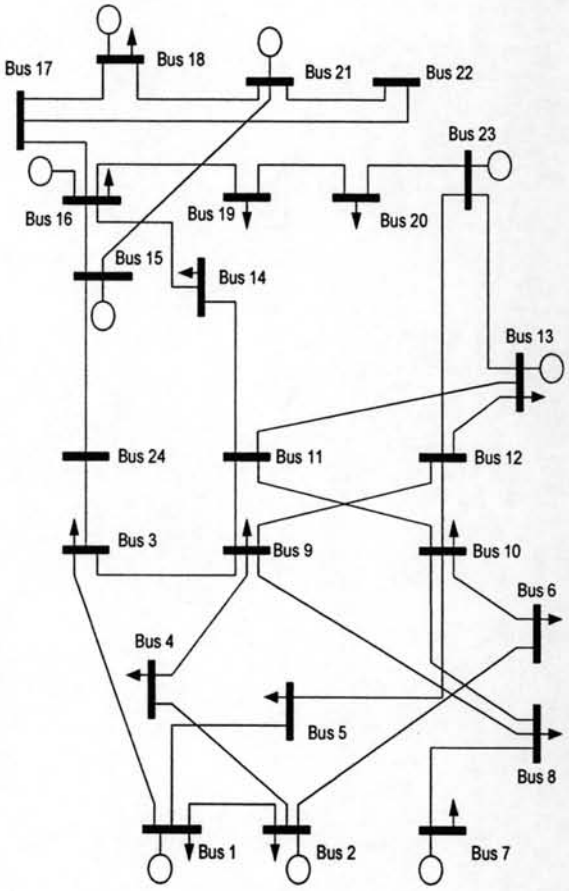

Figure A.1. A modified IEEE-24 bus system

Linearization of Polynomial Cost Function

The polynomial cost functions is replaced by piecewise linear cost functions where the elbow T_1 is obtained by dividing the range between minimum generation (P_{min}) and maximum generation (P_{max}) of each unit into two equal segments. The incremental price (F_1 and F_2) are such that the price at P_{min}, T_1, and P_{max} are equal to those obtained with the polynomial functions.

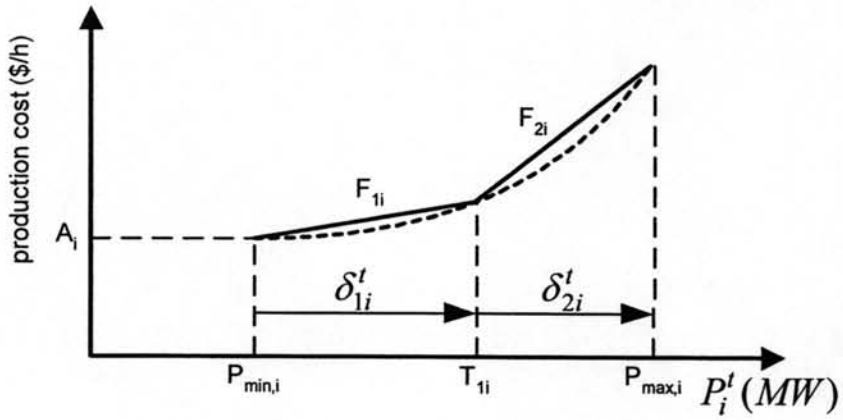

Figure A.2 Linearization of polynomial cost function

Linearization of start-up cost function

As shown in Figure A.2, the exponential start-up cost function is replaced by two-stairwise values, denoted by K^1 and K^2. These values represent hot start-up cost (HST) and cold start-up cost (CST) respectively. The cold start-up cost is associated with the units which is started-up after the unit has been down for more than a certain minimum time period. This minimum period, we call as cold down time (CDT).

