APPENDIX

A

DATA SHEETS FOR IEEE 14 BUS SYSTEM

The IEEE 14 bus system is shown in figure 3.1. The system data is taken from [9]. The data given in the following tables is on $100MVA$ base. The minimum and maximum limits of voltage magnitude and phase angle are considered to be $0.95p.u.$ to $1.05p.u.$ and -45° to +45° respectively.

Table A.1: Line data – IEEE 14 bus system

Line number	From bus	To bus	Line impedance (*p.u.*)		Half line charging susceptance (*p.u.*)	MVA rating
			Resistance	Reactance		
1	1	2	0.01938	0.05917	0.02640	120
2	1	5	0.05403	0.22304	0.02190	65
3	2	3	0.04699	0.19797	0.01870	36
4	2	4	0.05811	0.17632	0.02460	65
5	2	5	0.05695	0.17388	0.01700	50
6	3	4	0.06701	0.17103	0.01730	65
7	4	5	0.01335	0.04211	0.00640	45
8	4	7	0	0.20912	0	55
9	4	9	0	0.55618	0	32
10	5	6	0	0.25202	0	45
11	6	11	0.09498	0.1989	0	18
12	6	12	0.12291	0.25581	0	32
13	6	13	0.06615	0.13027	0	32
14	7	8	0	0.17615	0	32
15	7	9	0	0.11001	0	32
16	9	10	0.03181	0.0845	0	32
17	9	14	0.12711	0.27038	0	32
18	10	11	0.08205	0.19207	0	12
19	12	13	0.22092	0.19988	0	12
20	13	14	0.17093	0.34802	0	12

Table A.2: Capacity and cost coefficients – IEEE 14 bus system

Generator number	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	a_i $(\$/(MWhr)^2)$	b_i $(\$/MW\text{hr})$	c_i (\$/hr)
G_1	10	160	0.005	2.450	105.000
G_2	20	80	0.005	3.510	44.100
G_3	20	50	0.005	3.890	40.600

Table A.3: Transformer tap setting data – IEEE 14 bus system

From bus	To bus	Tap setting value (*p.u.*)
4	7	0.978
4	9	0.969
5	6	0.932

Table A.4: Bus data – IEEE 14 bus system

Bus number	Bus voltage		Generation		Load		Reactive power limits	
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$ ($MVAR$)	$Q_{\max}$ ($MVAR.$)
1	1.060	0	114.17	-16.9	0	0	0	10
2	1.045	0	40.00	0	21.7	12.7	-42.0	50.0
3	1.010	0	0	0	94.2	19.1	23.4	40.0
4	1	0	0	0	47.8	-3.9	–	–
5	1	0	0	0	7.6	1.6	–	–
6	1	0	0	0	11.2	7.5	–	–
7	1	0	0	0	0	0	–	–
8	1	0	0	0	0	0	–	–
9	1	0	0	0	29.5	16.6	–	–
10	1	0	0	0	9.0	5.8	–	–
11	1	0	0	0	3.5	1.8	–	–
12	1	0	0	0	6.1	1.6	–	–
13	1	0	0	0	13.8	5.8	–	–
14	1	0	0	0	14.9	5.0	–	–

Table A.5: Shunt capacitor data – IEEE 14 bus system

Bus number	Susceptance ($p.u.$)
9	0.19

APPENDIX

B

DATA SHEETS FOR IEEE 30 BUS SYSTEM

The IEEE 30 bus system is shown in figure 3.3. The system data is taken from [47]. The data given in the following tables is on $100MVA$ base. The minimum and maximum limits of voltage magnitude and phase angle are considered to be $0.95p.u.$ to $1.05p.u.$ and -45° to +45° respectively.

