APPENDIX A
TEST SYSTEM DATA

A.1 IEEE 30-bus Test System

Appendix A.1 provides the detailed data of the IEEE 30-bus test system used in this study. These standard benchmark parameters are widely adopted in the literature and serve as a reference dataset for validating the proposed optimisation framework. Table A.1 presents the bus load and power injection data of the IEEE 30-bus test system, in which Type 1, 2, and 3 represent the slack bus, the PV bus, and the PQ bus, respectively. Table A.2 summarises the transmission line parameters of the IEEE 30-bus test system, including line impedances and capacity limits. Table A.3 reports the generation cost parameters, emission coefficients, and capacity constraints of the generating units in the IEEE 30-bus test system. The AGC and SR offered prices and quantities of IEEE 30-bus test system are shown in Table A.4.

Table A.1 Bus load and injection data of IEEE 30-bus test system

Bus No.	Bus type	Load (MW)	Bus No.	Bus type	Load (MW)	Bus No.	Bus type	Load (MW)
1	1	0	11	2	0	21	3	17.5
2	2	21.7	12	3	11.2	22	3	0
3	3	2.4	13	2	0	23	3	3.2
4	3	7.6	14	3	6.2	24	3	8.7
5	2	94.2	15	3	8.2	25	3	0
6	3	0	16	3	3.5	26	3	3.5
7	3	22.8	17	3	9	27	3	0
8	2	30	18	3	3.2	28	3	0
9	3	0	19	3	9.5	29	3	2.4
10	3	5.8	20	3	2.2	30	3	10.6

Table A.2 Line parameter of IEEE 30-bus test system

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
1	2	0.0192	0.0575	0.0264		2.6428
1	3	0.0452	0.1652	0.0204		2.9309
2	4	0.057	0.1737	0.0184		0.8224
3	4	0.0132	0.0379	0.0042		2.7255
2	5	0.0472	0.1983	0.0209		1.2383
2	6	0.0581	0.1763	0.0187		0.9997
4	6	0.0119	0.0414	0.0045		1.7064
4	12		0.256		0.932	0.6202
5	7	0.046	0.116	0.0102		1.0603
6	7	0.0267	0.082	0.0085		1.2994
6	8	0.012	0.042	0.0045		0.316
6	9		0.208		0.978	0.5078
6	10		0.556		0.969	0.281
9	11		0.208			0.1771
9	10		0.11			0.4983
12	13		0.14			0.331
12	14	0.1231	0.2559			0.1714
12	15	0.0662	0.1304			0.2579
12	16	0.0945	0.1987			0.1584
14	15	0.221	0.1997			0.1029
16	17	0.0524	0.1923			0.1779
15	18	0.1073	0.2185			0.1582
18	19	0.0639	0.1292			0.1221
19	20	0.034	0.068			0.1726
10	20	0.0936	0.209			0.1986
10	17	0.0324	0.0845			0.2585
10	21	0.0348	0.0749			0.2653
10	22	0.0727	0.1499			0.2412

Table A.2 Line parameter of IEEE 30-bus test system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
21	22	0.0116	0.0236			0.2034
15	23	0.1	0.202			0.1215
22	24	0.115	0.179			0.2099
23	24	0.132	0.27			0.1103
24	25	0.1885	0.3292			0.194
25	26	0.2544	0.38			0.0428
25	27	0.1093	0.2087			0.1415
27	29	0.2198	0.4153			0.1443
27	30	0.3202	0.6027			0.1424
28	27		0.369		0.968	0.248
29	30	0.2399	0.4533			0.1122
8	28	0.0636	0.2	0.0214		0.3083
6	28	0.0169	0.0599	0.0065		0.4734

Table A.3 Generation cost parameters, emission coefficients, and capacity limits for generating units in the IEEE 30-bus test system

Bus No.	Generation cost			Carbon emission			$P_G^{\min}$ (MW)	$P_G^{\max}$ (MW)
	a (\$/MW^{2}h)	b (\$/MWh)	c (\$/h)	α (t/p.u^{2}h)	β (t/p.u.h)	ω (t/h)		
1	0.00375	2.00	0.00	0.06490	-0.05554	0.04091	50	200
2	0.01750	1.75	0.00	0.05638	-0.06047	0.02543	20	80
5	0.06250	1.00	0.00	0.04586	-0.05094	0.04258	15	50
8	0.00834	3.25	0.00	0.03380	-0.03550	0.05326	10	35
11	0.02500	3.00	0.00	0.04586	-0.05094	0.04258	10	30
13	0.02500	3.00	0.00	0.05151	-0.55550	0.06131	12	40

Table A.4 AGC and SR offered prices and quantities of IEEE 30-bus test system

Bus No.	AGC		SR	
	MW	\$/MW	MW	\$/MW
1	6	7	4	8
2	8	11	6	11
5	5	12	5	8
8	4	13	6	10
11	3	14	5	14
13	4	5	4	12

A.2 160 bus Equivalent Thai Power System

Appendix A.2 provides the data for the 160-bus equivalent Thai power system developed for this study. This system is a simplified, aggregated representation constructed for research purposes and does not fully replicate the Thai power grid. However, it captures the essential structural characteristics and generator operating ranges required for large-scale optimisation and electricity market analysis. Table A.5 presents the bus load and power injection data of the 160-bus equivalent Thai power system. Table A.6 summarises the transmission line parameters of the 160-bus equivalent Thai power system. Table A.7 presents the cost coefficients and emission coefficients of the generating units considered in this study. The emission coefficients for each generator are derived from the emission factors reported in the Emission Factor CFP Report (July 2022) published by the Thailand Greenhouse Gas Management Organization (TGO). Specifically, the emission coefficient assigned to each generating unit corresponds to its primary fuel type by matching the generator’s fuel characteristics with the relevant emission factors provided in the TGO report. This approach ensures that the emission modelling accurately reflects fuel-specific carbon intensities in the Thai power system context. The AGC and SR offered prices and quantities of 160-bus equivalent Thai power system are shown in Table A.8.

Table A.5 Bus load and injection data of the 160-bus equivalent Thai power system

Bus No.	Bus type	Load (MW)	Bus No.	Bus type	Load (MW)	Bus No.	Bus type	Load (MW)
1	1	0	28	2	60.64	55	3	0
2	2	0	29	2	0	56	3	0
3	2	0	30	2	23.29	57	3	0
4	2	0	31	2	0	58	3	0
5	2	16.57	32	2	0.23	59	3	0
6	2	0	33	2	0.08	60	3	297.8
7	2	23.15	34	2	0.18	61	3	640.4
8	2	0	35	2	0	62	3	662.5
9	2	0	36	2	98.05	63	3	837.5
10	2	26.13	37	2	0	64	3	359.4
11	2	0	38	2	0	65	3	486.9
12	2	0.98	39	2	0	66	3	340.8
13	2	0.98	40	2	9.6	67	3	0
14	2	1.36	41	2	0	68	3	0
15	2	0.38	42	2	0	69	3	241.5
16	2	24.26	43	3	51.51	70	3	0
17	2	0	44	3	553.3	71	3	0
18	2	0.55	45	3	0	72	3	0
19	2	0.28	46	3	0	73	3	0
20	2	22.61	47	3	0	74	3	0
21	2	0	48	3	0	75	3	0
22	2	0	49	3	0	76	3	0
23	2	0	50	3	0	77	3	0
24	2	0	51	3	0	78	3	0
25	2	36.46	52	3	0	79	3	0
26	2	0	53	3	0	80	3	29.3
27	2	0	54	3	0	81	3	0

Table A.5 Bus load and injection data of the 160-bus equivalent Thai power system (Continued)

Bus No.	Bus type	Load (MW)	Bus No.	Bus type	Load (MW)	Bus No.	Bus type	Load (MW)
82	3	0	109	3	29.8	136	3	184.5
83	3	0	110	3	30.2	137	3	462.4
84	3	0	111	3	249.4	138	3	168.6
85	3	0	112	3	80.5	139	3	302.1
86	3	49.6	113	3	248	140	3	60.9
87	3	0	114	3	137.2	141	3	110.4
88	3	0	115	3	42.2	142	3	146.2
89	3	0	116	3	3.3	143	3	281.4
90	3	0	117	3	42.8	144	3	126.6
91	3	0	118	3	198	145	3	70
92	3	0	119	3	161	146	3	95.9
93	3	0	120	3	341.1	147	3	515.2
94	3	0	121	3	69.7	148	3	0
95	3	0	122	3	280.2	149	3	0
96	3	0	123	3	238.2	150	3	0
97	3	0	124	3	180.3	151	3	0
98	3	0	125	3	137.6	152	3	0
99	3	0	126	3	87.9	153	3	0
100	3	0	127	3	245.4	154	3	0
101	3	122.1	128	3	119.3	155	3	0
102	3	121.9	129	3	50.8	156	3	0
103	3	48.2	130	3	50.5	157	3	0
104	3	151.7	131	3	45.8	158	3	0
105	3	231.4	132	3	45.6	159	3	177.1
106	3	177.8	133	3	196	160	3	0
107	3	-27.3	134	3	208.8			
108	3	72.8	135	3	86			