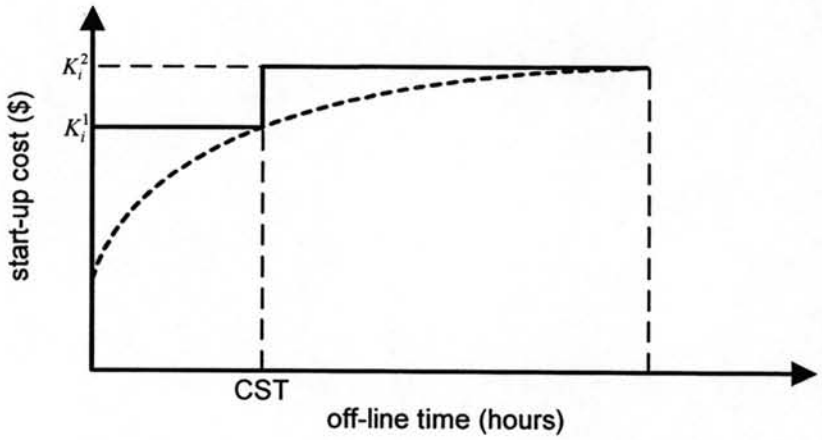

Figure A.3 Linearization of exponential start-up function

Table A.2 Unit data with piecewise linear cost function and other operational limits for the modified IEEE-24 bus system

Name	P_{min}	P_{max}	FC	MUT	MDT	IS	IUDT	T_1	F_1	F_2	CDT	HST	CST	Lamda1	Lamda2
G1	2.4	12	86	0	0	0	-1	7.2	25.79	26.03	1	0	0	1	2.98
G2	2.4	12	86	0	0	0	-1	7.2	25.93	26.18	1	0	0	1	2.98
G3	2.4	12	87	0	0	0	-1	7.2	26.07	26.34	1	0	0	1	2.98
G4	2.4	12	87	0	0	0	-1	7.2	26.2	26.48	1	0	0	1	2.98
G5	2.4	12	88	0	0	0	-1	7.2	26.34	26.61	1	0	0	1	2.98
G6	4	20	268	0	0	0	-1	12	37.74	37.93	2	32.642	40	6	19.47
G7	4	20	269	0	0	0	-1	12	37.87	38.07	2	32.642	40	6	19.47
G8	4	20	270	0	0	0	-1	12	37.99	38.21	2	32.642	40	6	19.47
G9	4	20	271	0	0	0	-1	12	38.12	38.35	2	32.642	40	6	19.47
G10	15.2	76	286	3	2	1	3	45.6	13.86	14.39	3	81.606	100	2	4.47
G11	15.2	76	286	3	2	1	3	45.6	13.9	14.44	3	81.606	100	2	4.47
G12	15.2	76	287	3	2	1	3	45.6	13.93	14.49	3	81.606	100	2	4.47
G13	15.2	76	288	3	2	1	3	45.6	13.97	14.54	3	81.606	100	2	4.47
G14	25	100	672	4	2	0	-3	60	18.53	19	4	114.25	140	3	7.3
G15	25	100	675	4	2	0	-3	60	18.62	19.08	4	114.25	140	3	7.3
G16	25	100	678	4	2	0	-3	60	18.71	19.16	4	114.25	140	3	7.3
G17	54.25	155	737	5	3	1	5	108.5	11.45	11.91	6	244.82	300	5	9.13
G18	54.25	155	738	5	3	1	5	108.5	11.49	11.96	6	244.82	300	5	9.13
G19	54.25	155	740	5	3	1	5	108.5	11.52	12	6	244.82	300	5	9.13
G20	54.25	155	742	5	3	1	5	108.5	11.55	12.04	6	244.82	300	5	9.13
G21	68.95	197	1857	5	4	0	-4	137.9	23.54	23.87	8	326.42	400	5	9.22
G22	68.95	197	1865	5	4	0	-4	137.9	23.64	23.97	8	326.42	400	5	9.22
G23	68.95	197	1872	5	4	0	-4	137.9	23.74	24.08	8	326.42	400	5	9.22
G24	140	350	1728	8	5	1	10	245	11.45	11.77	8	426.42	500	4	7.62
G25	100	400	1079	8	5	1	10	240	8.15	8.73	10	816.06	1000	4	7.96
G26	100	400	1082	8	5	1	10	240	8.17	8.75	10	816.06	1000	4	7.96

Nomenclature for Table A.2:

FC : Fixed Cost at minimum generation ($)

MUT : Minimum Up Time (hours)

MDT : Minimum Down Time (hours)

IS : Initial Status (0 = initially down; 1 = initially up)

IUDT : Initial Up/Down Time (+X = initially has been up at X hours; -X = initially has been down at X hours)

T_1 : Elbow point between segment#1 and #2

F_1 : Incremental Cost at 1st segment ($/MW)

F_2 : Incremental Cost at 2nd segment ($/MW)

CDT : Cold Down Time (hours)

HST : Hot Start-up Cost ($)

CST : Cold Start-up Cost ($)

