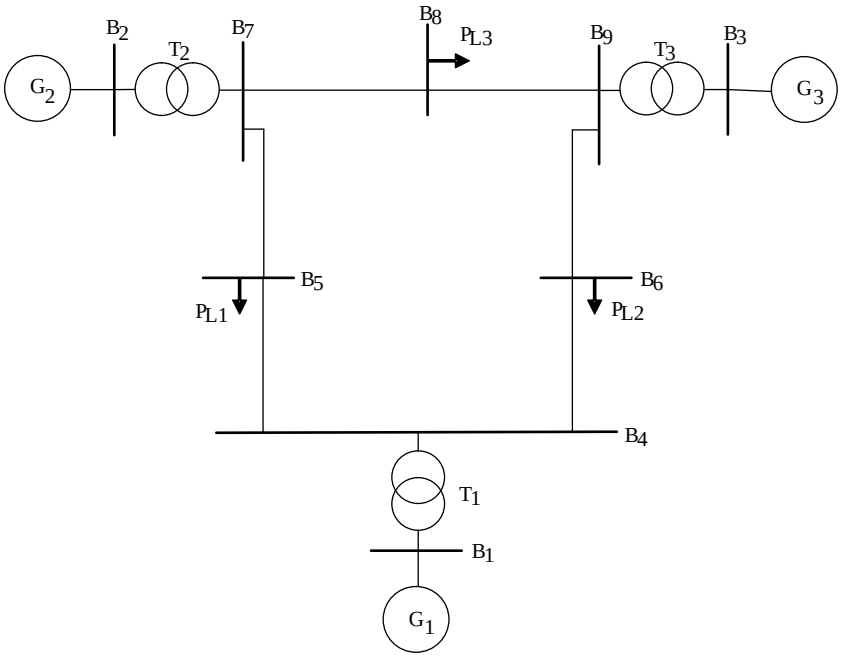
WSCC 3 Machine 9 Bus System

Network

This Western System Coordinating Council (WSCC) 3-machine, 9-bus system is used widely in the literature. All parameters shown below are come from the book titled “Power system control and stability” [1].



Basic Data and Characteristics

Generators

Parameters for the two-axis model of the synchronous machines are shown in Tables as follows. All values are given on the same system base MVA.

Mac#	Bus#	X_d	X_d'	X_q	X_q'	R_a	D	T_d'	T_q'	H
1	1	0.1460	0.0608	0.0969	0.0969	0.0000	0	8.9600	0.3100	23.6000
2	2	0.8958	0.1198	0.8645	0.1969	0.0000	0	6.0000	0.5350	6.4000
3	3	1.3125	0.1813	1.2578	0.2500	0.0000	0	5.8900	0.6000	3.0100

Line/transformers

The network data for this system is shown in the Table below. All values are given on the same system base MVA.

Line Data					Transformer Tap	
From Bus	To Bus	R	X	B	Magnitude	Angle
4	5	0.0100	0.0850	0.1760	0	0
4	6	0.0170	0.0920	0.1580	0	0
5	7	0.0320	0.1610	0.3060	0	0
6	9	0.0390	0.1700	0.3580	0	0
7	8	0.0085	0.0720	0.1490	0	0
8	9	0.0119	0.1008	0.2090	0	0
1	4	0	0.0576	0	1.0000	0
2	7	0	0.0625	0	1.0000	0
3	9	0	0.0586	0	1.0000	0

Power and Voltage Set Points

All values are given on the same system base MVA. Note that generator 1 is the swing node.

Bus	Type	Voltage[pu]	Load		Generator			Grounding Parameter	
			P_D	Q_D	P_G	Q_G	Machine-Type	G	B
1	PV	1.04	0	0	0.0000	0	1	0	0
2	PV	1.025	0	0	163.0000	0	1	0	0
3	PV	1.025	0	0	85.0000	0	1	0	0
4	PQ	-	0	0	0	0	-	0	0
5	PQ	-	125.0000	50.0000	0	0	-	0	0
6	PQ	-	90.0000	30.0000	0	0	-	0	0
7	PQ	-	0	0	0	0	-	0	0
8	PQ	-	100.0000	35.0000	0	0	-	0	0
9	PQ	-	0	0	0	0	-	0	0

* Where Machine-Type =1 denotes generator, Machine-Type =0 denotes phase modifier.

Exciter Model

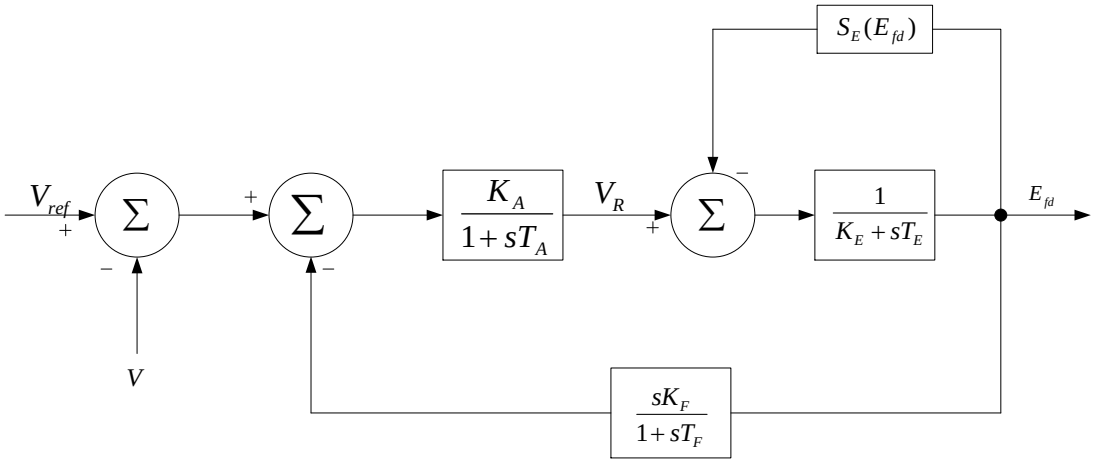


Fig. 1: IEEE-Type I exciter model

Where $S_E\left(E_{fd}\right)=A_e e^{B_e E_{fd}}$ is the field saturation function with coefficients A_e and B_e .

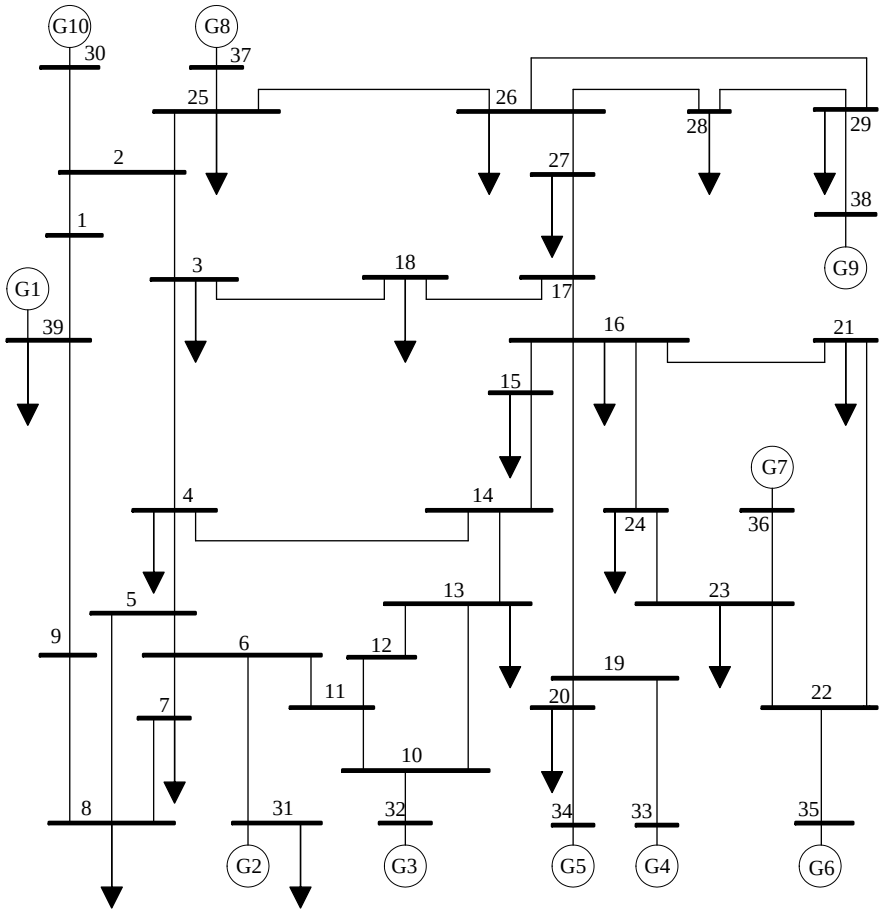
Excitation data

Mac#	Bus#	K_A	T_A	K_E	T_E	K_F	T_F	A_e	B_e
1	1	20.0000	0.2000	1.0000	0.3140	0.0630	0.3500	0.0039	1.5550
2	2	20.0000	0.2000	1.0000	0.3140	0.0630	0.3500	0.0039	1.5550
3	3	20.0000	0.2000	1.0000	0.3140	0.0630	0.3500	0.0039	1.5550

IEEE 10 Machines 39 Bus System

This IEEE 39 bus system is well known as 10-machine New-England Power System. All parameters shown below are come from [2].

