Appendix A

Data of power systems and wind turbines for robust PSS design and validation

The following parameters are used for simulation of the 16 plants (loading conditions) of the SMIB power system for IMOFC based PSS design.

Table A.1 Data of the generator in the single machine infinite bus system

Rated MVA (MVA)	160
Rated voltage (kV)	15
Excitation voltage (V)	375
Speed (r/min)	3600

Stator current (A)	6158.4
Field current (A)	926
Power factor	0.85
x_d (p.u.)	0.92
x_q (p.u.)	0.51
x'_d (p.u.)	0.30
x'_q (p.u.)	0.51

Table A.2 Data of the 16 loading conditions of the SMIB power system

	P_G (p.u.)	Q_G (p.u.)	K_1	K_2	K_3	K_4	K_5	K_6
1	0.40	0.20	1.0170	1.1239	0.2889	1.4385	0.0643	0.3291
2	0.50	0.20	1.1624	1.2983	0.2889	1.6618	0.0577	0.3083
3	0.60	0.20	1.4336	1.5855	0.2889	2.0294	0.0194	0.2628
4	0.75	0.20	1.1624	1.2983	0.2889	1.6618	0.0577	0.3308
5	1.00	0.20	1.5772	1.7402	0.2889	2.2274	-0.0309	0.2300
6	1.20	0.20	1.6342	1.8588	0.2889	2.3792	-0.1130	0.1988
7	1.40	0.20	1.6263	1.8752	0.2889	2.4003	-0.1328	0.1939
8	1.50	0.20	1.6117	1.8883	0.2889	2.4170	-0.1524	0.1898

9	1.60	0.20	1.6263	1.8152	0.2889	2.4003	-0.1328	0.1923
10	1.70	0.20	1.6117	1.8883	0.2889	2.4170	-0.1524	0.1838
11	1.80	0.20	1.5911	1.8987	0.2889	2.4303	-0.1717	0.1866
12	2.00	0.20	1.4977	1.9174	0.2889	2.4543	-0.1878	0.1805
13	1.0	0.25	1.4414	1.6216	0.3081	2.0641	-0.0469	0.2681
14	1.0	0.30	1.3197	1.5042	0.3263	1.9254	-0.0641	0.3020
15	1.0	0.35	1.2087	1.4107	0.3436	1.8057	-0.0820	0.3326
16	1.0	0.40	1.3288	1.7402	0.3600	1.7009	-0.1002	0.3608

Table A.3 Data of the exciter and time constant of synchronous generators

T_J (s)	K_A	T_E (s)	T'_{d0} (s)
10	100	0.02	6

The following parameters are used for simulation of IEEE three-machine nine-bus system for IMOFC based PSS design.

The diagram of the three-machine nine-bus system is also shown below in figure A.1.