Table A.6 Line parameter of the 160-bus equivalent Thai power system

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
60	61	0.0007	0.005	0.0052		500
60	65	0.0018	0.0146	0.0134		500
60	66	0.0019	0.014	0.0145		500
61	62	0.0002	0.0027	0.0223		500
61	66	0.0017	0.0128	0.0132		500
62	68	0.0001	0.0012	0.0389		500
62	69	0.0002	0.0011	0.0044		500
63	44	0.0004	0.0041	0.0347		500
63	68	0.0005	0.0041	0.0184		500
63	43	0.0011	0.0116	0.0945		500
44	64	0.00026	0.0027	0.0501		500
64	65	0.0001	0.0018	0.0149		500
64	100	0.0009	0.0102	0.0215		500
65	45	0.00147	0.01429	0.03442		500
65	100	0.0005	0.006	0.0127		500
45	66	0.0012	0.0087	0.0393		500
45	87	0.0035	0.0251	0.1129		500
45	96	0.0026	0.021	0.0791		500
66	67	0.0019	0.0214	0.0397		500
66	46	0.0019	0.0214	0.0397		500
67	94	0.0017	0.0179	0.0365		500
67	55	0.0021	0.0222	0.0453		500
67	68	0.0009	0.0096	0.0196		500
68	46	0.0009	0.0096	0.0196		500
68	55	0.0024	0.0148	0.1212		500
46	94	0.0017	0.0179	0.0365		500
46	55	0.0021	0.0222	0.0453		500
70	71	0.0052	0.0372	0.1673		500
70	88	0.0059	0.0432	0.1892		500

Table A.6 Line parameter of the 160-bus equivalent Thai power system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
71	72	0.0049	0.0347	0.1557		500
71	82	0.0079	0.0584	0.2629		500
72	47	0.0008	0.0088	0.0738		500
72	73	0.0057	0.0413	0.0196		500
72	74	0.0005	0.0036	0.0158		500
72	84	0.0087	0.0632	0.2797		500
48	75	0.0025	0.0214	0.0759		500
75	49	0.0038	0.03	0.1132		500
75	58	0.014	0.1032	0.4603		500
49	76	0.0048	0.0383	0.1444		500
76	77	0.0044	0.0352	0.1325		500
77	78	0.0044	0.0346	0.1303		500
79	153		0.0001			500
153	154	0.0026	0.0326	1.75205		500
154	59		0.0001			500
79	155		0.0001			500
155	156	0.0026	0.0326	1.75205		500
156	59		0.0001			500
79	157		0.0001			500
157	158	0.00265	0.03589	1.67202		500
158	59		0.0001			500
79	151		0.0001			500
79	152		0.0001			500
151	91	0.00169	0.02298	1.06595		500
152	91	0.00169	0.02298	1.06595		500
50	80	0.0054	0.0438	0.0406		500
50	81	0.0107	0.0833	0.3253		500
80	81	0.0159	0.1284	0.1189		500
81	82	0.0024	0.0277	0.0718		500

Table A.6 Line parameter of the 160-bus equivalent Thai power system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
81	83	0.0107	0.0538	0.1982		500
81	87	0.0049	0.0381	0.1503		500
82	86	0.0072	0.0525	0.2354		500
82	90	0.0032	0.0341	0.2784		500
82	53	0.0041	0.077	0.1956		500
51	83	0.009	0.0454	0.1671		500
83	84	0.006	0.045	0.1841		500
83	52	0.0079	0.0593	0.2428		500
52	85	0.0058	0.0424	0.1867		500
86	89	0.0024	0.0176	0.0788		500
87	90	0.0025	0.0185	0.0829		500
88	90	0.0015	0.011	0.0494		500
89	53	0.0006	0.0068	0.0556		500
43	94	0.0002	0.0021	0.0173		500
92	54	0.0025	0.0184	0.0828		500
92	93	0.0014	0.0103	0.0463		500
92	55	0.0026	0.0192	0.0877		500
54	93	0.0022	0.0159	0.0715		500
95	55	0.0018	0.0197	0.1667		500
96	97	0.002	0.0163	0.0617		500
97	56	0.0027	0.0213	0.3219		500
97	98	0.0196	0.1545	0.1456		500
97	99	0.0111	0.0883	0.0886		500
98	58	0.0029	0.0216	0.0945		500
56	57	0.0041	0.0325	0.1228		500
99	98	0.0084	0.0689	0.0673		500
53	67	0.00127	0.0172	0.03588		500
59	52	0.0014	0.0208		1.052	900
79	148	0.0014	0.02231		1.0165	600

Table A.6 Line parameter of the 160-bus equivalent Thai power system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
148	82		0.02514		1.05217	600
79	149	0.0014	0.02231		1.0165	600
149	82		0.02514		1.05217	600
79	150	0.0014	0.02231		1.0165	500
150	82		0.02514		1.05217	500
91	67	0.0014	0.0208		1	500
91	46	0.0014	0.0208		1	500
44	101	0.0006	0.0645		1	200
44	102	0.0006	0.0645		1	200
45	103	0.0006	0.0705		0.9	300
46	104	0.0006	0.0705		0.9244	200
47	105	0.0003	0.03255		0.9625	200
48	106	0.0003	0.0364		1.05	200
49	107	0.0014	0.131		1.075	100
50	108	0.0014	0.1417		1.025	100
51	109	0.0014	0.1685		1.025	66.7
51	110	0.0014	0.1535		1.025	66.7
52	111	0.0003	0.03376		0.95	400
52	112	0.0014	0.17583		0.9025	100
54	113	0.00012	0.0137		0.9875	1000
55	114	0.0003	0.02629		1	400
56	115	0.0014	0.14283		1.025	100
57	116	0.0014	0.16447		1.025	66.7
58	117	0.0003	0.03625		1	400
66	118	0.0002	0.0215		1.01	600
67	119	0.0006	0.0705		1.0882	200
70	120	0.0002	0.0217		0.975	600
71	121	0.0006	0.0651		0.975	200
73	122	0.0003	0.03255		0.9625	400

Table A.6 Line parameter of the 160-bus equivalent Thai power system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
74	123	0.0002	0.022		0.9875	600
75	124	0.00047	0.04683		1.0375	300
76	125	0.0003	0.0364		0.9875	100
77	126	0.0006	0.07279		1	200
78	127	0.0002	0.02426		1	600
81	128	0.0014	0.063		1.025	200
82	129	0.0006	0.0651		1	200
82	130	0.0006	0.066		1	200
83	131	0.0014	0.063		1	200
84	132	0.0014	0.1417		1.025	100
85	133		0.03255		0.9875	400
86	134	0.0003	0.03377		1.03342	400
87	135	0.0003	0.03103		0.96386	400
88	136	0.0002	0.02251		0.988	600
89	137	0.00015	0.01688		0.9505	800
90	138	0.0002	0.0217		0.975	600
92	139	0.0002	0.02092		1	600
93	140	0.0002	0.02092		0.9875	600
94	141	0.0002	0.02092		1	600
95	142	0.0003	0.03138		0.9625	400
96	143		0.02417		1.0125	600
97	144	0.0003	0.03582		0.975	400
98	145	0.0007	0.06675		0.9875	200
99	146	0.0006	0.0725		0.964	200
100	147	0.00015	0.01813		0.925	800
43	1		0.0174		0.95	680
43	2		0.0174		0.95	680
43	3		0.0326		0.95	340
43	4		0.02766		1	368

Table A.6 Line parameter of the 160-bus equivalent Thai power system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
44	5		0.0383		0.95	225
44	6		0.0383		0.95	225
44	7		0.0317		0.95	370
44	8		0.0317		0.95	370
44	9		0.0317		0.95	370
44	10		0.02608		0.95	425
44	11		0.02608		0.95	425
45	12		0.12987		1	125
46	13		0.06523		0.95	170
47	14		0.013		0.95	850
48	15		0.0442		0.95	270
49	16		0.04246		0.95	425
49	17		0.04246		0.95	425
50	18		0.01738		0.975	696
51	19		0.03613		1	450
52	20		0.0731		0.95	171
52	21		0.0731		0.95	171
52	22		0.0731		0.95	171
53	23		0.01276		1	750
53	24		0.01276		1	750
54	25		0.01956		0.95	570
54	26		0.01956		0.95	570
54	27		0.01956		0.95	570
55	28		0.0174		1.1	680
55	29		0.0174		1.1	680
55	30		0.02174		0.95	510
55	31		0.02174		0.95	510
56	32		0.02805		0.97	300
56	33		0.0291		0.95	440

