Appendix A: Network Data for the IEEE 118-bus System

This appendix contains the network data for the IEEE 118-bus test network used in the Wheatstone analysis of Chapter 6. The data was downloaded from the IEEE power systems test case archive at www.ee.washington.edu/research/pstca/. The data is given in a format consistent with Matpower, a free set of Matlab files for power system simulation and analysis, available at http://www.pserc.cornell.edu/matpower/.

A1. Bus and Demand Data

Bus and demand data for the 118-bus test network is given in Table A1. The variables and units used in the column headings of Table A1 are:

P_L: Real power demand, in [MW]

Q_L: Reactive power demand, in [MVar]

V: Bus voltage magnitude, in per-unit for a voltage base of 100 kV

θ: Bus voltage angle, in degrees

Vmax: Maximum bus voltage magnitude, in per-unit for a voltage base of 100 kV

Vmin: Maximum bus voltage magnitude, in per-unit for a voltage base of 100 kV

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Bus	P_L	Q_L	V	θ	Vmax	Vmin
1	51	27	0.955	10.983	1.06	0.94
2	20	9	0.97139	11.523	1.06	0.94
3	39	10	0.96769	11.866	1.06	0.94
4	39	12	0.998	15.583	1.06	0.94
5	0	0	1.00198	16.028	1.06	0.94
6	52	22	0.99	13.302	1.06	0.94
7	19	2	0.98933	12.857	1.06	0.94
8	28	0	1.015	21.049	1.06	0.94
9	0	0	1.04292	28.303	1.06	0.94
10	0	0	1.05	35.884	1.06	0.94
11	70	23	0.98509	13.016	1.06	0.94
12	47	10	0.99	12.499	1.06	0.94
13	34	16	0.9683	11.641	1.06	0.94
14	14	1	0.98359	11.783	1.06	0.94
15	90	30	0.97	11.489	1.06	0.94
16	25	10	0.98391	12.198	1.06	0.94
17	11	3	0.99513	14.006	1.06	0.94
18	60	34	0.973	11.793	1.06	0.94
19	45	25	0.963	11.314	1.06	0.94
20	18	3	0.95776	12.192	1.06	0.94
21	14	8	0.95841	13.779	1.06	0.94
22	10	5	0.96954	16.332	1.06	0.94
23	7	3	0.99972	21.249	1.06	0.94
24	13	0	0.992	21.118	1.06	0.94
25	0	0	1.05	28.184	1.06	0.94
26	0	0	1.015	29.965	1.06	0.94
27	71	13	0.968	15.613	1.06	0.94
28	17	7	0.96157	13.889	1.06	0.94
29	24	4	0.96322	12.897	1.06	0.94
30	0	0	0.98553	19.04	1.06	0.94
31	43	27	0.967	13.014	1.06	0.94
32	59	23	0.964	15.054	1.06	0.94
33	23	9	0.97161	10.864	1.06	0.94
34	59	26	0.986	11.505	1.06	0.94
35	33	9	0.9807	11.08	1.06	0.94
36	31	17	0.98	11.085	1.06	0.94
37	0	0	0.99208	11.969	1.06	0.94
38	0	0	0.96204	17.106	1.06	0.94

Table A1: Bus data for the IEEE 118-bus network

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Bus	P_L	Q_L	V	θ	Vmax	Vmin
39	27	11	0.97049	8.598	1.06	0.94
40	66	23	0.97	7.525	1.06	0.94
41	37	10	0.96683	7.079	1.06	0.94
42	96	23	0.985	8.674	1.06	0.94
43	18	7	0.97858	11.459	1.06	0.94
44	16	8	0.98505	13.945	1.06	0.94
45	53	22	0.98667	15.776	1.06	0.94
46	28	10	1.005	18.582	1.06	0.94
47	34	0	1.01705	20.805	1.06	0.94
48	20	11	1.02063	20.025	1.06	0.94
49	87	30	1.025	21.028	1.06	0.94
50	17	4	1.00108	18.989	1.06	0.94
51	17	8	0.96688	16.37	1.06	0.94
52	18	5	0.95682	15.417	1.06	0.94
53	23	11	0.94598	14.442	1.06	0.94
54	113	32	0.955	15.353	1.06	0.94
55	63	22	0.952	15.063	1.06	0.94
56	84	18	0.954	15.25	1.06	0.94
57	12	3	0.97058	16.455	1.06	0.94
58	12	3	0.95904	15.598	1.06	0.94
59	277	113	0.985	19.452	1.06	0.94
60	78	3	0.99316	23.234	1.06	0.94
61	0	0	0.995	24.125	1.06	0.94
62	77	14	0.998	23.509	1.06	0.94
63	0	0	0.96874	22.831	1.06	0.94
64	0	0	0.98374	24.597	1.06	0.94
65	0	0	1.005	27.722	1.06	0.94
66	39	18	1.05	27.563	1.06	0.94
67	28	7	1.01968	24.923	1.06	0.94
68	0	0	1.00325	27.601	1.06	0.94
69	0	0	1.035	30	1.06	0.94
70	66	20	0.984	22.62	1.06	0.94
71	0	0	0.98684	22.209	1.06	0.94
72	12	0	0.98	21.112	1.06	0.94
73	6	0	0.991	21.998	1.06	0.94
74	68	27	0.958	21.671	1.06	0.94
75	47	11	0.96733	22.933	1.06	0.94
76	68	36	0.943	21.803	1.06	0.94
77	61	28	1.006	26.757	1.06	0.94
78	71	26	1.00342	26.453	1.06	0.94