Network



Basic Data and Characteristics

Generators

Parameters for the two-axis model of the synchronous machines are shown in Tables as follows. All values are given on the same system base MVA.

Mac#	Bus#	X_d	X_d'	X_q	X_q'	R_a	D	T_d'	T_q'	H
1	39	0.0200	0.0060	0.0190	0.0080	0	0	7.0000	0.7000	500.0000
2	31	0.2950	0.0697	0.2820	0.1700	0	0	6.5600	1.5000	30.3000
3	32	0.2495	0.0531	0.2370	0.0876	0	0	5.7000	1.5000	35.8000
4	33	0.2620	0.0436	0.2580	0.1660	0	0	5.6900	1.5000	28.6000
5	34	0.6700	0.1320	0.6200	0.1660	0	0	5.4000	0.4400	26.0000
6	35	0.2540	0.0500	0.2410	0.0814	0	0	7.3000	0.4000	34.8000
7	36	0.2950	0.0490	0.2920	0.1860	0	0	5.6600	1.5000	26.4000
8	37	0.2900	0.0570	0.2800	0.0911	0	0	6.7000	0.4100	24.3000
9	38	0.2106	0.0570	0.2050	0.0587	0	0	4.7900	1.9600	34.5000
10	30	0.1000	0.0310	0.0690	0.0080	0	0	10.2000	0.5000	42.0000

Line/transformers

The network data for this system is shown in the Table below. All values are given on the same system base MVA.

Line Data					Transformer Tap	
From Bus	To Bus	R	X	B	Magnitude	Angle
1	2	0.0035	0.0411	0.6986	0	0
1	39	0.0010	0.0250	0.7500	0	0
2	3	0.0013	0.0151	0.2572	0	0
2	25	0.0070	0.0086	0.1460	0	0
3	4	0.0013	0.0213	0.2214	0	0
3	18	0.0011	0.0133	0.2138	0	0
4	5	0.0008	0.0128	0.1342	0	0
4	14	0.0008	0.0129	0.1382	0	0
5	6	0.0002	0.0026	0.0434	0	0
5	8	0.0008	0.0112	0.1476	0	0
6	7	0.0006	0.0092	0.1130	0	0
6	11	0.0007	0.0082	0.1389	0	0
7	8	0.0004	0.0046	0.0780	0	0
8	9	0.0023	0.0363	0.3804	0	0
9	39	0.0010	0.0250	1.2000	0	0
10	11	0.0004	0.0043	0.0729	0	0
10	13	0.0004	0.0043	0.0729	0	0
13	14	0.0009	0.0101	0.1723	0	0
14	15	0.0018	0.0217	0.3660	0	0
15	16	0.0009	0.0094	0.1710	0	0
16	17	0.0007	0.0089	0.1342	0	0
16	19	0.0016	0.0195	0.3040	0	0
16	21	0.0008	0.0135	0.2548	0	0
16	24	0.0003	0.0059	0.0680	0	0
17	18	0.0007	0.0082	0.1319	0	0
17	27	0.0013	0.0173	0.3216	0	0
21	22	0.0008	0.0140	0.2565	0	0
22	23	0.0006	0.0096	0.1846	0	0
23	24	0.0022	0.0350	0.3610	0	0
25	26	0.0032	0.0323	0.5130	0	0
26	27	0.0014	0.0147	0.2396	0	0
26	28	0.0043	0.0474	0.7802	0	0
26	29	0.0057	0.0625	1.0290	0	0
28	29	0.0014	0.0151	0.2490	0	0
12	11	0.0016	0.0435	0	1.0060	0
12	13	0.0016	0.0435	0	1.0060	0
6	31	0.0000	0.0250	0	1.0700	0
10	32	0.0000	0.0200	0	1.0700	0
19	33	0.0007	0.0142	0	1.0700	0
20	34	0.0009	0.0180	0	1.0090	0

22	35	0.0000	0.0143	0	1.0250	0
23	36	0.0005	0.0272	0	1.0000	0
25	37	0.0006	0.0232	0	1.0250	0
2	30	0.0000	0.0181	0	1.0250	0
29	38	0.0008	0.0156	0	1.0250	0
19	20	0.0007	0.0138	0	1.0600	0

Power and Voltage Set Points

All values are given on the same system base MVA. Note that generator 2 is the swing node.

Bus	Type	Voltage[pu]	Load		Generator			Grounding Parameter	
			P_D	Q_D	P_G	Q_G	Machine-type	G	B
1	PQ	-	0	0	0	0	-	0	0
2	PQ	-	0	0	0	0	-	0	0
3	PQ	-	322.0000	2.4000	0	0	-	0	0
4	PQ	-	500.0000	184.0000	0	0	-	0	0
5	PQ	-	0	0	0	0	-	0	0
6	PQ	-	0	0	0	0	-	0	0
7	PQ	-	233.8000	84.0000	0	0	-	0	0
8	PQ	-	522.0000	176.0000	0	0	-	0	0
9	PQ	-	0	0	0	0	-	0	0
10	PQ	-	0	0	0	0	-	0	0
11	PQ	-	0	0	0	0	-	0	0
12	PQ	-	7.5000	88.0000	0	0	-	0	0
13	PQ	-	0	0	0	0	-	0	0
14	PQ	-	0	0	0	0	-	0	0
15	PQ	-	320.0000	153.0000	0	0	-	0	0
16	PQ	-	329.0000	32.3000	0	0	-	0	0
17	PQ	-	0	0	0	0	-	0	0
18	PQ	-	158.0000	30.0000	0	0	-	0	0
19	PQ	-	0	0	0	0	-	0	0
20	PQ	-	628.0000	103.0000	0	0	-	0	0
21	PQ	-	274.0000	115.0000	0	0	-	0	0
22	PQ	-	0	0	0	0	-	0	0
23	PQ	-	247.5000	84.6000	0	0	-	0	0
24	PQ	-	308.6000	-92.0000	0	0	-	0	0
25	PQ	-	224.0000	47.2000	0	0	-	0	0
26	PQ	-	139.0000	17.0000	0	0	-	0	0
27	PQ	-	281.0000	75.5000	0	0	-	0	0
28	PQ	-	206.0000	27.6000	0	0	-	0	0
29	PQ	-	283.5000	26.9000	0	0	-	0	0
30	PV	1.0475	0	0	250.0000	0	1	0	0
31	PV	0.9820	9.2000	4.6000	0	0	1	0	0
32	PV	0.9831	0	0	650.0000	0	1	0	0
33	PV	0.9972	0	0	632.0000	0	1	0	0

34	PV	1.0123	0	0	508.0000	0	1	0	0
35	PV	1.0493	0	0	650.0000	0	1	0	0
36	PV	1.0635	0	0	560.0000	0	1	0	0
37	PV	1.0278	0	0	540.0000	0	1	0	0
38	PV	1.0265	0	0	830.0000	0	1	0	0
39	PV	1.0300	1104.0000	250.0000	1000.0000	0	1	0	0

* Where Machine-Type =1 denotes generator, Machine-Type =0 denotes phase modifier. All values shown are in per unit at 60Hz on a 100MVA base.