Table B.1: Line data – IEEE 30 bus system

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^3$\$/hr)
			Resistance	Reactance			
1	1	2	0.02	0.06	0.03	130	216.6125
2	1	3	0.05	0.20	0.02	130	307.2875
3	2	4	0.06	0.18	0.02	65	509.9500
4	2	5	0.05	0.02	0	130	721.5250
5	2	6	0.06	0.18	0.02	65	168.1750
6	3	4	0.01	0.04	0	130	700.000
7	4	6	0.01	0.04	0	90	474.3000
8	4	12	0	0.23	0	65	554.1250
9	5	7	0.05	0.12	0.01	70	62.2000
10	6	7	0.03	0.08	0	130	130.2000
11	6	8	0.01	0.09	0	32	104.6250
12	6	9	0	0.21	0	65	306.9000
13	6	10	0	0.56	0	32	20.9250
14	6	28	0.07	0.06	0.01	32	210.800
15	8	28	0.06	0.20	0.02	32	54.250
16	9	11	0	0.21	0	65	83.7000
17	9	10	0	0.11	0	65	927.6750
18	10	20	0.09	0.21	0	32	117.8000
19	10	17	0.03	0.09	0	32	167.4000
20	10	21	0.03	0.08	0	32	160.4250
21	10	22	0.07	0.15	0	32	195.3000

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Table B.1 – continued from previous page

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^3$\$/hr)
			Resistance	Reactance			
22	12	13	0	0.14	0	65	15.1125
23	12	14	0.12	0.26	0	32	30.2250
24	12	15	0.07	0.13	0	32	97.6250
25	12	16	0.01	0.12	0	32	179.0250
26	14	15	0.22	0.12	0	16	124.7750
27	15	18	0.11	0.22	0	16	80.6000
28	15	23	0.10	0.21	0	16	100.7500
29	16	17	0.08	0.19	0	16	146.4750
30	18	19	0.06	0.13	0	16	235.6000
31	19	20	0.03	0.07	0	32	186.000
32	21	22	0.01	0.22	0	32	166.2375
33	22	24	0.11	0.18	0	16	40.3000
34	23	24	0.13	0.27	0	16	65.1000
35	24	25	0.19	0.33	0	16	210.8000
36	25	26	0.25	0.38	0	16	204.600
37	25	27	0.11	0.21	0	16	83.7000
38	27	29	0.22	0.4	0	16	160.4250
39	27	30	0.32	0.60	0	16	90.6750
40	28	27	0	0.4	0	65	223.2000
41	29	30	0.24	0.45	0	16	216.6125

Table B.2: Bus data – IEEE 30 bus system

Bus number	Bus voltage		Generation		Load		Reactive power limits	
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$ ($MVAR$)	$Q_{\max}$ ($MVAR$)
1	1	0	0	0	24.963	-4.638	-20	150
2	1	0	21.7	12.7	60.97	27.677	-20	60
3	1	0	2.4	1.2	0	0	0	0
4	1	0	7.6	1.6	0	0	0	0
5	1	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0
7	1	0	22.8	10.9	0	0	0	0
8	1	0	30	30	0	0	0	0
9	1	0	0	0	0	0	0	0
10	1	0	5.919	2	0	0	0	0
11	1	0	0	0	0	0	0	0
12	1	0	11.2	7.5	0	0	0	0
13	1	0	0	0	37	13.949	-15	44.7
14	1	0	6.2	1.6	0	0	0	0
15	1	0	8.2	2.5	0	0	0	0
16	1	0	3.5	1.8	0	0	0	0
17	1	0	9	5.8	0	0	0	0
18	1	0	3.2	0.9	0	0	0	0
19	1	0	9.5	3.4	0	0	0	0

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Table B.2 – continued from previous page

Bus number	Bus voltage		Generation		Load		Reactive power limits	
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$ ($MVAR$)	$Q_{\max}$ ($MVAR$)
20	1	0	2.2	0.7	0	0	0	0
21	1	0	19.669	11.20	0	0	0	0
22	1	0	0	0	31.59	40.34	-15	62.5
23	1	0	3.2	1.6	22.2	8.13	-10	40
24	1	0	15	6.70	0	0	0	0
25	1	0	1.00	0.00	0	0	0	0
26	1	0	3.50	2.30	0	0	0	0
27	1	0	0	0	28.91	10.97	-15	48.7
28	1	0	0	0	0	0	0	0
29	1	0	3.659	0.90	0	0	0	0
30	1	0	12.00	1.90	0	0	0	0

Table B.3: Capacity and cost coefficients – IEEE 30 bus system

Generator number	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	a_i $(\$/(MW\text{hr})^2)$	b_i $(\$/MW\text{hr})$	c_i (\$/hr)
G_1	0	80	0.00375	2.0000	0.0000
G_2	0	80	0.01750	1.7500	0.0000
G_3	0	50	0.06250	1.0000	0.0000
G_4	0	55	0.00834	3.2500	0.0000
G_5	0	30	0.02500	3.0000	0.0000
G_6	0	40	0.02500	3.0000	0.0000