Lamda1 : failure rate used in Chapter 3 & 4 (fails/year)

Lamda2 : failure rate used in Chapter 5 (fails/year)

Demand for IEEE-24 bus system

Hour	Demand
1	1700
2	1730
3	1690
4	1700
5	1750
6	1850
7	2000
8	2430
9	2540
10	2600
11	2670
12	2590
13	2590
14	2550
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20	2550
21	2600
22	2480
23	2200
24	1840

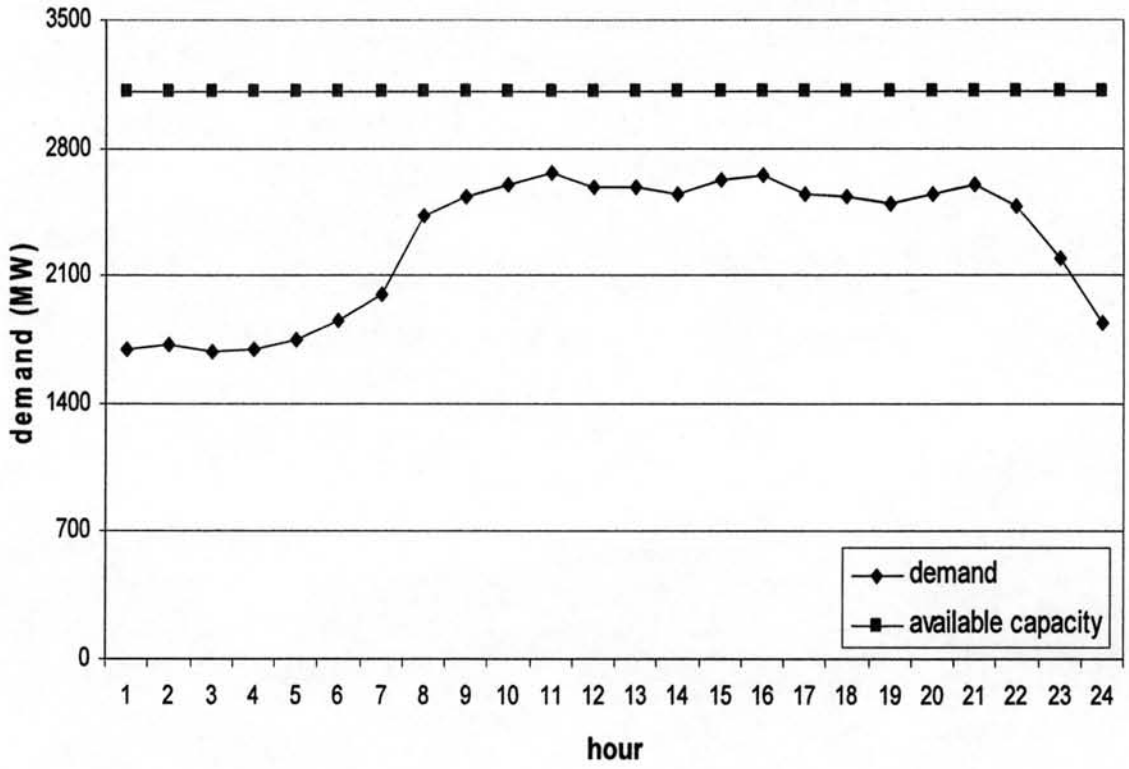

Figure A.4 Demand and available capacity for IEEE-24 bus system

Appendix B: A modified EGAT system

This data of cost functions of the EGAT system are derived from [93]. Other operational limit data are collected from several sources which correspond to the capacity and the fuel type. Table B.1 presents the operational unit data including piecewise-linear cost functions. The demand of the system is shown in Table B.2 and comparison between the available capacity and hourly demand are graphically shown in Figure B.1.