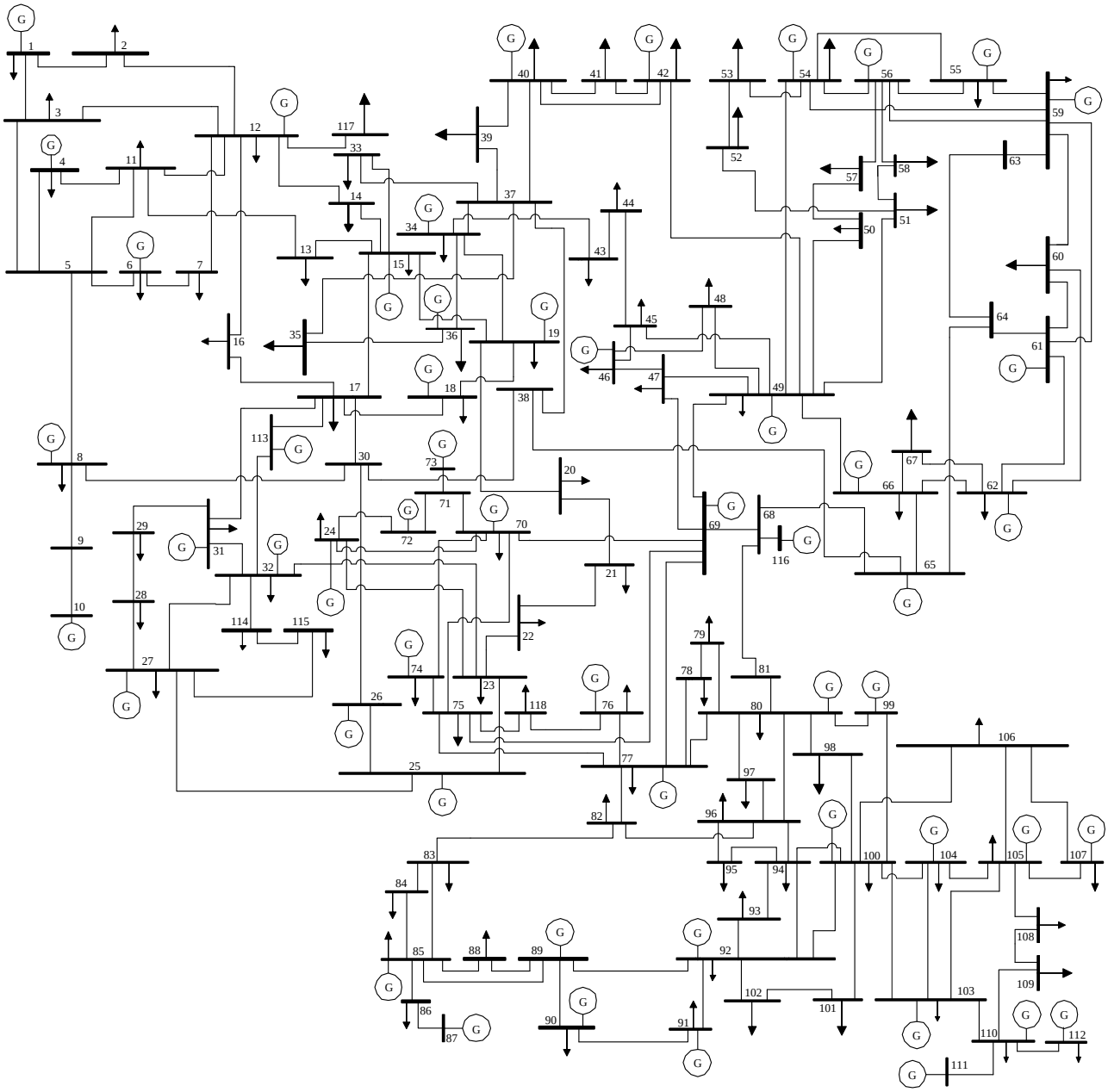
Excitation data

Mac#	**Bus#**	K_A	T_A	K_E	T_E	K_F	T_F	A_e	B_e
1	**39**	5.0000	0.0600	-0.0485	0.2500	0.0400	1.0000	0.0063	0.0171
2	**31**	6.2000	0.0500	-0.6330	0.4050	0.0570	0.5000	0.3700	0.4916
3	**32**	5.0000	0.0600	-0.0198	0.5000	0.0800	1.0000	0.0249	0.0853
4	**33**	5.0000	0.0600	-0.0525	0.5000	0.0800	1.0000	0.0055	0.0231
5	**34**	40.0000	0.0200	1.0000	0.7850	0.0300	1.0000	0.0002	0.0016
6	**35**	5.0000	0.0200	-0.0419	0.4710	0.0754	1.2460	0.0033	0.0104
7	**36**	40.0000	0.0200	1.0000	0.7300	0.0300	1.0000	0.2784	0.3980
8	**37**	5.0000	0.0200	-0.0470	0.5280	0.0854	1.2600	0.0043	0.0156
9	**38**	40.0000	0.0200	1.0000	1.4000	0.0300	1.0000	0.3005	0.3754
10	**30**	5.0000	0.0600	-0.0485	0.2500	0.0400	1.0000	0.0063	0.0171

IEEE 54 Machines 118 Bus System

The IEEE 118-bus modified test system consists of 54 synchronous machines with IEEE type-1 exciters, 20 of which are synchronous compensators used only for reactive power support and 15 of which are motors.

Network



Basic Data and Characteristics

Generators

Parameters for the two-axis model of the synchronous machines are shown in Tables as follows. All values are given on the same system base MVA.

Bus	X_d	X_d'	X_q	X_q'	R_a	D	T_d'	T_q'	H
10	0.357627	0.047458	0.342373	0.083051	0	11.8	0.5573	0.1371	13.6821
69	0.357627	0.047458	0.342373	0.083051	0	11.8	0.5573	0.1371	13.6821

80	0.357627	0.047458	0.342373	0.083051	0	11.8	0.5573	0.1371	13.6821
12	0.976	0.1392	0.928	0.2	0	2.5	8.97	0.5	5.96
25	0.590909	0.096061	0.581818	0.339394	0	6.6	0.9754	0.875	9.9198
49	0.590909	0.096061	0.581818	0.339394	0	6.6	0.9754	0.875	9.9198
100	0.590909	0.096061	0.581818	0.339394	0	6.6	0.9754	0.875	9.9198
26	0.430927	0.06678	0.426073	0.246439	0	8.2	0.8418	0.8676	15.1864
31	1.4	0.246667	1.306667	0.48	0	1.5	1.0748	0.1102	4.64025
46	1.4	0.246667	1.306667	0.48	0	1.5	1.0748	0.1102	4.64025
87	1.4	0.246667	1.306667	0.48	0	1.5	1.0748	0.1102	4.64025
54	1.18	0.22	1.05	0.38	0	2	1.1	0.1086	4.985
103	1.18	0.22	1.05	0.38	0	2	1.1	0.1086	4.985
111	1.18	0.22	1.05	0.38	0	2	1.1	0.1086	4.985
59	0.673391	0.139056	0.664378	0.393991	0	4.66	1.0614	0.8895	9.60426
61	0.673391	0.139056	0.664378	0.393991	0	4.66	1.0614	0.8895	9.60426
65	0.332031	0.052734	0.322266	0.091797	0	10.24	0.6035	0.1367	13.47072
66	0.332031	0.052734	0.322266	0.091797	0	10.24	0.6035	0.1367	13.47072
89	0.261437	0.049461	0.258323	0.153892	0	16.7	5.69	1.5	22.059865
1	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
6	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
15	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
19	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
32	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
34	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
36	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
55	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
56	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
62	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
74	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
76	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
77	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
85	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
92	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
104	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
105	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
110	7.076	1.216	3.42	2.318	0	0	8	0.008	0.3
18	5.9325	0.8575	2.93	0.43	0	0	11.6	0.159	0.608
70	5.9325	0.8575	2.93	0.43	0	0	11.6	0.159	0.608
4	5	0.928	4.88	2.86	0	0.5	4.75	1.5	1.254
24	5	0.928	4.88	2.86	0	0.5	4.75	1.5	1.254
27	5	0.928	4.88	2.86	0	0.5	4.75	1.5	1.254
72	5	0.928	4.88	2.86	0	0.5	4.75	1.5	1.254
73	5	0.928	4.88	2.86	0	0.5	4.75	1.5	1.254
8	3.967129	0.654576	3.887787	0.17002	0	0.7058	5.5	0.008	1.584274
91	3.967129	0.654576	3.887787	0.17002	0	0.7058	5.5	0.008	1.584274

107	3.967129	0.654576	3.887787	0.17002	0	0.7058	5.5	0.008	1.584274
40	2.480469	0.408203	2.421875	1.660156	0	1.024	6.6	0.008	2.599936
113	2.480469	0.408203	2.421875	1.660156	0	1.024	6.6	0.008	2.599936
42	1.4	0.246667	1.306667	0.48	0	1.5	6.1	0.3	4.6395
99	1.4	0.246667	1.306667	0.48	0	1.5	6.1	0.3	4.6395
90	1.18	0.22	1.05	0.38	0	2	5.9	0.3	4.985
112	1.18	0.22	1.05	0.38	0	2	5.9	0.3	4.985
116	0.468229	0.084375	0.463021	0.273698	0	7.68	5.21	1.5	10.06464

Line/transformers

The network data for this system is shown in the Table below. All values are given on the same system base MVA.