Table A1 (continued)

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Bus	P_L	Q_L	V	θ	Vmax	Vmin
79	39	32	1.00922	26.752	1.06	0.94
80	130	26	1.04	28.998	1.06	0.94
81	0	0	0.99681	28.149	1.06	0.94
82	54	27	0.98881	27.276	1.06	0.94
83	20	10	0.98457	28.465	1.06	0.94
84	11	7	0.97977	30.997	1.06	0.94
85	24	15	0.985	32.55	1.06	0.94
86	21	10	0.98669	31.181	1.06	0.94
87	0	0	1.015	31.44	1.06	0.94
88	48	10	0.98746	35.68	1.06	0.94
89	0	0	1.005	39.734	1.06	0.94
90	440	42	0.985	33.331	1.06	0.94
91	10	0	0.98	33.352	1.06	0.94
92	65	10	0.993	33.841	1.06	0.94
93	12	7	0.98737	30.837	1.06	0.94
94	30	16	0.99081	28.687	1.06	0.94
95	42	31	0.98111	27.716	1.06	0.94
96	38	15	0.9928	27.549	1.06	0.94
97	15	9	1.01143	27.923	1.06	0.94
98	34	8	1.02351	27.446	1.06	0.94
99	42	0	1.01	27.085	1.06	0.94
100	37	18	1.017	28.081	1.06	0.94
101	22	15	0.99276	29.649	1.06	0.94
102	5	3	0.99159	32.341	1.06	0.94
103	23	16	1.001	24.48	1.06	0.94
104	38	25	0.971	21.742	1.06	0.94
105	31	26	0.965	20.634	1.06	0.94
106	43	16	0.96114	20.379	1.06	0.94
107	50	12	0.952	17.576	1.06	0.94
108	2	1	0.96621	19.434	1.06	0.94
109	8	3	0.96703	18.982	1.06	0.94
110	39	30	0.973	18.135	1.06	0.94
111	0	0	0.98	19.78	1.06	0.94
112	68	13	0.975	15.036	1.06	0.94
113	6	0	0.993	14.004	1.06	0.94
114	8	3	0.96068	14.727	1.06	0.94
115	22	7	0.96053	14.72	1.06	0.94
116	184	0	1.005	27.166	1.06	0.94
117	20	8	0.97382	10.958	1.06	0.94
118	33	15	0.94944	21.945	1.06	0.94

Table A1 (continued)

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A2. Generator Data

Generator data for the IEEE 118-bus test network is shown in Table A2. The variables and units used in the column headings of Table A2 are:

P_G: Real power output, in [MW]

Q_G: Reactive power output, in [MVar]

$Q_{G,max}$: Maximum reactive power output, in [MVar]

$Q_{G,min}$: Minimum reactive power output, in [MVar]

V: Voltage magnitude setpoint, in per-unit for a base voltage of 100 kV.

$P_{G,max}$: Maximum real power output, in [MW]

$P_{G,min}$: Minimum real power output, in [MW]

Bus	P_G	Q_G	$Q_{G,max}$	$Q_{G,min}$	V	$P_{G,max}$	$P_{G,min}$
10	450	-51.04	200	-147	1.05	550	0
12	85	91.27	120	-35	0.99	185	0
25	220	49.72	140	-47	1.05	320	0
26	314	9.89	1000	-1000	1.015	414	0
31	7	31.57	300	-300	0.967	107	0
46	19	-5.25	100	-100	1.005	119	0
49	204	115.63	210	-85	1.025	304	0
54	48	3.9	300	-300	0.955	148	0
59	155	76.83	180	-60	0.985	255	0
61	160	-40.39	300	-100	0.995	260	0
65	391	80.76	200	-67	1.005	491	0
66	392	-1.95	200	-67	1.05	492	0
69	513.48	-82.39	300	-300	1.035	805.2	0
80	477	104.9	280	-165	1.04	577	0
87	4	11.02	1000	-100	1.015	104	0
92	607	0.49	9	-3	0.99	100	0
100	252	108.87	155	-50	1.017	352	0
103	40	41.69	40	-15	1.01	140	0
111	36	-1.84	1000	-100	0.98	136	0