Table B.4: Transformer tap setting data – IEEE 30 bus system

From bus	To bus	Tap setting value $(p.u.)$
6	9	1.0155
6	10	0.9629
4	12	1.0129
28	27	0.9581

Table B.5: Shunt capacitor data – IEEE 30 bus system

Bus number	Susceptance $(p.u.)$
10	19
24	4

APPENDIX

C

DATA SHEETS FOR INDIAN UTILITY 62 BUS SYSTEM

Indian utility 62 bus system is shown in figure 6.1. The system data is taken from [154]. The data given in the following tables is on $100MVA$ base. The minimum and maximum limits of voltage magnitude and phase angle are considered to be $0.95p.u.$ to $1.1p.u.$ and -45° to +45° respectively.

Table C.1: Line data – Indian utility 62 bus system

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^5$₹/yr)
			Resistance	Reactance			
1	1	2	0.00305	0.01565	0.01445	150	541
2	1	4	0.00716	0.03678	0.03397	100	522
3	1	6	0.00411	0.02113	0.01951	150	321
4	1	9	0.00229	0.01174	0.01084	150	812
5	1	10	0.01569	0.08061	0.07443	180	489
6	1	14	0.00548	0.02813	0.10392	300	256
7	2	3	0.00289	0.01487	0.01373	180	375
8	2	6	0.00168	0.00861	0.00795	150	584
9	3	4	0.00381	0.01957	0.01807	150	489
10	4	5	0.00716	0.03678	0.03397	180	494
11	4	14	0.00411	0.02113	0.01951	180	201
12	4	15	0.00411	0.02113	0.01951	180	628
13	5	6	0.00575	0.01478	0.00309	180	478
14	5	8	0.00575	0.01478	0.00309	180	630
15	6	7	0.00030	0.00157	0.00578	180	676
16	7	8	0.00049	0.00168	0.08612	90	229
17	11	10	0.00686	0.03522	0.03252	100	512
18	11	16	0.01406	0.07223	0.06670	180	579
19	12	11	0.01905	0.09783	0.09033	150	499
20	12	13	0.01537	0.07897	0.07292	180	146
21	12	20	0.01981	0.10174	0.09395	180	582

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Table C.1 – continued from previous page

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^5$₹/yr)
			Resistance	Reactance			
22	13	14	0.01315	0.06754	0.06237	180	300
23	13	17	0.01563	0.08030	0.07415	150	282
24	14	15	0.00520	0.02669	0.02464	150	454
25	14	16	0.00396	0.02035	0.01879	100	225
26	14	18	0.00135	0.00693	0.02558	180	489
27	14	19	0.00707	0.03631	0.03353	300	919
28	16	17	0.00343	0.01761	0.06504	180	295
29	17	21	0.01850	0.09548	0.08816	180	184
30	20	23	0.02042	0.10487	0.09684	180	266
31	21	22	0.01371	0.07043	0.06504	180	398
32	22	23	0.00396	0.02035	0.07516	150	390
33	23	24	0.00305	0.01565	0.01445	300	693
34	23	25	0.00126	0.00650	0.00600	180	403
35	24	41	0.01554	0.07993	0.07371	180	714
36	24	45	0.01219	0.06261	0.05781	100	231
37	25	26	0.00941	0.04828	0.04459	100	866
38	25	27	0.01173	0.06026	0.05565	180	309
39	25	28	0.01062	0.05554	0.05037	150	631
40	27	29	0.00533	0.02739	0.02529	90	569
41	29	30	0.02058	0.10573	0.09763	90	895
42	30	31	0.00992	0.05095	0.04705	90	563
43	32	31	0.01787	0.09180	0.08477	100	939

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Table C.1 – continued from previous page