Table B.1 Unit data with piecewise linear cost function and other operational limits for the modified EGAT system

Name	Fuel type	Pmin	Pmax	FC	MUT	MDT	IS	IUDT	T1	VC1	VC2	CDT	HST	CST	Lamda
G1	GAS	105	160	96463	5	4	1	5	132.5	919	919	6	3500	7000	5
G2	GAS	105	160	96463	5	4	1	5	132.5	919	919	6	3500	7000	5
G3	GAS	105	160	96463	5	4	1	5	132.5	919	919	6	3500	7000	5
G4	GAS	105	160	96463	5	4	1	5	132.5	919	919	6	3500	7000	5
G5	COAL	80	145	42289	5	4	0	-4	112.5	529	529	6	3500	7000	3
G6	COAL	80	145	42289	5	4	0	-4	112.5	529	529	6	3500	7000	3
G7	COAL	80	145	42289	5	4	0	-4	112.5	529	529	6	3500	7000	3
G8	COAL	80	145	42289	5	4	0	-4	112.5	529	529	6	3500	7000	3
G9	COAL	150	291	77705	5	4	1	5	220.5	518	518	6	7000	14000	5
G10	COAL	150	291	77705	5	4	1	5	220.5	518	518	6	7000	14000	5
G11	COAL	150	291	77705	5	4	1	5	220.5	518	518	6	7000	14000	5
G12	COAL	150	291	77705	5	4	1	5	220.5	518	518	6	7000	14000	5
G13	COAL	150	291	77705	5	4	1	5	220.5	518	518	6	7000	14000	5
G14	COAL	150	291	77705	5	4	1	5	220.5	518	518	6	7000	14000	5
G15	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G16	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G17	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G18	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G19	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G20	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G21	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G22	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6

G23	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G24	GAS	15	18	11984	1	1	0	-1	16.5	799	799	1	525	1050	6
G25	MIX GAS	60	70	109197	3	2	1	3	65	1820	1820	3	1400	2800	2
G26	MIX GAS	60	70	109197	3	2	1	3	65	1820	1820	3	1400	2800	2
G27	GAS	120	163	145595	5	4	1	5	141.5	1213	1213	6	3500	7000	5
G28	GAS	120	163	145595	5	4	1	5	141.5	1213	1213	6	3500	7000	5
G29	GAS	120	163	145595	5	4	1	5	141.5	1213	1213	6	3500	7000	5
G30	GAS	120	163	145595	5	4	1	5	141.5	1213	1213	6	3500	7000	5
G31	B. OIL	170	340	296962	8	5	1	8	255	1747	1747	9	8750	17500	4
G32	DIESEL	90	120	136051	4	2	1	4	105	1512	1512	3	1750	3500	3
G33	DIESEL	90	120	136051	4	2	1	4	105	1512	1512	3	1750	3500	3
G34	B. OIL	100	186	178633	5	4	1	5	143	1786	1786	6	4375	8750	5
G35	B. OIL	100	186	178633	5	4	1	5	143	1786	1786	6	4375	8750	5
G36	MIX GAS	155	294	222809	5	4	1	5	224.5	1437	1437	6	7000	14000	5
G37	MIX GAS	155	294	222809	5	4	1	5	224.5	1437	1437	6	7000	14000	5
G38	MIX GAS	155	294	222809	5	4	1	5	224.5	1437	1437	6	7000	14000	5
G39	GAS	135	158	150726	5	4	1	5	146.5	1116	1116	6	3500	7000	5
G40	GAS	135	158	150726	5	4	1	5	146.5	1116	1116	6	3500	7000	5
G41	GAS	210	281	222740	5	4	1	5	245.5	1061	1061	6	7000	14000	5
G42	GAS	210	281	222740	5	4	1	5	245.5	1061	1061	6	7000	14000	5
G43	MIX GAS	320	720	495416	10	6	1	10	520	1548	1548	11	17500	35000	4
G44	MIX GAS	320	720	495416	10	6	1	10	520	1548	1548	11	17500	35000	4
G45	ALT. GAS	260	336	305072	8	5	1	8	298	1173	1173	9	8750	17500	4
G46	ALT. GAS	260	336	305072	8	5	1	8	298	1173	1173	9	8750	17500	4
G47	ALT. GAS	260	336	305072	8	5	1	8	298	1173	1173	9	8750	17500	4
G48	ALT. GAS	260	336	305072	8	5	1	8	298	1173	1173	9	8750	17500	4
G49	ALT. GAS	260	336	305072	8	5	1	8	298	1173	1173	9	8750	17500	4
G50	ALT. GAS	260	336	305072	8	5	1	8	298	1173	1173	9	8750	17500	4
G51	ALT. GAS	250	350	293339	8	5	1	8	280	1173	1173	9	8750	17500	4
G52	ALT. GAS	250	350	293339	8	5	1	8	280	1173	1173	9	8750	17500	4
G53	ALT. GAS WEST	215	333	266286	8	5	1	8	274	1239	1239	9	8750	17500	4