Table A.6 Line parameter of the 160-bus equivalent Thai power system (Continued)

From Bus	To Bus	R (p.u.)	X (p.u.)	B/2 (p.u.)	Tap Ratio	Limit MVA
57	34		0.03077		0.975	333.3
58	35		0.0397		0.975	300
59	36		0.0317		0.975	370
59	37		0.0317		0.975	370
59	38		0.0317		0.975	370
59	39		0.0317		0.975	370
159	40		0.11		0.975	90
159	41		0.1144		0.975	90
159	42		0.1133		0.975	105
159	160		0.00721		1.0507	200
159	60	0.0006	0.07246		1.025	200

Table A.7 Modified generation cost and emission coefficients for generating units in the 160-bus equivalent Thai power system

Bus No.	Generation cost			Carbon emission			P_G^{min} (MW)	P_G^{max} (MW)
	a (\$/MW^{2}h)	b (\$/MWh)	c (\$/h)	α (t/p.u^{2}h)	β (t/p.u.h)	ω (t/h)		
1	43519.17	914.926	0.0012	0	0.558	0	240	3100
2	48211.38	913.503	0.0011	0	0.558	0	100	510
3	-21402.9	1186.901	0.0297	0	0.558	0	100	500
4	-23886.2	1202.975	0.0322	0	0.558	0	100	410
5	20825.59	969.934	0.1732	0	0.558	0	80	150
6	19623.75	989.860	0.1306	0	0.558	0	80	150
7	23407.79	980.789	0.0127	0	0.558	0	186	250
8	23376.01	979.458	0.0127	0	0.558	0	186	225
9	23396.59	980.323	0.0127	0	0.558	0	186	400
10	34072.57	-298.463	3.9100	0	0.558	0	120	250
11	-13071.1	917.5457	0.3649	0	0.558	0	120	450
12	34072.57	-298.463	3.9100	0	0.558	0	18	2030
13	34072.57	-298.463	3.9100	0	0.73	0	18	340

Table A.7 Modified generation cost and emission coefficients for generating units in the 160-bus equivalent Thai power system (Continued)

Bus No.	Generation cost			Carbon emission			$P_G^{\min}$ (MW)	$P_G^{\max}$ (MW)
	a (\$/MW^{2}h)	b (\$/MWh)	c (\$/h)	α (t/p.u^{2}h)	β (t/p.u.h)	ω (t/h)		
14	43519.17	914.926	0.0012	0	0.558	0	100	460
15	0	0	0	0	0	0	100	100
16	7576.921	876.873	0.3888	0	0.558	0	220	381
17	9215.791	958.689	0.6816	0	0.558	0	220	796
18	0	0	0	0	0	0	150	150
19	0	0	0	0	0	0	200	200
20	3058.372	441.381	0.0462	0	0.876	0	100	203
21	3082.437	444.742	0.0466	0	0.876	0	100	472
22	3071.661	443.200	0.0465	0	0.876	0	100	316
23	0	922.151	0.3476	0	0.558	0	100	500
24	0	982.104	0.4344	0	0.558	0	220	500
25	-53553.5	1380.261	1.1955	0	0.558	0	100	250
26	-55517.6	1408.05	1.3486	0	0.558	0	200	250
27	-13154.4	984.040	0.4014	0	0.558	0	184	250
28	36843.24	858.008	0.0623	0	0.558	0	300	320
29	36782.98	856.602	0.0622	0	0.558	0	320	1300
30	-55760.9	1362.416	1.3033	0	0.558	0	120	1300
31	-32118	1149.104	0.8689	0	0.558	0	120	575
32	0	0	0	0	0	0	200	200
33	0	0	0	0	0	0	300	300
34	0	0	0	0	0	0	200	200
35	0	0	0	0	0.558	0	0	0
36	20963.1	278.445	0.2309	0	0.876	0	180	550
37	20801.48	276.301	0.2291	0	0.876	0	180	350
38	20746.63	275.568	0.2285	0	0.876	0	180	403
39	20856.76	277.034	0.2297	0	0.876	0	180	445
40	9011.999	925.424	1.02	0	0.558	0	60	400
41	6906.259	1019.99	0.1553	0	0.558	0	60	700
42	7430.474	953.987	0.3381	0	0.558	0	60	350

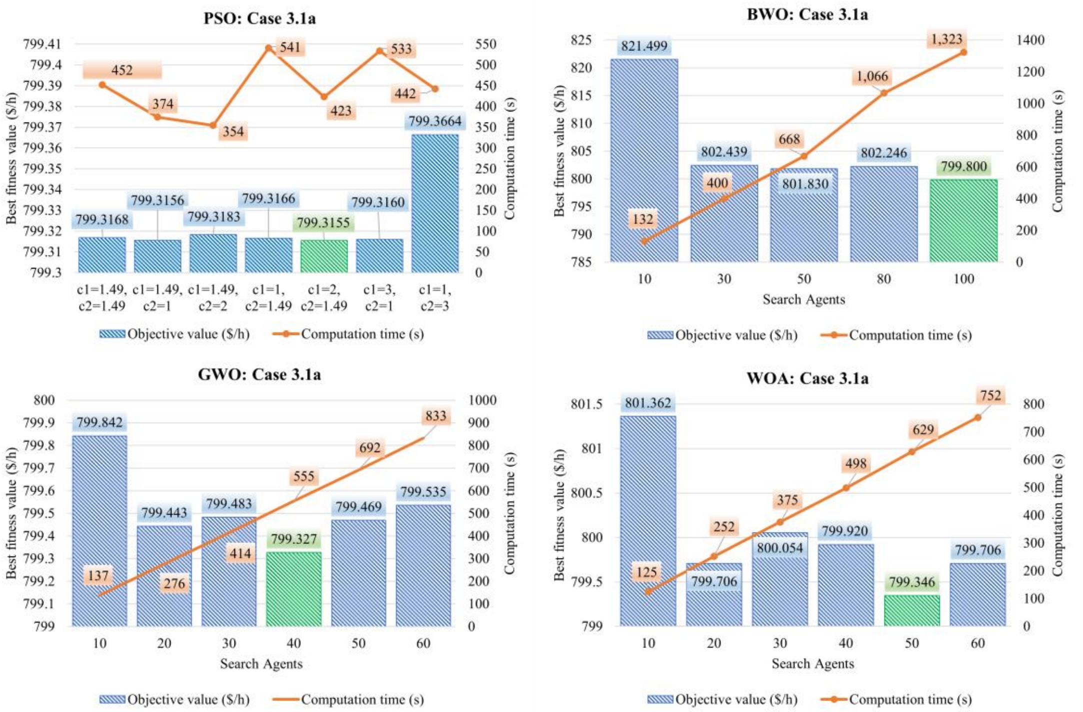
Table A.8 AGC and SR offered prices and quantities of 160-bus equivalent Thai power system

Bus No.	**AGC**		**SR**		**Bus No.**	**AGC**		**SR**	
	MW	$/MW	MW	$/MW		MW	$/MW	MW	$/MW
1	480	122	480	197	22	63	124	63	137
2	48	153	48	179	23	44	78	44	159
3	32	104	32	106	24	61	196	61	108
4	20	91	20	112	25	40	100	40	145
5	20	68	20	60	26	66	59	66	147
6	20	102	20	153	27	40	140	40	193
7	95	177	95	80	28	64	109	64	159
8	51	150	51	185	29	260	182	260	200
9	78	68	78	171	30	260	59	260	195
10	34	123	34	65	31	115	114	115	77
11	43	141	43	76	32	0	0	0	0
12	406	74	406	73	33	0	0	0	0
13	68	56	68	159	34	0	0	0	0
14	32	157	32	80	35	0	0	0	0
15	0	0	0	0	36	110	95	110	79
16	76	194	76	134	37	70	86	70	103
17	159	114	159	165	38	81	152	81	92
18	0	0	0	0	39	89	148	89	94
19	0	0	0	0	40	80	168	80	144
20	41	53	41	176	41	140	200	140	143
21	94	117	94	188	42	70	99	70	141