Line Data					Transformer Tap	
From Bus	To Bus	R	X	B	Magnitude	Angle
1	2	0.0303	0.0999	0.0254	0	0
1	3	0.0129	0.0424	0.01082	0	0
4	5	0.00176	0.00798	0.0021	0	0
3	5	0.0241	0.108	0.0284	0	0
5	6	0.0119	0.054	0.01426	0	0
6	7	0.00459	0.0208	0.0055	0	0
8	9	0.00244	0.0305	1.162	0	0
9	10	0.00258	0.0322	1.23	0	0
4	11	0.0209	0.0688	0.01748	0	0
5	11	0.0203	0.0682	0.01738	0	0
11	12	0.00595	0.0196	0.00502	0	0
2	12	0.0187	0.0616	0.01572	0	0
3	12	0.0484	0.16	0.0406	0	0
7	12	0.00862	0.034	0.00874	0	0
11	13	0.02225	0.0731	0.01876	0	0
12	14	0.0215	0.0707	0.01816	0	0
13	15	0.0744	0.2444	0.06268	0	0
14	15	0.0595	0.195	0.0502	0	0
12	16	0.0212	0.0834	0.0214	0	0
15	17	0.0132	0.0437	0.0444	0	0
16	17	0.0454	0.1801	0.0466	0	0
17	18	0.0123	0.0505	0.01298	0	0
18	19	0.01119	0.0493	0.01142	0	0
19	20	0.0252	0.117	0.0298	0	0
15	19	0.012	0.0394	0.0101	0	0
20	21	0.0183	0.0849	0.0216	0	0
21	22	0.0209	0.097	0.0246	0	0
22	23	0.0342	0.159	0.0404	0	0
23	24	0.0135	0.0492	0.0498	0	0
23	25	0.0156	0.08	0.0864	0	0
25	27	0.0318	0.163	0.1764	0	0

27	28	0.01913	0.0855	0.0216	0	0
28	29	0.0237	0.0943	0.0238	0	0
8	30	0.00431	0.0504	0.514	0	0
26	30	0.00799	0.086	0.908	0	0
17	31	0.0474	0.1563	0.0399	0	0
29	31	0.0108	0.0331	0.0083	0	0
23	32	0.0317	0.1153	0.1173	0	0
31	32	0.0298	0.0985	0.0251	0	0
27	32	0.0229	0.0755	0.01926	0	0
15	33	0.038	0.1244	0.03194	0	0
19	34	0.0752	0.247	0.0632	0	0
35	36	0.00224	0.0102	0.00268	0	0
35	37	0.011	0.0497	0.01318	0	0
33	37	0.0415	0.142	0.0366	0	0
34	36	0.00871	0.0268	0.00568	0	0
34	37	0.00256	0.0094	0.00984	0	0
37	39	0.0321	0.106	0.027	0	0
37	40	0.0593	0.168	0.042	0	0
30	38	0.00464	0.054	0.422	0	0
39	40	0.0184	0.0605	0.01552	0	0
40	41	0.0145	0.0487	0.01222	0	0
40	42	0.0555	0.183	0.0466	0	0
41	42	0.041	0.135	0.0344	0	0
43	44	0.0608	0.2454	0.06068	0	0
34	43	0.0413	0.1681	0.04226	0	0
44	45	0.0224	0.0901	0.0224	0	0
45	46	0.04	0.1356	0.0332	0	0
46	47	0.038	0.127	0.0316	0	0
46	48	0.0601	0.189	0.0472	0	0
47	49	0.0191	0.0625	0.01604	0	0
42	49	0.0715	0.323	0.086	0	0
42	49	0.0715	0.323	0.086	0	0
45	49	0.0684	0.186	0.0444	0	0
48	49	0.0179	0.0505	0.01258	0	0
49	50	0.0267	0.0752	0.01874	0	0
49	51	0.0486	0.137	0.0342	0	0
51	52	0.0203	0.0588	0.01396	0	0
52	53	0.0405	0.1635	0.04058	0	0
53	54	0.0263	0.122	0.031	0	0
49	54	0.073	0.289	0.0738	0	0
49	54	0.0869	0.291	0.073	0	0
54	55	0.0169	0.0707	0.0202	0	0
54	56	0.00275	0.00955	0.00732	0	0
55	56	0.00488	0.0151	0.00374	0	0

56	57	0.0343	0.0966	0.0242	0	0
50	57	0.0474	0.134	0.0332	0	0
56	58	0.0343	0.0966	0.0242	0	0
51	58	0.0255	0.0719	0.01788	0	0
54	59	0.0503	0.2293	0.0598	0	0
56	59	0.0825	0.251	0.0569	0	0
56	59	0.0803	0.239	0.0536	0	0
55	59	0.04739	0.2158	0.05646	0	0
59	60	0.0317	0.145	0.0376	0	0
59	61	0.0328	0.15	0.0388	0	0
60	61	0.00264	0.0135	0.01456	0	0
60	62	0.0123	0.0561	0.01468	0	0
61	62	0.00824	0.0376	0.0098	0	0
63	64	0.00172	0.02	0.216	0	0
38	65	0.00901	0.0986	1.046	0	0
64	65	0.00269	0.0302	0.38	0	0
49	66	0.018	0.0919	0.0248	0	0
49	66	0.018	0.0919	0.0248	0	0
62	66	0.0482	0.218	0.0578	0	0
62	67	0.0258	0.117	0.031	0	0
66	67	0.0224	0.1015	0.02682	0	0
65	68	0.00138	0.016	0.638	0	0
47	69	0.0844	0.2778	0.07092	0	0
49	69	0.0985	0.324	0.0828	0	0
69	70	0.03	0.127	0.122	0	0
24	70	0.00221	0.4115	0.10198	0	0
70	71	0.00882	0.0355	0.00878	0	0
24	72	0.0488	0.196	0.0488	0	0
71	72	0.0446	0.18	0.04444	0	0
71	73	0.00866	0.0454	0.01178	0	0
70	74	0.0401	0.1323	0.03368	0	0
70	75	0.0428	0.141	0.036	0	0
69	75	0.0405	0.122	0.124	0	0
74	75	0.0123	0.0406	0.01034	0	0
76	77	0.0444	0.148	0.0368	0	0
69	77	0.0309	0.101	0.1038	0	0
75	77	0.0601	0.1999	0.04978	0	0
77	78	0.00376	0.0124	0.01264	0	0
78	79	0.00546	0.0244	0.00648	0	0
77	80	0.017	0.0485	0.0472	0	0
77	80	0.0294	0.105	0.0228	0	0
79	80	0.0156	0.0704	0.0187	0	0
68	81	0.00175	0.0202	0.808	0	0
77	82	0.0298	0.0853	0.08174	0	0

82	83	0.0112	0.03665	0.03796	0	0
83	84	0.0625	0.132	0.0258	0	0
83	85	0.043	0.148	0.0348	0	0
84	85	0.0302	0.0641	0.01234	0	0
85	86	0.035	0.123	0.0276	0	0
86	87	0.02828	0.2074	0.0445	0	0
85	88	0.02	0.102	0.0276	0	0
85	89	0.0239	0.173	0.047	0	0
88	89	0.0139	0.0712	0.01934	0	0
89	90	0.0518	0.188	0.0528	0	0
89	90	0.0238	0.0997	0.106	0	0
90	91	0.0254	0.0836	0.0214	0	0
89	92	0.0099	0.0505	0.0548	0	0
89	92	0.0393	0.1581	0.0414	0	0
91	92	0.0387	0.1272	0.03268	0	0
92	93	0.0258	0.0848	0.0218	0	0
92	94	0.0481	0.158	0.0406	0	0
93	94	0.0223	0.0732	0.01876	0	0
94	95	0.0132	0.0434	0.0111	0	0
80	96	0.0356	0.182	0.0494	0	0
82	96	0.0162	0.053	0.0544	0	0
94	96	0.0269	0.0869	0.023	0	0
80	97	0.0183	0.0934	0.0254	0	0
80	98	0.0238	0.108	0.0286	0	0
80	99	0.0454	0.206	0.0546	0	0
92	100	0.0648	0.295	0.0472	0	0
94	100	0.0178	0.058	0.0604	0	0
95	96	0.0171	0.0547	0.01474	0	0
96	97	0.0173	0.0885	0.024	0	0
98	100	0.0397	0.179	0.0476	0	0
99	100	0.018	0.0813	0.0216	0	0
100	101	0.0277	0.1262	0.0328	0	0
92	102	0.0123	0.0559	0.01464	0	0
101	102	0.0246	0.112	0.0294	0	0
100	103	0.016	0.0525	0.0536	0	0
100	104	0.0451	0.204	0.0541	0	0
103	104	0.0466	0.1584	0.0407	0	0
103	105	0.0535	0.1625	0.0408	0	0
100	106	0.0605	0.229	0.062	0	0
104	105	0.00994	0.0378	0.00986	0	0
105	106	0.014	0.0547	0.01434	0	0
105	107	0.053	0.183	0.0472	0	0
105	108	0.0261	0.0703	0.01844	0	0
106	107	0.053	0.183	0.0472	0	0