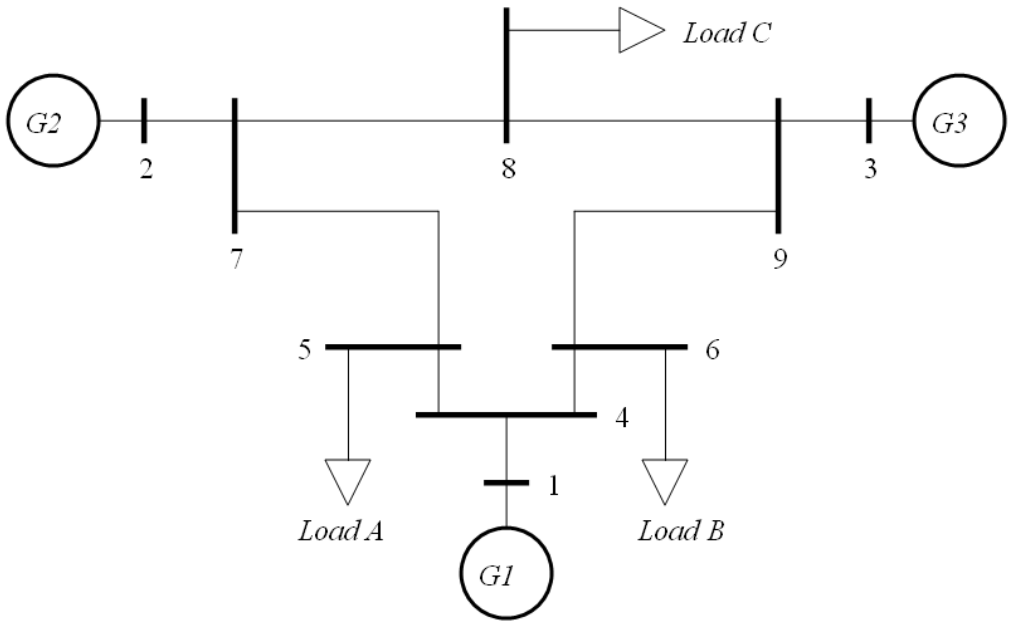

Figure A.1 Three-machine nine-bus power system

Table A.4 Data of generators in the three-machine nine-bus power system

Generator	1	2	3
Rated MVA (MVA)	247.5	192.0	128.0
Rated voltage (kV)	16.5	18.0	13.8
Power factor	1.0	0.85	0.85
Type	Hydro	Steam	Steam
Speed (r/min)	180	3600	3600
D_{pg}	12	6	4
E'_q (p.u.)	1.0558	0.7882	0.7659
x_d (p.u.)	0.1460	0.8958	1.3125

x_q (p.u.)	0.0969	0.8645	1.2578
x'_d (p.u.)	0.0608	0.1198	0.1813
x'_q (p.u.)	0.0969	0.1969	0.2500
x_l (leakage) (p.u.)	0.0336	0.0521	0.0742
T'_{d0} (s)	8.96	6.00	5.89
T'_{q0} (s)	0	0.535	0.600
T_J (s)	47.28	12.80	6.02
K_A	200	200	200
T_E (s)	0.02	0.02	0.02
Stored energy at rated speed	2364 MWs	640MWs	301MWs

Table A.5 Prefault network of the three-machine nine-bus power system

	Bus number	Impedance	
		Resistance (p.u.)	Reactance (p.u.)
G1	1 – 4	0	0.1184
G2	2 – 7	0	0.1823
G3	3 – 9	0	0.2399

Transmission line 4	4 – 5	0.0100	0.0850
Transmission line 5	5 – 7	0.0320	0.1610
Transmission line 6	4 – 6	0.0170	0.0920
Transmission line 7	7 – 8	0.0085	0.0720
Transmission line 8	8 – 9	0.0119	0.1008
Transmission line 9	6 – 9	0.0390	0.1700

Table A.6 Prefault admittance matrix of the three-machine nine-bus power system

Node	1	2	3
1	0.846 - j2.988	0.287 + j1.513	0.210 + j1.226
2	0.287 + j1.513	0.420 - j2.724	0.213 + j1.088
3	0.210 + j1.226	0.213 + j1.088	0.277 – j2.368

The following parameters are used for simulation of the DFIG wind turbine for IMOFC based PSS design.

Table A.7 Data of the DFIG wind turbine for PSS study

Blade radius (m)	40	Base power (MVA)	1.5
Rated power of DFIG (MVA)	1.5	Rated rotor speed (p.u.)	1.1

T_j (s)	7	ω_s (p.u.)	1
Stator voltage (V)	575	Wind speed (m/s)	12
R_s (p.u.)	0.00488	R_r (p.u.)	0.00549
L_s (p.u.)	0.09241	L_r (p.u.)	0.09955
L_m (p.u.)	3.95279	φ (rad)	0.5637
DC capacitor (F)	0.06	Friction factor (p.u.)	0.01
Inertia constant of wind turbine	0.01	Optimal constant of wind turbine	0.579
Resistance of grid-side inductor (p.u.)	0.003	Inductance of grid-side inductor (p.u.)	0.3
DC link voltage (V)	1200	Infinite bus voltage (V)	25
Resistance of transformer and transmission line (Ω)	4	Inductance of transformer and transmission line (H)	0.085
K_{P1}	0.0406	K_{I1}	3.0530
K_{P2}	0.1491	K_{I2}	15.5313