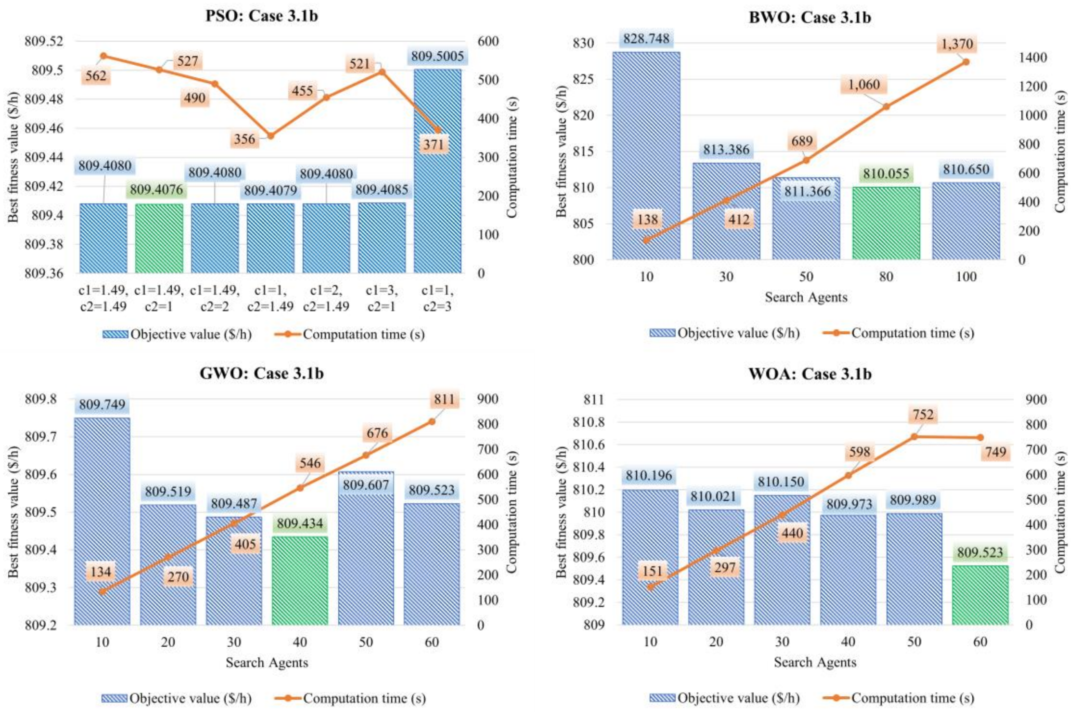
APPENDIX B
ADDITIONAL SIMULATION RESULTS

B.1 Hyperparameter Sensitivity Analyses

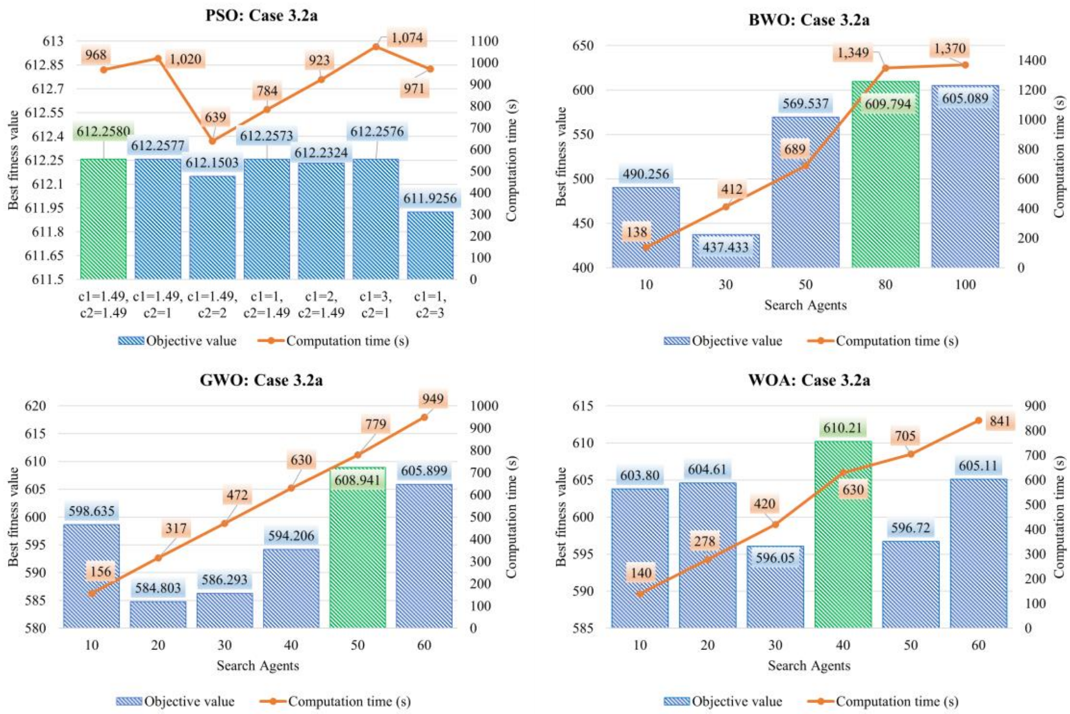
The hyperparameter sensitivity analyses were conducted for all four stochastic optimisation algorithms, which are summarised in Table 3.2 of Chapter 3. Each algorithm was simulated under systematically varied hyperparameter settings, such as the inertia weight for PSO, control coefficients for BWO, leadership and encircling parameters for GWO, and exploration–exploitation factors for WOA, to evaluate their influence on convergence behaviour, solution quality, and computational robustness. The resulting performance patterns from these simulations are illustrated in Figure B.1, which presents a comprehensive comparison of the algorithms under the full range of tested configurations. This appendix, therefore, serves to supplement the main chapter by offering detailed visual and analytical insights into how hyperparameter adjustments affect algorithmic performance.



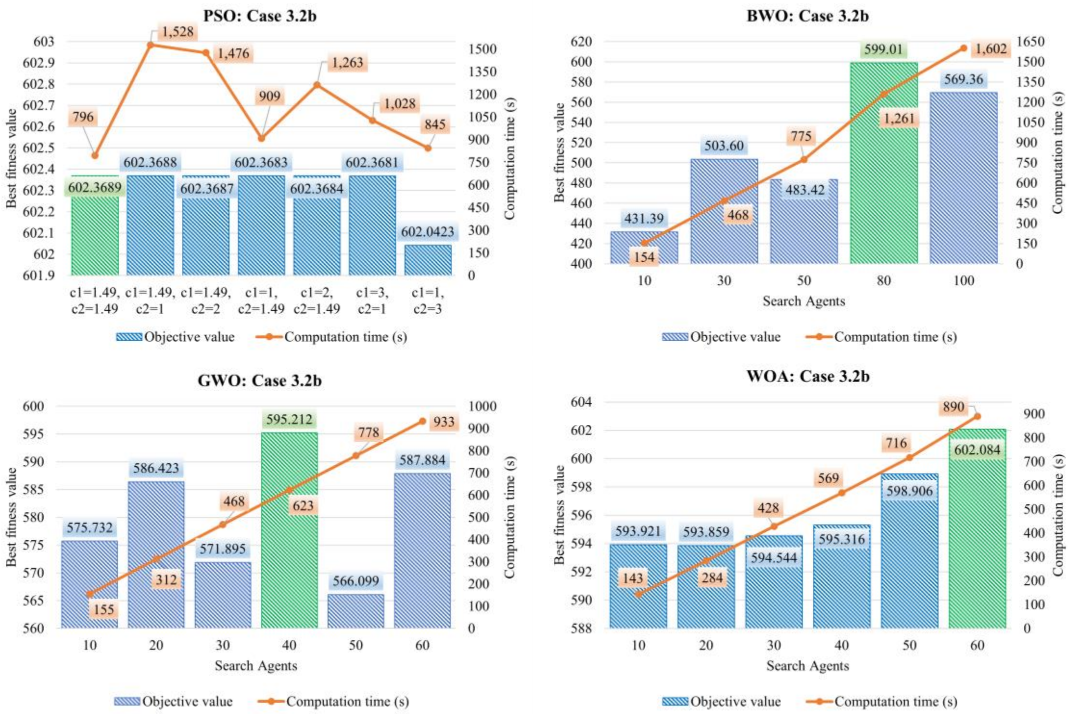
(a) Case 3.1a: Conventional single-side auction scheme



(b) Case 3.1b: Carbon-accounted single-side auction scheme



(c) Case 3.2a: Conventional double-side auction scheme



(d) Case 3.2b: Carbon-accounted double-side auction scheme

Figure B.1 Hyperparameter sensitivity analysis in different optimisation algorithms

B.2 Additional Simulation Results

This appendix presents supplementary optimisation results for the multi-dimensional market framework. The tables report the final values of the control variables obtained from two solution approaches, (i) QP method and (ii) the hybrid PSO-QP method. These results complement the summary tables in Chapter 6 by providing full optimised outputs for all decision variables under each method, thereby enabling a more detailed comparison of solution performance. Table B.1 reports the complete set of optimised control variables derived from the QP-based solution, illustrating the deterministic behaviour of the convex optimisation model. Moreover, Table B.2 presents the corresponding results from the hybrid PSO-QP method, highlighting the improvements achieved when combining stochastic search with deterministic refinement.