108	109	0.0105	0.0288	0.0076	0	0
103	110	0.03906	0.1813	0.0461	0	0
109	110	0.0278	0.0762	0.0202	0	0
110	111	0.022	0.0755	0.02	0	0
110	112	0.0247	0.064	0.062	0	0
17	113	0.00913	0.0301	0.00768	0	0
32	113	0.0615	0.203	0.0518	0	0
32	114	0.0135	0.0612	0.01628	0	0
27	115	0.0164	0.0741	0.01972	0	0
114	115	0.0023	0.0104	0.00276	0	0
68	116	0.00034	0.00405	0.164	0	0
12	117	0.0329	0.14	0.0358	0	0
75	118	0.0145	0.0481	0.01198	0	0
76	118	0.0164	0.0544	0.01356	0	0
8	5	0	0.0267	0	0.985	0
26	25	0	0.0382	0	0.96	0
30	17	0	0.0388	0	0.96	0
38	37	0	0.0375	0	0.935	0
63	59	0	0.0386	0	0.96	0
64	61	0	0.0268	0	0.985	0
65	66	0	0.037	0	0.935	0
68	69	0	0.037	0	0.935	0
81	80	0	0.037	0	0.935	0
92	100	0.0648	0.295	0	1	0
106	107	0.053	0.183	0	1	0

Power and Voltage Set Points

All values are given on the same system base MVA. Note that generator 69 is the swing node.

Bus	Type	Voltage[pu]	Load		Generator			Grounding Parameter	
			P_D	Q_D	P_G	Q_G	Machine-type	G	B
1	PV	0.955	51	27	0	0	0	0	0
2	PQ	--	20	9	0	0	--	0	0
3	PQ	--	39	10	0	0	--	0	0
4	PV	0.998	30	12	-9	0	0	0	0
5	PQ	--	0	0	0	0	--	0	-0.4
6	PV	0.99	52	22	0	0	0	0	0
7	PQ	--	19	2	0	0	--	0	0
8	PV	1.015	0	0	-28	0	0	0	0
10	PV	1.05	0	0	450	0	1	0	0
11	PQ	--	70	23	0	0	--	0	0
12	PV	0.99	47	10	85	0	1	0	0
13	PQ	--	34	16	0	0	--	0	0
14	PQ	--	14	1	0	0	--	0	0
15	PV	0.97	90	30	0	0	0	0	0

16	PQ	--	25	10	0	0	--	0	0
17	PQ	--	11	3	0	0	--	0	0
18	PV	0.973	60	34	0	0	0	0	0
19	PV	0.962	45	25	0	0	0	0	0
20	PQ	--	18	3	0	0	--	0	0
21	PQ	--	14	8	0	0	--	0	0
22	PQ	--	10	5	0	0	--	0	0
23	PQ	--	7	3	0	0	--	0	0
24	PV	0.992	0	0	-13	0	0	0	0
25	PV	1.05	0	0	220	0	1	0	0
26	PV	1.015	0	0	314	0	1	0	0
27	PV	0.968	62	13	-9	0	0	0	0
28	PQ	--	17	7	0	0	--	0	0
29	PQ	--	24	4	0	0	--	0	0
31	PV	0.967	43	27	7	0	0	0	0
32	PV	0.963	59	23	0	0	0	0	0
33	PQ	--	23	9	0	0	--	0	0
34	PV	0.984	59	26	0	0	0	0	0.14
35	PQ	--	33	9	0	0	--	0	0
36	PV	0.98	31	17	0	0	0	0	0
37	PQ	--	0	0	0	0	--	0	-0.25
39	PQ	--	27	11	0	0	--	0	0
40	PV	0.97	20	23	-46	0	0	0	0
41	PQ	--	37	10	0	0	--	0	0
42	PV	0.985	37	23	-59	0	0	0	0
43	PQ	--	18	7	0	0	--	0	0
44	PQ	--	16	8	0	0	--	0	0.1
45	PQ	--	53	22	0	0	--	0	0.1
46	PV	1.005	28	10	19	0	0	0	0.1
47	PQ	--	34	0	0	0	--	0	0
48	PQ	--	20	11	0	0	--	0	0.15
49	PV	1.025	87	30	204	0	1	0	0
50	PQ	--	17	4	0	0	--	0	0
51	PQ	--	17	8	0	0	--	0	0
52	PQ	--	18	5	0	0	--	0	0
53	PQ	--	23	11	0	0	--	0	0
54	PV	0.955	113	32	48	0	1	0	0
55	PV	0.952	63	22	0	0	0	0	0
56	PV	0.954	84	18	0	0	0	0	0
57	PQ	--	12	3	0	0	--	0	0
58	PQ	--	12	3	0	0	--	0	0
59	PV	0.985	277	113	155	0	1	0	0
60	PQ	--	78	3	0	0	--	0	0
61	PV	0.995	0	0	160	0	1	0	0

62	PV	0.998	77	14	0	0	0	0	0
65	PV	1.005	0	0	391	0	1	0	0
66	PV	1.05	39	18	392	0	1	0	0
67	PQ	--	28	7	0	0	--	0	0
69	PV	1.035	0	0	516.4	0	1	0	0
70	PV	0.984	66	20	0	0	0	0	0
72	PV	0.98	0	0	-12	0	0	0	0
73	PV	0.991	0	0	-6	0	0	0	0
74	PV	0.958	68	27	0	0	0	0	0.12
75	PQ	--	47	11	0	0	--	0	0
76	PV	0.943	68	36	0	0	0	0	0
77	PV	1.006	61	28	0	0	--	0	0
78	PQ	--	71	26	0	0	--	0	0
79	PQ	--	39	32	0	0	--	0	0.2
80	PV	1.04	130	26	477	0	1	0	0
82	PQ	--	54	27	0	0	--	0	0.2
83	PQ	--	20	10	0	0	--	0	0.1
84	PQ	--	11	7	0	0	--	0	0
85	PV	0.985	24	15	0	0	0	0	0
86	PQ	--	21	10	0	0	--	0	0
87	PV	1.015	0	0	4	0	0	0	0
88	PQ	--	48	10	0	0	--	0	0
89	PV	1.005	0	0	607	0	1	0	0
90	PV	0.985	78	42	-85	0	0	0	0
91	PV	0.98	0	0	-10	0	0	0	0
92	PV	0.99	65	10	0	0	0	0	0
93	PQ	--	12	7	0	0	--	0	0
94	PQ	--	30	16	0	0	--	0	0
95	PQ	--	42	31	0	0	--	0	0
96	PQ	--	38	15	0	0	--	0	0
97	PQ	--	15	9	0	0	--	0	0
98	PQ	--	34	8	0	0	--	0	0
99	PV	1.01	0	0	-42	0	0	0	0
100	PV	1.017	37	18	252	0	1	0	0
101	PQ	--	22	15	0	0	--	0	0
102	PQ	--	5	3	0	0	--	0	0
103	PV	1.01	23	16	40	0	1	0	0
104	PV	0.971	38	25	0	0	0	0	0
105	PV	0.965	31	26	0	0	0	0	0.2
106	PQ	--	43	16	0	0	--	0	0
107	PV	0.952	28	12	-22	0	0	0	0.06
108	PQ	--	2	1	0	0	--	0	0
109	PQ	--	8	3	0	0	--	0	0
110	PV	0.973	39	30	0	0	0	0	0.06

111	PV	0.98	0	0	36	0	1	0	0
112	PV	0.975	25	13	-43	0	0	0	0
113	PV	0.993	0	0	-6	0	0	0	0
114	PQ	--	8	3	0	0	--	0	0
115	PQ	--	22	7	0	0	--	0	0
116	PV	1.005	0	0	-184	0	0	0	0
117	PQ	--	20	8	0	0	--	0	0
118	PQ	--	33	15	0	0	--	0	0

* Where Machine-Type =1 denotes generator, Machine-Type =0 denotes phase modifier.