Nomenclature for Table B.1:

FC	: Fix Cost (Baht)
MUT	: Minimum Up Time (hours)
MDT	: Minimum Down Time (hours)
IS	: Initial Status (0 = down; 1 = up)
IUDT	: Initial Up/Down Time (+ : initially up; - : initially down)
T1	: Knee point between segment#1 and #2
IC1	: Incremental Cost at 1st segment (Baht/MW)
IC2	: Incremental Cost at 2nd segment (Baht/MW)
CDT	: Cold Down Time (hours)
HST	: Hot Start-up Cost (Baht)
CST	: Cold Start-up Cost (Baht)
Lamda	: failure rate (fails/year)

Table B.2 Demand for EGAT system on Saturday, December 25th 2005

Hour	Demand
1	10024
2	9825
3	9624
4	9724
5	9824
6	10823
7	11073
8	11206
9	12330
10	12513
11	12664
12	11864
13	12063
14	13063
15	13214
16	13163
17	12713
18	14113
19	14814
20	13964
21	12964
22	12157
23	11547
24	11023

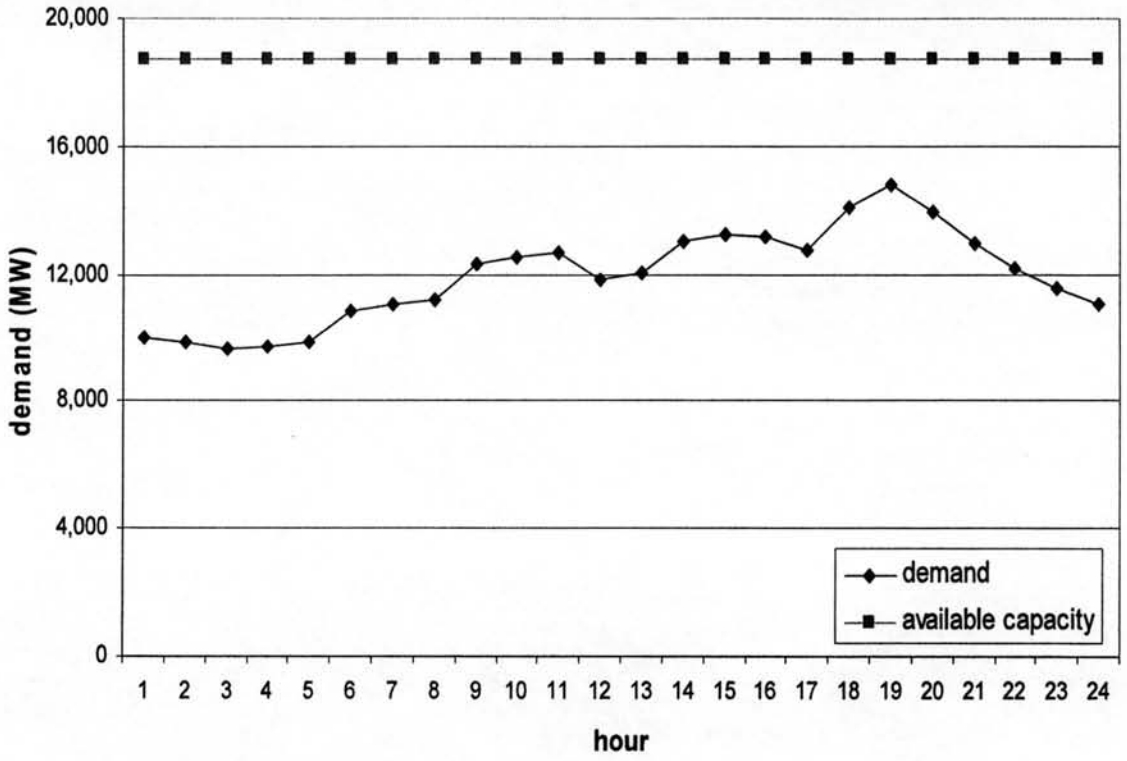

Figure B.1 Demand and available capacity for EGAT system

BIOGRAPHY

Mr. Sarjiya was born in Kulon Progo, Yogyakarta Province, Indonesia in 1973. He received the B.Eng and M.Eng degree in Electrical Engineering from Gadjah Mada University in 1998 and 2001 respectively. He has been with Department of Electrical Engineering, Gadjah Mada University Indonesia since 1999. His interested topics include economic operation of power system and system reliability.