Table B.1 Optimised control variable results obtained using QP method for the multi-dimensional market framework

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
$P_{G,1}$ (MW)	3100	3100	3100	3100	3100	$P_{G,18}$ (MW)	150	150	150	150	150
$P_{G,2}$ (MW)	510	510	510	510	510	$P_{G,19}$ (MW)	200	200	200	200	200
$P_{G,3}$ (MW)	500	500	500	500	500	$P_{G,20}$ (MW)	203	203	203	203	203
$P_{G,2}$ (MW)	410	410	410	410	410	$P_{G,21}$ (MW)	472	472	472	472	472
$P_{G,5}$ (MW)	150	150	150	150	150	$P_{G,22}$ (MW)	316	316	316	316	316
$P_{G,6}$ (MW)	150	150	150	150	150	$P_{G,23}$ (MW)	500	500	500	500	500
$P_{G,7}$ (MW)	250	250	250	250	250	$P_{G,24}$ (MW)	500	500	500	500	500
$P_{G,8}$ (MW)	225	225	225	225	225	$P_{G,25}$ (MW)	250	250	250	250	250
$P_{G,9}$ (MW)	400	400	400	400	400	$P_{G,26}$ (MW)	250	250	250	200	200
$P_{G,10}$ (MW)	250	250	250	241.5045	217.9716	$P_{G,27}$ (MW)	250	250	250	250	250
$P_{G,11}$ (MW)	450	450	450	450	450	$P_{G,28}$ (MW)	320	320	320	320	320
$P_{G,12}$ (MW)	443.318	429.065	427.905	418.311	390.092	$P_{G,29}$ (MW)	1300	1300	1300	1300	1300
$P_{G,13}$ (MW)	340	340	340	295.415	270.862	$P_{G,30}$ (MW)	692.786	650.029	646.550	617.765	533.109
$P_{G,14}$ (MW)	460	460	460	460	460	$P_{G,31}$ (MW)	575	575	575	433.310	345
$P_{G,15}$ (MW)	100	100	100	100	100	$P_{G,32}$ (MW)	200	200	200	200	200
$P_{G,16}$ (MW)	381	381	381	381	381	$P_{G,33}$ (MW)	300	300	300	300	300
$P_{G,17}$ (MW)	796	796	796	552.400	478	$P_{G,34}$ (MW)	200	200	200	200	200

Table B.1 Optimised control variable results obtained using QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
$P_{G,35}$ (MW)	0	0	0	0	0	$P_{D,10}$ (MW)	452.813	452.813	452.813	452.813	452.813
$P_{G,36}$ (MW)	550	550	550	550	550	$P_{D,11}$ (MW)	54.938	54.938	54.938	54.938	54.938
$P_{G,37}$ (MW)	350	350	350	350	350	$P_{D,12}$ (MW)	93	93	93	93	93
$P_{G,38}$ (MW)	403	403	403	403	403	$P_{D,13}$ (MW)	228.938	228.938	228.938	228.938	228.938
$P_{G,39}$ (MW)	445	445	445	445	445	$P_{D,14}$ (MW)	228.563	228.563	228.563	228.563	228.563
$P_{G,40}$ (MW)	400	400	400	400	391.967	$P_{D,15}$ (MW)	90.375	90.375	90.375	90.375	90.375
$P_{G,41}$ (MW)	700	700	700	700	700	$P_{D,16}$ (MW)	284.438	284.438	284.438	284.438	284.438
$P_{G,42}$ (MW)	350	350	350	350	350	$P_{D,17}$ (MW)	433.875	433.875	433.875	433.875	433.875
$P_{D,1}$ (MW)	96.581	96.581	96.581	96.581	96.581	$P_{D,18}$ (MW)	333.375	333.375	333.375	333.375	333.375
$P_{D,2}$ (MW)	1037.438	1037.438	1037.438	1037.438	1037.438	$P_{D,19}$ (MW)	136.5	136.5	136.5	136.5	136.5
$P_{D,3}$ (MW)	558.375	558.375	558.375	558.375	558.375	$P_{D,20}$ (MW)	55.875	55.875	55.875	55.875	55.875
$P_{D,4}$ (MW)	1200.75	1200.75	1200.75	1200.75	1200.75	$P_{D,21}$ (MW)	56.625	56.625	56.625	56.625	56.625
$P_{D,5}$ (MW)	0	0	623.124	0	0	$P_{D,22}$ (MW)	0	0	467.625	0	467.625
$P_{D,6}$ (MW)	662.835	605.826	1570.313	74.437	1570.313	$P_{D,23}$ (MW)	150.938	150.938	150.938	150.938	150.938
$P_{D,7}$ (MW)	673.875	673.875	673.875	673.875	673.875	$P_{D,24}$ (MW)	465	465	465	465	465
$P_{D,8}$ (MW)	912.938	912.938	912.938	912.938	912.938	$P_{D,25}$ (MW)	257.25	257.25	257.25	257.25	257.25
$P_{D,9}$ (MW)	639	639	639	639	639	$P_{D,26}$ (MW)	79.125	79.125	79.125	79.125	79.125

Table B.1 Optimised control variable results obtained using QP method for the multi-dimensional market framework (Continued)

Variable	*Case 6.0*	*Case 6.1*	*Case 6.2*	*Case 6.3*	*Case 6.4*	*Variable*	*Case 6.0*	*Case 6.1*	*Case 6.2*	*Case 6.3*	*Case 6.4*
$P_{D,27}$ (MW)	6.188	6.188	6.187	6.187	6.188	$P_{D,44}$ (MW)	367.5	367.5	367.5	367.5	367.5
$P_{D,28}$ (MW)	80.25	80.25	80.25	80.25	80.25	$P_{D,45}$ (MW)	391.5	391.5	391.5	391.5	391.5
$P_{D,29}$ (MW)	371.25	371.25	371.25	371.25	371.25	$P_{D,46}$ (MW)	161.25	161.25	161.25	161.25	161.25
$P_{D,30}$ (MW)	301.875	301.875	301.875	301.875	301.875	$P_{D,47}$ (MW)	345.938	345.938	345.938	345.938	345.938
$P_{D,31}$ (MW)	639.563	639.563	639.563	639.563	639.563	$P_{D,48}$ (MW)	867	867	867	867	867
$P_{D,32}$ (MW)	130.688	130.688	130.688	130.688	130.688	$P_{D,49}$ (MW)	316.125	316.125	316.125	316.125	316.125
$P_{D,33}$ (MW)	525.375	525.375	525.375	525.375	525.375	$P_{D,50}$ (MW)	566.438	566.438	566.438	566.438	566.438
$P_{D,34}$ (MW)	446.625	446.625	446.625	446.625	446.625	$P_{D,51}$ (MW)	114.188	114.188	114.188	114.188	114.188
$P_{D,35}$ (MW)	338.063	338.063	338.063	338.063	338.063	$P_{D,52}$ (MW)	207	207	207	207	207
$P_{D,36}$ (MW)	258	258	258	258	258	$P_{D,53}$ (MW)	274.125	274.125	274.125	274.125	274.125
$P_{D,37}$ (MW)	164.813	164.813	164.813	164.813	164.813	$P_{D,54}$ (MW)	527.625	527.625	527.625	527.625	527.625
$P_{D,38}$ (MW)	0	0	460.125	0	224.795	$P_{D,55}$ (MW)	237.375	237.375	237.375	237.375	237.375
$P_{D,39}$ (MW)	0	0	0	0	0	$P_{D,56}$ (MW)	131.25	131.25	131.25	131.25	131.25
$P_{D,40}$ (MW)	95.25	95.25	95.25	95.25	95.25	$P_{D,57}$ (MW)	179.813	179.813	179.813	179.813	179.813
$P_{D,41}$ (MW)	94.688	94.688	94.688	94.688	94.688	$P_{D,58}$ (MW)	966	966	966	966	966
$P_{D,42}$ (MW)	85.875	85.875	85.875	85.875	85.875	$P_{D,59}$ (MW)	332.063	332.063	332.063	332.063	332.063
$P_{D,43}$ (MW)	85	85	85	85	85	AGC_1 (MW)	0	0	0	0	0