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^5$₹/yr)
			Resistance	Reactance			
44	32	34	0.00396	0.02035	0.07516	100	183
45	32	36	0.00305	0.01565	0.01445	180	741
46	32	37	0.02200	0.11301	0.10435	90	318
47	32	46	0.02095	0.10761	0.09937	90	987
48	33	32	0.01676	0.08609	0.07949	90	197
49	34	33	0.01737	0.08922	0.08258	90	126
50	34	35	0.00701	0.02600	0.03324	90	40
51	34	37	0.01990	0.01022	0.09438	100	419
52	35	32	0.00036	0.00184	0.00679	180	899
53	36	46	0.01828	0.09391	0.08672	180	645
54	37	46	0.00104	0.00536	0.01980	180	414
55	38	34	0.01076	0.05525	0.05102	300	516
56	38	37	0.01044	0.05361	0.04950	100	54
57	39	37	0.00229	0.01174	0.01084	180	55
58	39	42	0.00686	0.03522	0.03252	180	374
59	40	30	0.00716	0.03678	0.03397	180	558
60	40	41	0.00609	0.03130	0.02891	100	101
61	41	42	0.00076	0.00391	0.01445	150	417
62	41	45	0.00335	0.01712	0.01590	300	963
63	42	43	0.00914	0.04696	0.04336	100	163
64	42	44	0.01417	0.07278	0.06721	90	432
65	44	59	0.00884	0.04539	0.04191	100	612

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Table C.1 – continued from previous page

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^5$₹/yr)
			Resistance	Reactance			
66	46	44	0.01676	0.08609	0.07949	300	13
67	47	46	0.00792	0.04070	0.03758	90	932
68	47	48	0.01371	0.07043	0.06504	400	96
69	48	50	0.00066	0.00337	0.01242	400	751
70	48	54	0.01254	0.06441	0.05948	400	226
71	49	48	0.00366	0.01878	0.06938	300	206
72	49	50	0.00670	0.03443	0.03180	300	87
73	51	53	0.01190	0.06112	0.05644	180	832
74	51	54	0.00407	0.02090	0.01930	400	557
75	51	55	0.01417	0.07278	0.06721	400	767
76	52	53	0.01132	0.05815	0.05369	300	588
77	52	61	0.01127	0.05791	0.05348	150	560
78	55	58	0.00670	0.03443	0.03180	90	481
79	56	58	0.00259	0.01330	0.01229	90	660
80	57	56	0.00152	0.00783	0.00723	180	913
81	57	58	0.00183	0.00939	0.00867	400	501
82	58	12	0.01211	0.06222	0.05745	400	68
83	58	60	0.00411	0.02113	0.01951	400	292
84	58	61	0.00335	0.01722	0.06359	400	79
85	59	61	0.00922	0.04735	0.04372	180	411
86	60	12	0.01365	0.07012	0.06475	300	431
87	60	61	0.00244	0.01252	0.04625	300	373

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Table C.1 – continued from previous page

Line number	From bus	To bus	Line impedance ($p.u.$)		Half line charging susceptance ($p.u.$)	MVA rating	Annual cost ($\times 10^5$₹/yr)
			Resistance	Reactance			
88	61	62	0.01499	0.07701	0.07111	300	475
89	62	25	0.01383	0.07106	0.06562	150	643

Table C.2: Bus data – Indian utility 62 bus system

Bus number	Bus voltage		Generation		Load		Reactive power limits ($MVAR$)		Shunt capacitor data ($MVAR$)
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$	$Q_{\max}$	Susceptance
1	1.05	0	0	0	192.649	23.554	0	450	0
2	1.05	0	0	0	190.581	0	0	130	0
3	1	0	40	10	0	0	0	5	0
4	1	0	0	0	0	0	0	0	0
5	1.05	0	0	0	255.687	0	0	255	0
6	1	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0
8	1	0	109	78	0	0	0	0	0
9	1.05	0	66	23	78.202	1.218	0	100	0
10	1	0	40	10	0	0	0	0	0
11	1	0	161	93	0	0	0	0	0
12	1	0	155	79	0	0	0	0	0
13	1	0	132	46	0	0	0	0	0

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Table C.2 – continued from previous page

Bus number	Bus voltage		Generation		Load		Reactive power limits ($MVAR$)		Shunt capacitor data ($MVAR$)
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$	$Q_{\max}$	Susceptance
14	1.05	0	0	0	171.083	233.905	0	500	0
15	1	0	155	63	0	0	0	0	0
16	1	0	0	0	0	0	0	0	0
17	1.05	0	0	0	190.612	0	0	0	0
18	1	0	121	46	0	0	0	0	0
19	1	0	130	70	0	0	0	0	0
20	1	0	81	70	0	0	0	0	0
21	1.05	0	0	0	0	0	0	0	0
22	1	0	0	64	50	0	0	0	0
23	1.05	0	0	0	151.842	147.932	0	340	0
24	1	0	58	34	0	0	0	0	0
25	1.05	0	0	0	250.249	86.526	0	395	0
26	1	0	116	52	0	0	0	0	0
27	1	0	85	35	0	0	0	0	0
28	1	0	63	8	0	0	0	0	0
29	1	0	0	0	0	0	0	0	0
30	1	0	77	41	0	0	0	0	0
31	1	0	51	25	0	0	0	0	0
32	1.05	0	0	0	106.624	0	-100	400	0
33	1.05	0	46	25	62.380	0	0	30	0