Table A2: Generator data for the IEEE 118-bus network

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A3. Branch Data

Branch data for the IEEE 118-bus test network are shown in Table A3. The variables and units used in the column headings of Table A3 are:

From: Identifies the bus number of one end of the branch

To: Identifies the bus number of the other end of the branch

R: Resistance, in per-unit for a base voltage of 100 kV

X: Reactance, in per-unit for a base voltage of 100 kV

B: Line charging susceptance, in per-unit for a base voltage of 100 kV

RateA: Long-term or stability limit of the line, in [MVA]

RateB: Short-term limit of the line, in [MVA]

RateC: Emergency limit of the line, in [MVA]

Users of this data should note that the susceptances used in the DC power flows in this thesis were calculated directly from the line reactances *X*, according to the formula:

$$(A1) \quad B_{ij} = \begin{cases} -\dfrac{1}{X_{ij}} & i \neq j \\ \displaystyle\sum_{i=0, i\neq j} \frac{1}{X_{ij}} & i = j \\ 0 & X_{ij} = 0. \end{cases}$$

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From	To	R	X	B	RateA	RateB	RateC
1	2	0.0303	0.0999	0.0254	220	230	250
1	3	0.0129	0.0424	0.01082	220	230	250
2	12	0.0187	0.0616	0.01572	220	230	250
3	5	0.0241	0.108	0.0284	220	230	250
3	12	0.0484	0.16	0.0406	220	230	250
4	5	0.00176	0.00798	0.0021	440	460	500
4	11	0.0209	0.0688	0.01748	220	230	250
5	6	0.0119	0.054	0.01426	220	230	250
5	11	0.0203	0.0682	0.01738	220	230	250
6	7	0.00459	0.0208	0.0055	220	230	250
7	12	0.00862	0.034	0.00874	220	230	250
8	9	0.00244	0.0305	1.162	1100	1150	1250
8	5	0	0.0267	0	880	920	1000
8	30	0.00431	0.0504	0.514	220	230	250
9	10	0.00258	0.0322	1.23	1100	1150	1250
11	12	0.00595	0.0196	0.00502	220	230	250
11	13	0.02225	0.0731	0.01876	220	230	250
12	15	0.0215	0.0707	0.01816	220	230	250
12	17	0.0212	0.0834	0.0214	220	230	250
12	117	0.0329	0.14	0.0358	220	230	250
13	15	0.0744	0.2444	0.06268	220	230	250
14	15	0.0595	0.195	0.0502	220	230	250
15	17	0.0132	0.0437	0.0444	440	460	500
15	19	0.012	0.0394	0.0101	220	230	250
15	33	0.038	0.1244	0.03194	220	230	250
16	17	0.0454	0.1801	0.0466	220	230	250
17	19	0.0123	0.0505	0.01298	220	230	250
17	31	0.0474	0.1563	0.0399	220	230	250
17	113	0.00913	0.0301	0.00768	220	230	250
18	19	0.01119	0.0493	0.01142	220	230	250
19	20	0.0252	0.117	0.0298	220	230	250
19	34	0.0752	0.247	0.0632	220	230	250
20	21	0.0183	0.0849	0.0216	220	230	250
21	22	0.0209	0.097	0.0246	220	230	250
22	23	0.0342	0.159	0.0404	220	230	250
23	24	0.0135	0.0492	0.0498	220	230	250
23	25	0.0156	0.08	0.0864	440	460	500
23	32	0.0317	0.1153	0.1173	220	230	250
24	70	0.00221	0.4115	0.10198	220	230	250