Table B.1 Optimised control variable results obtained using QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
AGC_{2} (MW)	0	0	0	0	0	AGC_{19} (MW)	0	0	0	0	0
AGC_{3} (MW)	0	0	0	0	0	AGC_{20} (MW)	0	0	0	0	0
AGC_{4} (MW)	0	0	0	0	0	AGC_{21} (MW)	0	0	0	0	0
AGC_{2} (MW)	0	0	0	0	0	AGC_{22} (MW)	0	0	0	0	0
AGC_{6} (MW)	0	0	0	0	0	AGC_{23} (MW)	0	0	0	0	0
AGC_{7} (MW)	0	0	0	0	0	AGC_{24} (MW)	0	0	0	0	0
AGC_{8} (MW)	0	0	0	0	0	AGC_{25} (MW)	0	0	0	0	0
AGC_{9} (MW)	0	0	0	0	0	AGC_{26} (MW)	0	0	0	50	46.433
AGC_{10} (MW)	0	0	0	8.495	32.028	AGC_{27} (MW)	0	0	0	0	0
AGC_{11} (MW)	0	0	0	0	0	AGC_{28} (MW)	0	0	0	0	0
AGC_{12} (MW)	0	0	0	406	406	AGC_{29} (MW)	0	0	0	0	0
AGC_{13} (MW)	0	0	0	0	1.1383	AGC_{30} (MW)	0	0	0	260	260
AGC_{14} (MW)	0	0	0	0	0	AGC_{31} (MW)	0	0	0	26.690	115
AGC_{15} (MW)	0	0	0	0	0	AGC_{32} (MW)	0	0	0	0	0
AGC_{16} (MW)	0	0	0	0	0	AGC_{33} (MW)	0	0	0	0	0
AGC_{17} (MW)	0	0	0	159	159	AGC_{34} (MW)	0	0	0	0	0
AGC_{18} (MW)	0	0	0	0	0	AGC_{35} (MW)	0	0	0	0	0

Table B.1 Optimised control variable results obtained using QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
AGC_{36} (MW)	0	0	0	0	0	SR_{11} (MW)	0	0	0	0	0
AGC_{37} (MW)	0	0	0	0	0	SR_{12} (MW)	0	0	0	406	406
AGC_{38} (MW)	0	0	0	0	0	SR_{13} (MW)	0	0	0	44.585	68
AGC_{39} (MW)	0	0	0	0	0	SR_{14} (MW)	0	0	0	0	0
AGC_{40} (MW)	0	0	0	0	0	SR_{15} (MW)	0	0	0	0	0
AGC_{41} (MW)	0	0	0	0	0	SR_{16} (MW)	0	0	0	0	0
AGC_{42} (MW)	0	0	0	0	0	SR_{17} (MW)	0	0	0	84.6	159
SR_{1} (MW)	0	0	0	0	0	SR_{18} (MW)	0	0	0	0	0
SR_{2} (MW)	0	0	0	0	0	SR_{19} (MW)	0	0	0	0	0
SR_{3} (MW)	0	0	0	0	0	SR_{20} (MW)	0	0	0	0	0
SR_{4} (MW)	0	0	0	0	0	SR_{21} (MW)	0	0	0	0	0
SR_{5} (MW)	0	0	0	0	0	SR_{22} (MW)	0	0	0	0	0
SR_{6} (MW)	0	0	0	0	0	SR_{23} (MW)	0	0	0	0	0
SR_{7} (MW)	0	0	0	0	0	SR_{24} (MW)	0	0	0	0	0
SR_{8} (MW)	0	0	0	0	0	SR_{25} (MW)	0	0	0	0	0
SR_{9} (MW)	0	0	0	0	0	SR_{26} (MW)	0	0	0	0	3.567
SR_{10} (MW)	0	0	0	0	0	SR_{27} (MW)	0	0	0	0	0

Table B.1 Optimised control variable results obtained using QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
SR_{28} (MW)	0	0	0	0	0	SR_{38} (MW)	0	0	0	0	0
SR_{29} (MW)	0	0	0	0	0	SR_{39} (MW)	0	0	0	0	0
SR_{30} (MW)	0	0	0	260	260	SR_{40} (MW)	0	0	0	0	8.033
SR_{31} (MW)	0	0	0	115	115	SR_{41} (MW)	0	0	0	0	0
SR_{32} (MW)	0	0	0	0	0	SR_{42} (MW)	0	0	0	0	0
SR_{33} (MW)	0	0	0	0	0	$P_{RE,1}$ (MW)	0	0	400	0	400
SR_{34} (MW)	0	0	0	0	0	$P_{RE,2}$ (MW)	0	0	750	0	750
SR_{35} (MW)	0	0	0	0	0	$P_{RE,3}$ (MW)	0	0	300	0	300
SR_{36} (MW)	0	0	0	0	0	$P_{RE,4}$ (MW)	0	0	650	0	650
SR_{37} (MW)	0	0	0	0	0	$P_{RE,5}$ (MW)	0	0	420	0	420

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
V_1 (p.u.)	0.95	0.990	1.009	0.996	0.955	V_{18} (p.u.)	0.965	0.95	0.956	0.975	1.012
V_2 (p.u.)	0.960	1.043	0.969	0.95	1.003	V_{19} (p.u.)	0.95	0.968	1.027	1.05	1.022
V_3 (p.u.)	0.95	0.984	1.007	0.978	0.994	V_{20} (p.u.)	0.95	1.035	1.05	1.05	1.003
V_4 (p.u.)	1.05	0.955	0.970	0.95	0.988	V_{21} (p.u.)	1.013	0.996	0.969	0.968	0.994
V_5 (p.u.)	0.95	1.032	0.971	0.970	0.961	V_{22} (p.u.)	0.95	1.024	0.956	1.037	0.973
V_6 (p.u.)	1.006	0.986	1.046	1.003	1.004	V_{23} (p.u.)	1.028	0.95	0.973	1.025	0.990
V_7 (p.u.)	1.046	0.976	0.95	1.012	1.004	V_{24} (p.u.)	1.045	0.969	1.028	0.991	0.994
V_8 (p.u.)	0.971	0.95	0.95	0.984	1.004	V_{25} (p.u.)	1.035	0.957	1.001	1.033	0.994
V_9 (p.u.)	0.95	1.042	0.95	0.965	0.993	V_{26} (p.u.)	1.041	0.956	1.003	1.05	0.994
V_{10} (p.u.)	0.95	0.961	0.957	0.95	1.019	V_{27} (p.u.)	1.05	0.972	1.001	0.968	0.950
V_{11} (p.u.)	1.05	0.954	1.040	1.016	1.004	V_{28} (p.u.)	0.95	1.026	1.044	1.041	1.004
V_{12} (p.u.)	0.959	0.993	0.978	0.95	0.995	V_{29} (p.u.)	0.955	0.963	0.999	1.05	0.995
V_{13} (p.u.)	0.95	0.958	1.001	1.016	1.002	V_{30} (p.u.)	1.016	0.986	1.012	1.022	1.005
V_{14} (p.u.)	1.05	0.950	0.996	1.05	1.004	V_{31} (p.u.)	1.05	1.027	1.011	1.008	0.995
V_{15} (p.u.)	0.95	0.985	1.011	1.030	0.995	V_{32} (p.u.)	0.957	0.95	1.05	0.978	0.993
V_{16} (p.u.)	0.961	0.95	0.960	0.95	0.995	V_{33} (p.u.)	0.95	0.982	0.988	1.026	0.994
V_{17} (p.u.)	1.017	1.019	0.967	0.95	0.995	V_{34} (p.u.)	1.007	1.004	1.048	1.005	1.006

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
V_{35} (p.u.)	0.95	0.956	1.002	1.028	1.038	T_{9} (p.u.)	0.945	0.941	1.036	0.914	1.014
V_{36} (p.u.)	0.936	1.1	1.041	1.081	0.990	T_{10} (p.u.)	0.972	1.003	0.965	0.919	0.994
V_{37} (p.u.)	0.921	0.907	0.958	1.016	1.053	T_{11} (p.u.)	0.939	1.044	0.915	0.987	1.031
V_{38} (p.u.)	0.925	1.021	0.936	0.996	1.010	T_{12} (p.u.)	1.024	1.1	1.085	1.064	0.985
V_{39} (p.u.)	0.958	0.966	1.020	1.026	0.998	T_{13} (p.u.)	1.000	1.028	1.039	0.930	0.989
V_{40} (p.u.)	0.943	1.035	0.960	1.041	1.052	T_{14} (p.u.)	1.036	1.065	0.974	1.073	0.966
V_{41} (p.u.)	1.020	1.1	1.066	1.1	1.057	T_{15} (p.u.)	0.9	0.946	1.1	1.042	0.948
V_{42} (p.u.)	1.016	1.084	1.013	1.060	0.962	T_{16} (p.u.)	0.922	0.931	1.067	0.971	0.947
T_{1} (p.u.)	1.055	1.008	0.927	1.044	0.943	T_{17} (p.u.)	1.028	1.060	0.989	0.9	1.043
T_{2} (p.u.)	0.948	0.931	1.077	0.908	0.991	T_{18} (p.u.)	1.1	1.042	0.936	1.012	1.084
T_{3} (p.u.)	1.001	0.927	1.035	0.935	0.936	T_{19} (p.u.)	1.003	1.080	1.022	0.979	0.987
T_{4} (p.u.)	1.053	1.057	1.049	1.036	0.987	T_{20} (p.u.)	0.999	1.003	0.924	1.1	0.987
T_{5} (p.u.)	1.059	0.993	1.064	0.921	0.989	T_{21} (p.u.)	1.062	0.956	1.053	0.994	0.957
T_{6} (p.u.)	1.062	1.001	1.014	0.908	0.991	T_{22} (p.u.)	1.1	1.028	1.034	0.9	1.037
T_{7} (p.u.)	0.945	1.024	1.044	1.1	0.987	T_{23} (p.u.)	0.995	0.905	0.923	1.007	0.986
T_{8} (p.u.)	1.022	1.051	0.947	0.946	0.994	T_{24} (p.u.)	1.088	1.013	1.011	0.983	0.995