Excitation data

Mac#	Bus#	K_A	T_A	K_E	T_E	K_F	T_F	A_e	B_e
10	10	200	0.3575	1	0.011	0.0529	1	0	0
69	69	200	0.3575	1	0.011	0.0529	1	0	0
80	80	200	0.3575	1	0.011	0.0529	1	0	0
12	12	25	0.2	-0.061	0.6758	0.108	0.35	0.0016	1.6353
25	25	400	0.05	-0.17	0.95	0.04	1	0.0027	0.3863
49	49	400	0.05	-0.17	0.95	0.04	1	0.0027	0.3863
100	100	400	0.05	-0.17	0.95	0.04	1	0.0027	0.3863
26	26	400	0.02	1	0.92	0.03	1	0.1658	0.3909
31	31	20	0.05	1	1.98	0	0.1	0.0016	1.713
46	46	20	0.05	1	1.98	0	0.1	0.0016	1.713
87	87	20	0.05	1	1.98	0	0.1	0.0016	1.713
54	54	25	0.2	-0.0582	0.6544	0.105	0.35	0.0015	1.5838
103	103	25	0.2	-0.0582	0.6544	0.105	0.35	0.0015	1.5838
111	111	25	0.2	-0.0582	0.6544	0.105	0.35	0.0015	1.5838
59	59	250	0.06	1	0.613	0.053	0.33	0	0
61	61	250	0.06	1	0.613	0.053	0.33	0	0
65	65	200	0.395	1	0.008	0.0635	1	0	0
66	66	200	0.395	1	0.008	0.0635	1	0	0
89	89	200	0.02	1	0.942	0.03	1	0.023	0.9475
1	1	200	0.05	1	0.95	0.04	1	0.0027	1.0355
6	6	200	0.05	1	0.95	0.04	1	0.0027	1.0355
15	15	200	0.05	1	0.95	0.04	1	0.0027	1.0355
19	19	200	0.05	1	0.95	0.04	1	0.0027	1.0355
32	32	200	0.05	1	0.95	0.04	1	0.0027	1.0355
34	34	200	0.05	1	0.95	0.04	1	0.0027	1.0355
36	36	200	0.05	1	0.95	0.04	1	0.0027	1.0355
55	55	200	0.05	1	0.95	0.04	1	0.0027	1.0355
56	56	200	0.05	1	0.95	0.04	1	0.0027	1.0355
62	62	200	0.05	1	0.95	0.04	1	0.0027	1.0355
74	74	200	0.05	1	0.95	0.04	1	0.0027	1.0355
76	76	200	0.05	1	0.95	0.04	1	0.0027	1.0355
77	77	200	0.05	1	0.95	0.04	1	0.0027	1.0355
85	85	200	0.05	1	0.95	0.04	1	0.0027	1.0355

92	92	200	0.05	1	0.95	0.04	1	0.0027	1.0355
104	104	200	0.05	1	0.95	0.04	1	0.0027	1.0355
105	105	200	0.05	1	0.95	0.04	1	0.0027	1.0355
110	110	200	0.05	1	0.95	0.04	1	0.0027	1.0355
18	18	200	0.05	1	0.95	0.04	1	0.0027	0.6884
70	70	200	0.05	1	0.95	0.04	1	0.0027	0.6884
4	4	20	0.05	1	0.7	0	0.008	0.0392	0.8809
24	24	20	0.05	1	0.7	0	0.008	0.0392	0.8809
27	27	20	0.05	1	0.7	0	0.008	0.0392	0.8809
72	72	20	0.05	1	0.7	0	0.008	0.0392	0.8809
73	73	20	0.05	1	0.7	0	0.008	0.0392	0.8809
8	8	57.14	0.05	-0.0445	0.5	0.08	1	0.0012	1.2101
91	91	57.14	0.05	-0.0445	0.5	0.08	1	0.0012	1.2101
107	107	57.14	0.05	-0.0445	0.5	0.08	1	0.0012	1.2101
40	40	400	0.05	-0.0769	1.37	0.04	1	0.0137	0.6774
113	113	400	0.05	-0.0769	1.37	0.04	1	0.0137	0.6774
42	42	20	0.05	1	1.98	0	0.008	0.0016	1.713
99	99	20	0.05	1	1.98	0	0.008	0.0016	1.713
90	90	25	0.02	-0.0582	0.6544	0.105	0.35	0.0015	1.5838
112	112	25	0.02	-0.0582	0.6544	0.105	0.35	0.0015	1.5838
116	116	400	0.02	1	0.812	0.06	1	0.1572	0.2909

TABLE I SPECTRAL ABSCISSA

Test systems	λ_η
WSCC 3-machine 9-bus system	-0.1907+8.3677i
New England 10-machine 39-bus system	-0.1055 + 0.4373i
IEEE 54-machine 118-bus system	-0.0768

*Where λ_η denotes the spectral abscissa of the state matrix at the equilibrium point.

TABLE II

SPECTRAL ABSCISSA SENSITIVITIES SENSITIVITIES FOR 3-MACHINE-9-BUS SYSTEM

Bus	Active power			Reactive power	
	NSAS	CFSAS-Y	CFSAS -N	CFSAS-Y	CFSAS-N
1	——	-0.0014	-0.2365	-0.0042	-0.0673
2	**0.1210**	**0.0794**	0.0549	-0.0840	0.0721
3	0.0369	-0.0114	-0.0364	-0.0187	0.0671

*NSAS: Numerical spectral abscissa sensitivity *CFSAS-Y: Closed-form spectral abscissa sensitivity with additional processing *CFSAS-N: Closed-form spectral abscissa sensitivity without additional processing

TABLE III

SPECTRAL ABSCISSA SENSITIVITIES FOR 10-MACHINE-39-BUS SYSTEM

Bus	Active power	Reactive power

	NSAS	CFSAS-Y	CFSAS -N	CFSAS-Y	CFSAS -N
30	-5.75E-04	-1.38E-04	-1.80E-03	-2.09E-05	-2.22E-03
31	——	-9.31E-06	-7.91E-06	-5.85E-06	-1.58E-05
32	1.03E-05	1.53E-04	-1.89E-04	-5.81E-05	-3.22E-05
33	5.28E-05	8.11E-05	-1.02E-04	-1.68E-04	-5.18E-05
34	-1.75E-05	5.46E-05	7.16E-05	1.61E-05	7.29E-06
35	7.31E-05	1.88E-04	-2.07E-04	-9.60E-05	-3.14E-05
36	-1.10E-04	1.20E-05	4.54E-05	4.31E-06	2.49E-05
37	**8.19E-03**	**6.26E-03**	-6.93E-03	-3.14E-02	-3.57E-02
38	-6.29E-06	1.42E-04	-1.08E-04	-1.06E-06	-8.63E-05
39	-7.30E-05	3.21E-04	1.84E-04	-9.14E-08	7.46E-05

TABLE IV

EIGENVALUE SENSITIVITIES FOR 54-MACHINE-118-BUS SYSTEM

Bus	Active power			Reactive power	
	NSAS	CFSAS-Y	CFSAS -N	CFSAS-Y	CFSAS -N
10	3.06E-06	2.11E-10	1.45E-10	-4.00E-11	-1.04E-09
12	3.47E-06	1.08E-10	1.30E-10	-1.05E-11	1.15E-10
25	2.57E-06	-4.99E-09	-1.09E-08	-3.90E-11	-1.92E-09
26	2.66E-06	-6.91E-10	8.77E-09	-1.26E-11	1.76E-09
49	1.34E-05	2.49E-03	-6.34E-02	1.58E-05	-2.34E-02
54	**-3.49E-02**	**-3.34E-02**	-2.04E-02	5.91E-03	1.22E-02
59	-8.26E-05	1.94E-03	-8.18E-02	1.48E-06	-2.62E-02
61	-4.07E-05	-8.29E-05	3.73E-03	-3.48E-11	1.12E-03
65	-1.08E-05	-3.23E-07	-7.46E-05	-1.84E-11	-3.76E-07
66	4.49E-06	-4.77E-05	2.32E-03	3.80E-09	7.88E-04
69	——	4.73E-11	9.65E-03	-1.61E-10	3.92E-03
80	-4.24E-06	2.47E-08	2.02E-08	-1.66E-10	6.93E-08
89	-3.57E-06	2.35E-09	3.91E-08	-1.78E-11	-1.80E-07
100	-4.01E-06	1.99E-09	7.49E-10	-4.42E-11	-5.04E-09
103	-4.16E-06	7.58E-10	5.26E-10	-2.12E-11	-1.77E-10
111	-4.32E-06	-5.69E-10	-3.00E-10	5.99E-12	2.17E-09