Table A3: Branch data for the IEEE 118-bus network

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From	To	R	X	B	RateA	RateB	RateC
24	72	0.0488	0.196	0.0488	220	230	250
25	27	0.0318	0.163	0.1764	440	460	500
26	25	0	0.0382	0	220	230	250
26	30	0.00799	0.086	0.908	660	690	750
27	28	0.01913	0.0855	0.0216	220	230	250
27	32	0.0229	0.0755	0.01926	220	230	250
27	115	0.0164	0.0741	0.01972	220	230	250
28	31	0.0237	0.0943	0.0238	220	230	250
29	31	0.0108	0.0331	0.0083	220	230	250
30	17	0	0.0388	0	660	690	750
30	38	0.00464	0.054	0.422	220	230	250
31	32	0.0298	0.0985	0.0251	220	230	250
32	113	0.0615	0.203	0.0518	220	230	250
32	114	0.0135	0.0612	0.01628	220	230	250
33	37	0.0415	0.142	0.0366	220	230	250
34	36	0.00871	0.0268	0.00568	220	230	250
34	37	0.00256	0.0094	0.00984	440	460	500
34	43	0.0413	0.1681	0.04226	220	230	250
35	36	0.00224	0.0102	0.00268	220	230	250
35	37	0.011	0.0497	0.01318	220	230	250
37	39	0.0321	0.106	0.027	220	230	250
37	40	0.0593	0.168	0.042	220	230	250
38	37	0	0.0375	0	660	690	750
38	65	0.00901	0.0986	1.046	440	460	500
39	40	0.0184	0.0605	0.01552	220	230	250
40	41	0.0145	0.0487	0.01222	220	230	250
40	42	0.0555	0.183	0.0466	220	230	250
41	42	0.041	0.135	0.0344	220	230	250
42	49	0.0715	0.323	0.086	220	230	250
42	49	0.0715	0.323	0.086	220	230	250
43	44	0.0608	0.2454	0.06068	220	230	250
44	45	0.0224	0.0901	0.0224	220	230	250
45	46	0.04	0.1356	0.0332	220	230	250
45	49	0.0684	0.186	0.0444	220	230	250
46	47	0.038	0.127	0.0316	220	230	250
46	48	0.0601	0.189	0.0472	220	230	250
47	49	0.0191	0.0625	0.01604	220	230	250
47	69	0.0844	0.2778	0.07092	220	230	250
48	49	0.0179	0.0505	0.01258	220	230	250

Table A3 (continued)

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From	To	R	X	B	RateA	RateB	RateC
49	50	0.0267	0.0752	0.01874	220	230	250
49	51	0.0486	0.137	0.0342	220	230	250
49	54	0.073	0.289	0.0738	220	230	250
49	54	0.0869	0.291	0.073	220	230	250
49	66	0.018	0.0919	0.0248	440	460	500
49	66	0.018	0.0919	0.0248	440	460	500
49	69	0.0985	0.324	0.0828	220	230	250
50	57	0.0474	0.134	0.0332	220	230	250
51	52	0.0203	0.0588	0.01396	220	230	250
51	58	0.0255	0.0719	0.01788	220	230	250
52	53	0.0405	0.1635	0.04058	220	230	250
53	54	0.0263	0.122	0.031	220	230	250
54	55	0.0169	0.0707	0.0202	220	230	250
54	56	0.00275	0.00955	0.00732	220	230	250
54	59	0.0503	0.2293	0.0598	220	230	250
55	56	0.00488	0.0151	0.00374	220	230	250
55	59	0.04739	0.2158	0.05646	220	230	250
56	57	0.0343	0.0966	0.0242	220	230	250
56	58	0.0343	0.0966	0.0242	220	230	250
56	59	0.0825	0.251	0.0569	220	230	250
56	59	0.0803	0.239	0.0536	220	230	250
59	60	0.0317	0.145	0.0376	220	230	250
59	61	0.0328	0.15	0.0388	220	230	250
60	61	0.00264	0.0135	0.01456	440	460	500
60	62	0.0123	0.0561	0.01468	220	230	250
61	62	0.00824	0.0376	0.0098	220	230	250
62	66	0.0482	0.218	0.0578	220	230	250
62	67	0.0258	0.117	0.031	220	230	250
63	59	0	0.0386	0	440	460	500
63	64	0.00172	0.02	0.216	440	460	500
64	61	0	0.0268	0	220	230	250
64	65	0.00269	0.0302	0.38	440	460	500
65	66	0	0.037	0	220	230	250
65	68	0.00138	0.016	0.638	220	230	250
66	67	0.0224	0.1015	0.02682	220	230	250
68	69	0	0.037	0	440	460	500
68	81	0.00175	0.0202	0.808	220	230	250
68	116	0.00034	0.00405	0.164	440	460	500
69	70	0.03	0.127	0.122	440	460	500

Table A3 (continued)