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Table C.2 – continued from previous page

Bus number	Bus voltage		Generation		Load		Reactive power limits ($MVAR$)		Shunt capacitor data ($MVAR$)
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$	$Q_{\max}$	Susceptance
34	1	0	100	70	134.508	41	0	41	0
35	1	0	107	33	0	0	0	0	0
36	1	0	20	5	0	0	0	0	0
37	1.05	0	0	0	78.533	0	0	87	0
38	1	0	166	22	0	0	0	0	0
39	1	0	30	5	0	0	0	0	0
40	1	0	25	5	0	0	0	0	0
41	1	0	92	91	0	0	0	0	0
42	1	0	35	25	0	0	0	0	0
43	1	0	20	5	0	0	0	0	0
44	1	0	109	17	0	0	0	0	0
45	1	0	20	4	0	0	0	0	0
46	1	0	0	0	0	0	0	0	0
47	1	0	0	0	0	0	0	0	0
48	1	0	0	0	0	0	0	0	0
49	1.05	0	0	0	213.957	0	0	80	0
50	1.05	0	0	0	92.784	0	0	200	0
51	1.05	0	0	0	82.957	41.542	0	245	0
52	1.05	0	0	0	24.608	35	0	35	0
53	1	0	248	78	0	0	0.0	0	0

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Table C.2 – continued from previous page

Bus number	Bus voltage		Generation		Load		Reactive power limits ($MVAR$)		Shunt capacitor data ($MVAR$)
	Magnitude ($p.u.$)	Phase angle (degree)	Real power (MW)	Reactive power ($MVAR$)	Real power (MW)	Reactive power ($MVAR$)	$Q_{\min}$	$Q_{\max}$	Susceptance
54	1.05	0	0	0	72.633	0	0	100	0
55	1	0	94	29	0	0	0	0	0
56	1.05	0	0	0	0	0	0	0	0
57	1.05	0	0	0	219.441	0	0	20	0
58	1.05	0	0	0	339.708	100	100	420	0
59	1	0	0	0	0	0	0	0	0
60	1	0	0	0	0	0	0	0	0
61	1	0	0	0	0	0	0	0	0
62	1	0	93	23	0	0	0	0	0

Table C.3: Capacity and cost coefficients – Indian utility 62 bus system

Generator number	$P_i^{\min}$ (MW)	$P_i^{\max}$ (MW)	a_i (₹/$(MW\text{hr})^2$)	b_i (₹/MWhr)	c_i (₹/hr)
G_1	50	300	0.0070	6.80	95
G_2	50	450	0.0055	4.00	30
G_3	50	450	0.0055	4.00	45
G_4	0	150	0.0025	0.85	10
G_5	50	300	0.0060	4.60	20
G_6	50	450	0.0055	4.00	90
G_7	50	200	0.0065	4.70	42
G_8	50	500	0.0075	5.00	46
G_9	0	600	0.0085	6.00	55
G_{10}	0	100	0.0020	0.50	58
G_{11}	50	150	0.0045	1.60	65
G_{12}	0	100	0.0025	0.85	78
G_{13}	50	300	0.0050	1.80	75
G_{14}	0	150	0.0045	1.60	85
G_{15}	0	500	0.0065	4.70	80
G_{16}	50	150	0.0045	1.40	90
G_{17}	0	100	0.0025	0.85	10
G_{18}	50	300	0.0045	1.60	25
G_{19}	100	600	0.0080	5.50	90

Table C.4: Transformer tap setting data – Indian utility 62 bus system

From bus	To bus	Tap setting value $(p.u.)$
1	14	0.9639
14	15	0.9539
4	14	1.0158
13	14	1.0124
12	13	0.9621
14	19	0.9630
14	18	1.0121
14	16	1.0135
48	50	0.9630
49	50	1.0132
47	18	0.9630