TABLE V

THE EIGENVALUE SENSITIVITY WITH RESPECT TO δ , I_d , I_q , E'_d , E'_q AND E_{fd} FOR 3-MACHINE-9-BUS SYSTEM

Bus	$\partial\lambda/\partial\delta$	$\partial\lambda/\partial I_d$	$\partial\lambda/\partial I_q$	$\partial\lambda/\partial E'_d$	$\partial\lambda/\partial E'_q$	$\partial\lambda/\partial E_{fd}$
1	–0.0286 + 0.0797i	–0.0037 + 0.0138i	0.0017 – 0.0007i	0.0366 – 0.0478i	–0.0123 + 1.0502i	–3.4482e-6– 1.2449e-5i
2	0.0870 – 0.8550i	0.0500 – 0.0697i	–0.0226 + 0.4151i	0.0948 + 2.7669i	–0.1574 + 0.7793i	1.3967e-5 + 1.8324e-3i
3	0.0363 – 0.1783i	0.0095 – 0.0282i	–0.0160 + 0.0896i	–0.0378 + 0.4633i	–0.0266 + 0.1362i	1.3012e-5 + 2.4155e-4i

TABLE VI

THE EIGENVALUE SENSITIVITY WITH RESPECT TO δ , I_d , I_q , E'_d , E'_q AND E_{fd} FOR 10-MACHINE-39-BUS SYSTEM

Bus	$\partial\lambda/\partial\delta$	$\partial\lambda/\partial I_d$	$\partial\lambda/\partial I_q$	$\partial\lambda/\partial E'_d$	$\partial\lambda/\partial E'_q$	$\partial\lambda/\partial E_{fd}$
30	-3.16e-4 - 0.00232i	1.39e-5 + 1.0e-4i	5.27e-5 + 1.06e-4i	0.00242 - 9.89e-4i	- 3.54e-4 + 1.43e-4i	- 1.59e-5 + 2.86e-6i
31	-3.92e-5 - 2.85e-5i	- 2.3e-6 - 1.03e-6i	5.24e-6 + 2.17e-6i	2.68e-5 + 1.02e-5i	- 6.74e-6 - 2.5e-6i	- 2.61e-5 + 3.6e-5i
32	2.25e-4 - 0.00108i	4.91e-5 + 6.85e-5i	1.24e-4 + 2.47e-5i	3.12e-4 + 1.54e-4i	- 2.36e-4 - 1.04e-4i	- 1.50e-5 + 9.60e-6i
33	0.00101 - 0.00131i	5.86e-6 + 1.41e-4i	1.72e-4 + 7.88e-5i	1.84e-4 + 1.28e-4i	- 2.96e-4 - 1.52e-4i	- 1.05e-6 + 2.86e-7i
34	- 4.27e-5 + 1.8e-5i	- 1.15e-6 - 6.82e-6i	- 2.35e-5 - 1.83e-5i	- 6.84e-5 - 3.91e-5i	2.46e-5 + 1.37e-5i	4.0e-11 + 3.32e-11i
35	4.64e-4 - 0.00198i	4.04e-5 + 1.44e-4i	1.69e-4 + 5.7e-5i	4.35e-4 + 1.44e-4i	- 3.31e-4 - 9.07e-5i	- 3.78e-7 + 1.81e-7i
36	9.6e-5 + 8.31e-5i	-5.38e-6 - 3.51e-6i	- 2.09e-5 + 2.0e-6i	- 7.93e-5 + 1.77e-6i	5.28e-5 - 7.6e-6i	2.40e-5 + 1.11e-6i
37	0.181 - 0.155i	- 0.00837 + 0.028i	0.018 + 0.0145i	- 0.0089 - 0.00111i	- 0.0269 - 0.00806i	- 7.91e-5 - 1.30e-5i
38	-8.81e-4 - 0.00132i	8.51e-5 + 1.65e-6i	8.7e-5 - 7.61e-5i	2.79e-4 + 1.84e-4i	- 3.33e-4 - 7.76e-5i	- 3.24e-4 + 2.28e-4i
39	-1.79e-4 - 8.04e-5i	1.55e-7 + 1.68e-7i	1.62e-6 + 6.07e-7i	1.99e-4 + 5.42e-5i	- 2.86e-5 - 9.54e-6i	- 8.65e-8 + 1.01e-8i

TABLE VII

THE EIGENVALUE SENSITIVITY WITH RESPECT TO δ , I_d , I_q , E'_d , E'_q AND E_{fd} FOR 54-MACHINE-118-BUS SYSTEM

Bus	$\partial\lambda/\partial\delta$	$\partial\lambda/\partial I_d$	$\partial\lambda/\partial I_q$	$\partial\lambda/\partial E'_d$	$\partial\lambda/\partial E'_q$	$\partial\lambda/\partial E_{fd}$
10	5.1355e-09	5.2416e-11	-9.4100e-10	-1.1331e-08	-1.1104e-09	0
12	-1.1219e-09	1.4844e-10	1.4861e-10	7.6561e-10	-1.0634e-09	-1.2443e-11
25	3.6262e-09	2.5786e-10	-2.4252e-09	-7.1555e-09	-2.6930e-09	-2.8417e-14
26	4.5515e-09	1.2276e-10	-2.3310e-09	-9.4631e-09	-1.8446e-09	4.5222e-12
49	-4.3117e-05	-2.7353e-07	-3.3200e-05	-1.7483e-05	6.1140e-06	-5.5457e-07
54	-1.6234e-10	2.0614e-10	6.5119e-11	1.1625e-10	-8.3695e-10	-2.0612e-13
59	-3.4595e-03	-3.6862e-05	-2.7438e-02	-9.2154e-03	4.6920e-03	-9.0607e-03
61	-6.1512e-09	1.1018e-09	1.9096e-09	5.0725e-09	-5.0107e-09	-2.8909e-11
65	1.3498e-09	1.6066e-09	-1.6750e-09	-4.4204e-09	-7.3138e-09	-1.7325e-13
66	5.1286e-05	-2.8096e-06	-2.3138e-05	-5.3497e-05	2.0581e-05	0
69	-1.3274e-08	2.1136e-09	-5.2400e-09	-6.6154e-08	-4.5031e-08	0
80	3.6265e-08	4.1593e-10	-5.2035e-09	-6.2663e-08	-8.7947e-09	0
89	-1.9281e-08	8.7254e-09	-2.2950e-08	-5.8174e-08	-6.2924e-08	0
100	1.5075e-08	7.6177e-10	-9.1609e-09	-2.6989e-08	-7.9480e-09	1.5982e-14
103	4.2425e-07	-6.9775e-08	5.2766e-08	-3.5608e-07	1.0277e-07	-3.7526e-08
111	-5.2941e-10	9.8249e-10	1.7374e-10	3.4629e-10	-3.9872e-09	-6.4511e-14