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
T_{25} (p.u.)	0.955	1.020	1.008	0.923	0.988	T_{41} (p.u.)	0.903	0.988	1.026	0.9	0.949
T_{26} (p.u.)	1.083	0.900	0.930	1.053	0.968	T_{42} (p.u.)	0.9	0.9	1.1	1.040	1.053
T_{27} (p.u.)	1.073	1.054	1.076	0.983	1.035	T_{43} (p.u.)	1.1	1.062	1.1	1.031	0.985
T_{28} (p.u.)	1.021	0.943	1.085	0.985	0.990	T_{44} (p.u.)	0.9	1.093	1.041	0.907	1.024
T_{29} (p.u.)	1.025	0.923	1.007	0.983	0.976	T_{45} (p.u.)	0.937	0.908	0.902	0.962	1.009
T_{30} (p.u.)	0.902	1.064	1.037	1.017	0.990	$X_{C,1}$ (p.u.)	-4.503	-5	-2.419	-3.869	-4.028
T_{31} (p.u.)	1.073	0.9	0.987	1.010	1.042	$X_{C,2}$ (p.u.)	-4.133	-2.514	-3.666	-3.566	-3.354
T_{32} (p.u.)	1.006	1.018	1.033	0.9	0.922	$X_{C,3}$ (p.u.)	-5	-4.785	-2.856	-2	-2.304
T_{33} (p.u.)	0.931	1.057	0.989	1.0	0.928	$X_{C,4}$ (p.u.)	-5	-2.099	-2.608	-3.739	-2.999
T_{34} (p.u.)	1.022	1.100	1.070	1.1	0.988	$X_{C,5}$ (p.u.)	-4.663	-2.593	-3.713	-2.716	-4.019
T_{35} (p.u.)	1.072	1.049	1.055	0.939	1.009	$X_{C,6}$ (p.u.)	-5	-2.075	-3.435	-4.196	-4.025
T_{36} (p.u.)	1.1	0.937	1.059	1.1	1.008	$X_{C,7}$ (p.u.)	-4.110	-4.915	-4.622	-2.452	-3.999
T_{37} (p.u.)	1.025	1.036	0.977	0.974	1.010	$X_{C,8}$ (p.u.)	-3.851	-3.049	-3.225	-4.507	-3.004
T_{38} (p.u.)	0.977	1.018	0.948	0.973	1.010	$X_{C,9}$ (p.u.)	-3.795	-2.166	-4.809	-3.749	-3.873
T_{39} (p.u.)	0.978	1.1	0.976	0.990	0.990	$X_{C,10}$ (p.u.)	-5	-3.017	-2.830	-3.792	-3.992
T_{40} (p.u.)	0.991	1.058	1.028	1.005	0.999	$X_{C,11}$ (p.u.)	-4.835	-2	-2.257	-3.047	-3.094

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
$X_{C,12}$ (p.u.)	-2.403	-4.3942	-3.994	-3.153	-4.001	$P_{G,14}$ (MW)	460	460	460	460	460
$X_{C,13}$ (p.u.)	-3.466	-2.4851	-5	-4.714	-2.002	$P_{G,15}$ (MW)	100	100	100	100	100
$X_{C,14}$ (p.u.)	-4.379	-4.3394	-2.3810	-4.594	-4.003	$P_{G,16}$ (MW)	381	381	381	381	381
$P_{G,1}$ (MW)	107.855	100.7782	104.2273	102.736	100.013	$P_{G,17}$ (MW)	796	796	796	552.4	478
$P_{G,2}$ (MW)	510	510	510	510	510	$P_{G,18}$ (MW)	150	150	150	150	150
$P_{G,3}$ (MW)	500	500	500	500	500	$P_{G,19}$ (MW)	200	200	200	200	200
$P_{G,2}$ (MW)	410	410	410	410	410	$P_{G,20}$ (MW)	203	203	203	203	203
$P_{G,5}$ (MW)	150	150	150	150	150	$P_{G,21}$ (MW)	472	472	472	472	472
$P_{G,6}$ (MW)	150	150	150	150	150	$P_{G,22}$ (MW)	316	316	316	316	316
$P_{G,7}$ (MW)	250	250	250	250	250	$P_{G,23}$ (MW)	500	500	500	500	500
$P_{G,8}$ (MW)	225	225	225	225	225	$P_{G,24}$ (MW)	500	500	500	500	500
$P_{G,9}$ (MW)	400	400	400	400	400	$P_{G,25}$ (MW)	250	250	250	250	250
$P_{G,10}$ (MW)	250	250	250	241.505	217.972	$P_{G,26}$ (MW)	250	250	250	200	200
$P_{G,11}$ (MW)	450	450	450	450	450	$P_{G,27}$ (MW)	250	250	250	250	250
$P_{G,12}$ (MW)	443.318	429.065	427.905	418.311	390.092	$P_{G,28}$ (MW)	320	320	320	320	320
$P_{G,13}$ (MW)	340	340	340	295.415	270.862	$P_{G,29}$ (MW)	1300	1300	1300	1300	1300

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
$P_{G,30}$ (MW)	692.786	650.029	646.550	617.765	533.109	$P_{D,4}$ (MW)	1200.750	1200.750	1200.750	1200.750	1200.750
$P_{G,31}$ (MW)	575	575	575	433.31	345	$P_{D,5}$ (MW)	0	0	623.124	0	0
$P_{G,32}$ (MW)	200	200	200	200	200	$P_{D,6}$ (MW)	662.835	605.826	1570.313	74.437	1570.313
$P_{G,33}$ (MW)	300	300	300	300	300	$P_{D,7}$ (MW)	673.875	673.875	673.875	673.875	673.875
$P_{G,34}$ (MW)	200	200	200	200	200	$P_{D,8}$ (MW)	912.938	912.938	912.938	912.938	912.938
$P_{G,35}$ (MW)	0	0	0	0	0	$P_{D,9}$ (MW)	639	639	639	639	639
$P_{G,36}$ (MW)	550	550	550	550	550	$P_{D,10}$ (MW)	452.813	452.813	452.813	452.813	452.813
$P_{G,37}$ (MW)	350	350	350	350	350	$P_{D,11}$ (MW)	54.938	54.938	54.938	54.938	54.938
$P_{G,38}$ (MW)	403	403	403	403	403	$P_{D,12}$ (MW)	93	93	93	93	93
$P_{G,39}$ (MW)	445	445	445	445	445	$P_{D,13}$ (MW)	228.938	228.938	228.938	228.938	228.938
$P_{G,40}$ (MW)	400	400	400	400	391.967	$P_{D,14}$ (MW)	228.563	228.563	228.563	228.563	228.563
$P_{G,41}$ (MW)	700	700	700	700	700	$P_{D,15}$ (MW)	90.375	90.375	90.375	90.375	90.375
$P_{G,42}$ (MW)	350	350	350	350	350	$P_{D,16}$ (MW)	284.438	284.438	284.438	284.438	284.438
$P_{D,1}$ (MW)	96.581	96.581	96.581	96.581	96.581	$P_{D,17}$ (MW)	433.875	433.875	433.875	433.875	433.875
$P_{D,2}$ (MW)	1037.438	1037.438	1037.438	1037.438	1037.438	$P_{D,18}$ (MW)	333.375	333.375	333.375	333.375	333.375
$P_{D,3}$ (MW)	558.375	558.375	558.375	558.375	558.375	$P_{D,19}$ (MW)	136.5	136.5	136.5	136.5	136.5