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From	To	R	X	B	RateA	RateB	RateC
69	75	0.0405	0.122	0.124	440	460	500
69	77	0.0309	0.101	0.1038	220	230	250
70	71	0.00882	0.0355	0.00878	220	230	250
70	74	0.0401	0.1323	0.03368	220	230	250
70	75	0.0428	0.141	0.036	220	230	250
71	72	0.0446	0.18	0.04444	220	230	250
71	73	0.00866	0.0454	0.01178	220	230	250
74	75	0.0123	0.0406	0.01034	220	230	250
75	77	0.0601	0.1999	0.04978	220	230	250
75	118	0.0145	0.0481	0.01198	220	230	250
76	77	0.0444	0.148	0.0368	220	230	250
76	118	0.0164	0.0544	0.01356	220	230	250
77	78	0.00376	0.0124	0.01264	220	230	250
77	80	0.017	0.0485	0.0472	440	460	500
77	80	0.0294	0.105	0.0228	220	230	250
77	82	0.0298	0.0853	0.08174	220	230	250
78	79	0.00546	0.0244	0.00648	220	230	250
79	80	0.0156	0.0704	0.0187	220	230	250
80	96	0.0356	0.182	0.0494	220	230	250
80	97	0.0183	0.0934	0.0254	220	230	250
80	98	0.0238	0.108	0.0286	220	230	250
80	99	0.0454	0.206	0.0546	220	230	250
81	80	0	0.037	0	220	230	250
82	83	0.0112	0.03665	0.03796	220	230	250
82	96	0.0162	0.053	0.0544	220	230	250
83	84	0.0625	0.132	0.0258	220	230	250
83	85	0.043	0.148	0.0348	220	230	250
84	85	0.0302	0.0641	0.01234	220	230	250
85	86	0.035	0.123	0.0276	220	230	250
85	88	0.02	0.102	0.0276	220	230	250
85	89	0.0239	0.173	0.047	220	230	250
86	87	0.02828	0.2074	0.0445	220	230	250
88	89	0.0139	0.0712	0.01934	440	460	500
89	90	0.0518	0.032	0.032	660	230	250
89	91	0.0099	0.032	0.065	220	220	220
89	92	0.0099	0.0505	0.065	220	690	750
90	91	0.0254	0.0505	0.065	660	230	250
91	92	0.0387	0.1272	0.032	220	230	250
92	93	0.0258	0.032	0.0218	220	230	250

Table A3 (continued)

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From	To	R	X	B	RateA	RateB	RateC
92	94	0.0481	0.158	0.0406	220	230	250
92	100	0.0648	0.295	0.0472	220	230	250
92	102	0.0123	0.0559	0.01464	220	230	250
93	94	0.0223	0.0732	0.01876	220	230	250
94	95	0.0132	0.0434	0.0111	220	230	250
94	96	0.0269	0.0869	0.023	220	230	250
94	100	0.0178	0.058	0.0604	220	230	250
95	96	0.0171	0.0547	0.01474	220	230	250
96	97	0.0173	0.0885	0.024	220	230	250
98	100	0.0397	0.179	0.0476	220	230	250
99	100	0.018	0.0813	0.0216	220	230	250
100	101	0.0277	0.1262	0.0328	220	230	250
100	103	0.016	0.0525	0.0536	440	460	500
100	104	0.0451	0.204	0.0541	220	230	250
100	106	0.0605	0.229	0.062	220	230	250
101	102	0.0246	0.112	0.0294	220	230	250
103	104	0.0466	0.1584	0.0407	220	230	250
103	105	0.0535	0.1625	0.0408	220	230	250
103	110	0.03906	0.1813	0.0461	220	230	250
104	105	0.00994	0.0378	0.00986	220	230	250
105	106	0.014	0.0547	0.01434	220	230	250
105	107	0.053	0.183	0.0472	220	230	250
105	108	0.0261	0.0703	0.01844	220	230	250
106	107	0.053	0.183	0.0472	220	230	250
108	109	0.0105	0.0288	0.0076	220	230	250
109	110	0.0278	0.0762	0.0202	220	230	250
110	111	0.022	0.0755	0.02	220	230	250
110	112	0.0247	0.064	0.062	220	230	250
114	115	0.0023	0.0104	0.00276	220	230	250

Table A3 (continued)

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A4. Generator Marginal Cost Data

Generator marginal costs for the IEEE 118-bus test network are shown in Table A4. The linearized DC power flow used in Chapter 6 of this thesis assumes a constant marginal cost of generation. For simplicity, I assumed that there was no intercept term to the cost curve.

Generator bus	Marginal Cost ($/MWh)
10	0.217
12	1.052
25	0.434
26	0.308
31	5.882
46	3.448
49	0.467
54	1.724
59	0.606
61	0.588
65	0.2493
66	0.2487
69	0.1897
80	0.205
87	7.142
92	10
100	0.381
103	2
111	2.173

Table A4: Generator marginal costs in the IEEE 118-bus network

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