TABLE VIII

THE EIGENVALUE SENSITIVITY WITH RESPECT TO V AND θ FOR THREE BENCHMARK SYSTEMS

Bus	3-machine-9-bus system		10-machine-39-bus system		54-machine-118-bus system	
	$\partial\lambda/\partial V$	$\partial\lambda/\partial\theta$	$\partial\lambda/\partial V$	$\partial\lambda/\partial\theta$	$\partial\lambda/\partial V$	$\partial\lambda/\partial\theta$
1	- 0.104 + 1.06i	- 0.0409 + 0.253i	- 7.12e-4 + 0.00274i	2.08e-4 - 5.98e-4i	7.80e-11	2.12e-10
2	0.304 - 0.478i	0.0989 - 0.162i	- 4.79e-4 + 0.0362i	0.00531 - 0.0467i	-1.62e-12	1.74e-12
3	0.0671 - 0.226i	0.00887 - 0.0332i	2.17e-4 + 0.00310i	5.50e-4 - 0.00180i	-6.63e-11	-1.82e-11
4	- 0.0488 + 0.920i	- 0.0267 + 0.222i	1.61e-4 + 0.00140i	2.34e-4 - 1.41e-4i	4.42e-9	-1.24e-9
5	- 0.0524 + 0.893i	- 0.0247 + 0.111i	- 1.86e-5 + 2.35e-4i	- 2.84e-5 + 2.87e-5i	7.58e-10	-9.27e-10
6	- 0.0344 + 0.470i	- 0.00577 + 0.0171i	3.71e-5 + 1.08e-4i	- 5.00e-5 + 3.01e-5i	2.45e-10	6.15e-10
7	- 0.0642 + 1.05i	- 0.0659 + 0.353i	2.46e-5 + 6.12e-6i	5.05e-5 + 1.75e-5i	-2.12e-11	-1.63e-11
8	- 0.00343 + 0.0843i	- 0.0113 + 0.0421i	- 2.17e-5 + 1.68e-5i	1.11e-4 + 2.97e-5i	3.18e-10	3.37e-10
9	- 0.0308 + 0.382i	- 0.0273 + 0.150i	- 1.03e-4 + 8.28e-7i	- 9.33e-6 + 5.01e-6i	4.05e-10	7.10e-11
10	--	--	2.68e-4 + 9.94e-4i	- 2.34e-4 - 8.55e-5i	1.01e-8	-6.80e-9
11	--	--	4.16e-5 + 1.06e-4i	- 3.84e-5 + 1.35e-5i	-7.33e-11	8.21e-12
12	--	--	1.08e-5 + 1.59e-5i	5.40e-7 + 7.34e-7i	1.48e-9	-4.77e-11
13	--	--	3.02e-5 + 1.72e-4i	- 4.16e-5 - 5.72e-7i	-2.55e-10	1.08e-10
14	--	--	2.49e-5 + 3.04e-4i	- 7.1e-5 + 5.03e-5i	-3.09e-10	1.21e-10
15	--	--	3.85e-5 + 1.99e-5i	6.57e-5 + 6.59e-6i	-2.92e-9	1.26e-9
16	--	--	- 4.91e-4 + 0.00255i	- 1.03e-4 - 9.67e-5i	-1.21e-11	7.02e-11
17	--	--	- 5.30e-4 + 0.00316i	- 6.33e-5 - 8.02e-5i	-6.63e-10	1.21e-9
18	--	--	4.12e-5 + 4.55e-4i	1.28e-4 - 1.88e-4i	-3.61e-10	-1.76e-11
19	--	--	- 1.29e-4 + 0.00137i	- 1.61e-4 - 4.17e-4i	-5.07e-9	1.91e-9
20	--	--	1.42e-4 - 7.41e-5i	- 2.89e-6 - 4.04e-5i	-2.62e-10	7.38e-11
21	--	--	- 3.46e-5 + 6.39e-4i	- 1.37e-4 - 4.86e-5i	-2.19e-10	8.56e-11
22	--	--	2.97e-4 + 0.00121i	- 2.33e-4 - 3.43e-4i	-2.56e-10	1.61e-10
23	--	--	3.90e-5 + 2.06e-4i	- 4.99e-5 - 9.38e-5i	4.87e-9	-1.06e-9
24	--	--	- 8.04e-5 + 2.46e-4i	- 2.12e-5 + 1.95e-6i	1.57e-8	5.95e-10
25	--	--	- 0.0147 + 0.171i	0.00234 - 0.0192i	8.50e-9	-7.33e-9
26	--	--	7.43e-4 + 0.0109i	4.25e-4 - 0.00234i	6.86e-9	-4.77e-9
27	--	--	- 2.79e-4 + 0.0021i	7.07e-4 - 0.00167i	2.54e-10	-4.86e-10
28	--	--	3.79e-4 + 0.00106i	2.10e-4 + 1.39e-4i	-3.68e-11	-1.42e-11
29	--	--	6.73e-4 + 0.00287i	- 3.80e-4 + 7.80e-4i	-4.23e-11	-4.94e-11
30	--	--	-0.00335+ 0.00448i	2.68e-4 + 0.00235i	-4.23e-10	6.71e-9
31	--	--	- 8.78e-5 - 3.98e-6i	- 5.32e-5 - 1.35e-5i	3.09e-10	-3.01e-10
32	--	--	- 0.00173 - 0.00118i	3.45e-5 + 0.00102i	1.98e-10	8.59e-10
33	--	--	- 9.69e-4 - 0.00266i	-7.65e-4 + 0.00173i	-4.45e-9	2.10e-9
34	--	--	1.55e-4 + 2.08e-4i	2.06e-5 + 1.05e-6i	-9.05e-8	-1.25e-8
35	--	--	- 0.00179 - 0.00289i	-3.89e-5 + 0.00237i	-8.14e-11	1.11e-10
36	--	--	2.32e-4 + 1.99e-5i	- 6.58e-5 - 4.85e-5i	-1.62e-9	-1.34e-9
37	--	--	0.0318 - 0.406i	- 0.190 + 0.227i	2.79e-9	9.31e-9
38	--	--	-0.00305+ 0.00195i	3.50e-4 + 9.44e-4i	1.26e-7	3.66e-9
39	--	--	- 3.12e-4 + 9.52e-4i	2.04e-4 + 3.55e-5i	-1.32e-9	3.99e-9
40	--	--	--	--	-1.59e-7	-6.89e-8
41	--	--	--	--	-7.30e-8	-1.06e-8
42	--	--	--	--	-1.67e-6	3.00e-7

43	--	--	--	--	-1.82e-7	4.03e-9
44	--	--	--	--	-1.03e-7	6.74e-8
45	--	--	--	--	-1.25e-7	4.30e-7
46	--	--	--	--	-2.09e-6	3.07e-7
47	--	--	--	--	-1.07e-6	4.12e-7
48	--	--	--	--	-2.08e-7	3.86e-7
49	--	--	--	--	-0.00422	0.00109
50	--	--	--	--	-2.18e-4	2.21e-5
51	--	--	--	--	-6.49e-4	5.24e-5
52	--	--	--	--	-4.91e-4	2.46e-5
53	--	--	--	--	-3.51e-4	3.51e-4
54	--	--	--	--	0.0758	-0.0135
55	--	--	--	--	-0.0118	0.00161
56	--	--	--	--	-0.0435	0.0076
57	--	--	--	--	-2.41e-4	1.73e-5
58	--	--	--	--	5.09e-6	2.79e-5
59	--	--	--	--	-0.0033	5.14e-4
60	--	--	--	--	1.27e-7	3.24e-8
61	--	--	--	--	2.61e-7	-4.56e-8
62	--	--	--	--	7.12e-8	-7.26e-9
63	--	--	--	--	3.58e-7	2.83e-7
64	--	--	--	--	5.00e-7	7.06e-8
65	--	--	--	--	4.29e-7	-8.38e-8
66	--	--	--	--	-6.09e-6	5.38e-8
67	--	--	--	--	3.51e-8	-6.78e-9
68	--	--	--	--	5.77e-8	-1.58e-8
69	--	--	--	--	-1.27e-6	4.49e-7
70	--	--	--	--	9.23e-9	1.47e-9
71	--	--	--	--	2.70e-9	-1.29e-9
72	--	--	--	--	6.29e-9	-1.43e-9
73	--	--	--	--	9.67e-10	-1.36e-10
74	--	--	--	--	8.62e-10	1.39e-9
75	--	--	--	--	-2.05e-9	-7.07e-10
76	--	--	--	--	-5.8e-10	8.10e-11
77	--	--	--	--	-8.08e-9	4.55e-9
78	--	--	--	--	-2.47e-10	-6.38e-10
79	--	--	--	--	-4.61e-11	-1.44e-11
80	--	--	--	--	6.02e-8	-3.32e-9
81	--	--	--	--	1.28e-8	-2.76e-8
82	--	--	--	--	-1.10e-9	-3.31e-9
83	--	--	--	--	3.15e-9	3.28e-9
84	--	--	--	--	6.36e-10	-4.23e-10
85	--	--	--	--	-3.26e-9	-1.52e-8
86	--	--	--	--	-3.87e-10	-1.28e-9

87	--	--	--	--	4.00e-9	-7.26e-10
88	--	--	--	--	6.29e-10	-1.17e-10
89	--	--	--	--	7.43e-8	-6.15e-8
90	--	--	--	--	4.60e-9	-2.13e-10
91	--	--	--	--	3.96e-9	6.62e-10
92	--	--	--	--	-2.63e-9	-1.28e-8
93	--	--	--	--	7.92e-10	-3.44e-10
94	--	--	--	--	1.58e-9	-8.50e-10
95	--	--	--	--	2.53e-10	-3.16e-10
96	--	--	--	--	2.66e-9	1.07e-8
97	--	--	--	--	-2.75e-11	1.17e-10
98	--	--	--	--	2.15e-10	3.28e-11
99	--	--	--	--	5.28e-9	-2.72e-10
100	--	--	--	--	2.07e-8	-2.79e-8
101	--	--	--	--	2.17e-10	7.34e-12
102	--	--	--	--	2.06e-10	-5.92e-11
103	--	--	--	--	5.21e-9	-6.53e-10
104	--	--	--	--	-5.31e-10	6.33e-10
105	--	--	--	--	-9.82e-10	7.47e-10
106	--	--	--	--	-4.12e-10	1.31e-10
107	--	--	--	--	4.13e-9	1.05e-9
108	--	--	--	--	-1.6e-10	-3.31e-11
109	--	--	--	--	-8.94e-11	2.93e-11
110	--	--	--	--	-1.02e-9	1.73e-9
111	--	--	--	--	8.20e-9	-6.03e-9
112	--	--	--	--	7.69e-9	2.46e-10
113	--	--	--	--	1.69e-10	-5.99e-12
114	--	--	--	--	-1.30e-12	1.02e-12
115	--	--	--	--	4.30e-12	-3.61e-12
116	--	--	--	--	3.81e-8	2.10e-8
117	--	--	--	--	5.17e-13	6.79e-13
118	--	--	--	--	-4.57e-10	6.47e-11

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