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
$P_{D,20}$ (MW)	55.875	55.875	55.875	55.875	55.875	$P_{D,36}$ (MW)	258	258	258	258	258
$P_{D,21}$ (MW)	56.625	56.625	56.625	56.625	56.625	$P_{D,37}$ (MW)	164.813	164.813	164.813	164.813	164.813
$P_{D,22}$ (MW)	0	0	467.625	0	467.625	$P_{D,38}$ (MW)	0	0	460.125	0	224.795
$P_{D,23}$ (MW)	150.938	150.938	150.938	150.938	150.938	$P_{D,39}$ (MW)	0	0	0	0	0
$P_{D,24}$ (MW)	465	465	465	465	465	$P_{D,40}$ (MW)	95.25	95.25	95.25	95.25	95.25
$P_{D,25}$ (MW)	257.25	257.25	257.25	257.25	257.25	$P_{D,41}$ (MW)	94.688	94.688	94.688	94.688	94.688
$P_{D,26}$ (MW)	79.125	79.125	79.125	79.125	79.125	$P_{D,42}$ (MW)	85.875	85.875	85.875	85.875	85.875
$P_{D,27}$ (MW)	6.188	6.188	6.187	6.187	6.188	$P_{D,43}$ (MW)	85	85	85	85	85
$P_{D,28}$ (MW)	80.25	80.25	80.25	80.25	80.25	$P_{D,44}$ (MW)	367.5	367.5	367.5	367.5	367.5
$P_{D,29}$ (MW)	371.25	371.25	371.25	371.25	371.25	$P_{D,45}$ (MW)	391.5	391.5	391.5	391.5	391.5
$P_{D,30}$ (MW)	301.875	301.875	301.875	301.875	301.875	$P_{D,46}$ (MW)	161.25	161.25	161.25	161.25	161.25
$P_{D,31}$ (MW)	639.563	639.563	639.563	639.563	639.563	$P_{D,47}$ (MW)	345.938	345.938	345.938	345.938	345.938
$P_{D,32}$ (MW)	130.688	130.688	130.688	130.688	130.688	$P_{D,48}$ (MW)	867	867	867	867	867
$P_{D,33}$ (MW)	525.375	525.375	525.375	525.375	525.375	$P_{D,49}$ (MW)	316.125	316.125	316.125	316.125	316.125
$P_{D,34}$ (MW)	446.625	446.625	446.625	446.625	446.625	$P_{D,50}$ (MW)	566.438	566.438	566.438	566.438	566.438
$P_{D,35}$ (MW)	338.063	338.063	338.063	338.063	338.063	$P_{D,51}$ (MW)	114.188	114.188	114.188	114.188	114.188

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
$P_{D,52}$ (MW)	207	207	207	207	207	AGC_9 (MW)	0	0	0	0	0
$P_{D,53}$ (MW)	274.125	274.125	274.125	274.125	274.125	AGC_{10} (MW)	0	0	0	8.495	32.028
$P_{D,54}$ (MW)	527.625	527.625	527.625	527.625	527.625	AGC_{11} (MW)	0	0	0	0	0
$P_{D,55}$ (MW)	237.375	237.375	237.375	237.375	237.375	AGC_{12} (MW)	0	0	0	406	406
$P_{D,56}$ (MW)	131.25	131.25	131.25	131.25	131.25	AGC_{13} (MW)	0	0	0	0	1.1383
$P_{D,57}$ (MW)	179.813	179.813	179.813	179.813	179.813	AGC_{14} (MW)	0	0	0	0	0
$P_{D,58}$ (MW)	966	966	966	966	966	AGC_{15} (MW)	0	0	0	0	0
$P_{D,59}$ (MW)	332.063	332.063	332.063	332.063	332.063	AGC_{16} (MW)	0	0	0	0	0
AGC_1 (MW)	0	0	0	0	0	AGC_{17} (MW)	0	0	0	159	159
AGC_2 (MW)	0	0	0	0	0	AGC_{18} (MW)	0	0	0	0	0
AGC_3 (MW)	0	0	0	0	0	AGC_{19} (MW)	0	0	0	0	0
AGC_4 (MW)	0	0	0	0	0	AGC_{20} (MW)	0	0	0	0	0
AGC_2 (MW)	0	0	0	0	0	AGC_{21} (MW)	0	0	0	0	0
AGC_6 (MW)	0	0	0	0	0	AGC_{22} (MW)	0	0	0	0	0
AGC_7 (MW)	0	0	0	0	0	AGC_{23} (MW)	0	0	0	0	0
AGC_8 (MW)	0	0	0	0	0	AGC_{24} (MW)	0	0	0	0	0

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
AGC_{25} (MW)	0	0	0	0	0	AGC_{41} (MW)	0	0	0	0	0
AGC_{26} (MW)	0	0	0	50	46.433	AGC_{42} (MW)	0	0	0	0	0
AGC_{27} (MW)	0	0	0	0	0	SR_{1} (MW)	0	0	0	0	0
AGC_{28} (MW)	0	0	0	0	0	SR_{2} (MW)	0	0	0	0	0
AGC_{29} (MW)	0	0	0	0	0	SR_{3} (MW)	0	0	0	0	0
AGC_{30} (MW)	0	0	0	260	260	SR_{4} (MW)	0	0	0	0	0
AGC_{31} (MW)	0	0	0	26.690	115	SR_{5} (MW)	0	0	0	0	0
AGC_{32} (MW)	0	0	0	0	0	SR_{6} (MW)	0	0	0	0	0
AGC_{33} (MW)	0	0	0	0	0	SR_{7} (MW)	0	0	0	0	0
AGC_{34} (MW)	0	0	0	0	0	SR_{8} (MW)	0	0	0	0	0
AGC_{35} (MW)	0	0	0	0	0	SR_{9} (MW)	0	0	0	0	0
AGC_{36} (MW)	0	0	0	0	0	SR_{10} (MW)	0	0	0	0	0
AGC_{37} (MW)	0	0	0	0	0	SR_{11} (MW)	0	0	0	0	0
AGC_{38} (MW)	0	0	0	0	0	SR_{12} (MW)	0	0	0	406	406
AGC_{39} (MW)	0	0	0	0	0	SR_{13} (MW)	0	0	0	44.585	68
AGC_{40} (MW)	0	0	0	0	0	SR_{14} (MW)	0	0	0	0	0

Table B.2 Optimised control variable results obtained using the hybrid PSO-QP method for the multi-dimensional market framework (Continued)

Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4	Variable	Case 6.0	Case 6.1	Case 6.2	Case 6.3	Case 6.4
SR_{15} (MW)	0	0	0	0	0	SR_{31} (MW)	0	0	0	115	115
SR_{16} (MW)	0	0	0	0	0	SR_{32} (MW)	0	0	0	0	0
SR_{17} (MW)	0	0	0	84.6	159	SR_{33} (MW)	0	0	0	0	0
SR_{18} (MW)	0	0	0	0	0	SR_{34} (MW)	0	0	0	0	0
SR_{19} (MW)	0	0	0	0	0	SR_{35} (MW)	0	0	0	0	0
SR_{20} (MW)	0	0	0	0	0	SR_{36} (MW)	0	0	0	0	0
SR_{21} (MW)	0	0	0	0	0	SR_{37} (MW)	0	0	0	0	0
SR_{22} (MW)	0	0	0	0	0	SR_{38} (MW)	0	0	0	0	0
SR_{23} (MW)	0	0	0	0	0	SR_{39} (MW)	0	0	0	0	0
SR_{24} (MW)	0	0	0	0	0	SR_{40} (MW)	0	0	0	0	8
SR_{25} (MW)	0	0	0	0	0	SR_{41} (MW)	0	0	0	0	0
SR_{26} (MW)	0	0	0	0	3.567	SR_{42} (MW)	0	0	0	0	0
SR_{27} (MW)	0	0	0	0	0	$P_{RE,1}$ (MW)	0	0	400	0	400
SR_{28} (MW)	0	0	0	0	0	$P_{RE,2}$ (MW)	0	0	750	0	750
SR_{29} (MW	0	0	0	0	0	$P_{RE,3}$ (MW)	0	0	300	0	300
SR_{30} (MW	0	0	0	260	260	$P_{RE,4}$ (MW)	0	0	650	0	650
						$P_{RE,5}$ (MW)	0	0	420	0	420

APPENDIX C
PUBLICATION

Muangkhiew, P., & Chayakulkheeree, K. (2024). Carbon-Accounted Optimal Power Dispatch and Spot Pricing. 2024 IEEE/IAS Industrial and Commercial Power System Asia (I&CPS Asia). Pattaya, Thailand, pp. 671-676, https://doi.org/10.1109/ICPSAsia61913.2024.10761212.

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