IEEE 9 BUS POWER SYSTEM

1.1 INTRODUCTION

The IEEE 9 bus power system represents a reduced equivalent of the Western System Coordinating Council (WSCC) system. Figure 1 shows the one line diagram of the test system [1]. The data pertaining to the system are given in Section 1.2. The power flow results from RSCAD® and PSS®E are compared in Section 1.3 to show that a close match can be achieved. Section 1.4 lists references related to the data and models used in the system.

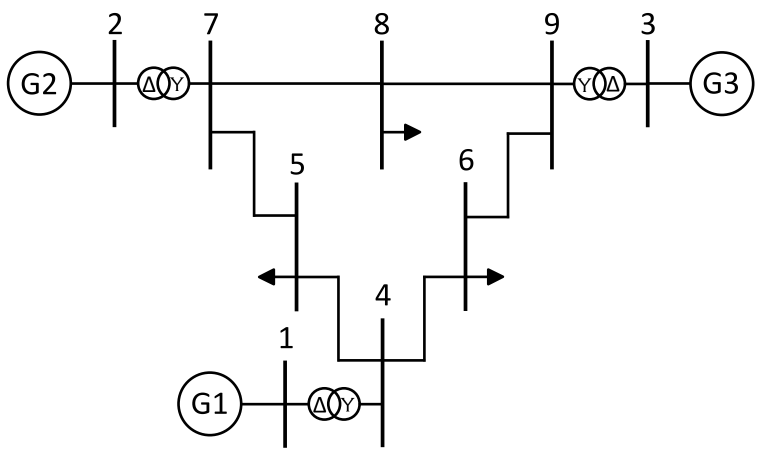

Figure 1: One-Line Diagram of IEEE 9 Bus Power System

1.2 SYSTEM DATA

1.2.1 Power Flow Data

The power flow data of the system expressed in 100 MVA base are taken from [1].

Table 1: Power Flow Data

BUS	Type	V (pu)	PG (MW)	QG (MVAr)	PL (MW)	QL (MVAr)
1	SLACK	1.040 ∠0.0°	71.6	27.0	-	-
2	P-V	1.025 ∠9.3°	163.0	6.7	-	-
3	P-V	1.025 ∠4.7°	85.0	-10.9	-	-
4	P-Q	1.026 ∠-2.2°	-	-	-	-
5	P-Q	0.996 ∠-4.0°	-	-	125.0	50.0
6	P-Q	1.013 ∠-3.7°	-	-	90.0	30.0
7	P-Q	1.026 ∠3.7°	-	-	-	-
8	P-Q	1.016 ∠0.7°	-	-	100.0	35.0
9	P-Q	1.032 ∠2.0°	-	-	-	-

Table 2: Line Data

From BUS	To BUS	R (pu)	X (pu)	B (pu)
4	5	0.0100	0.0850	0.1760
4	6	0.0170	0.0920	0.1580
5	7	0.0320	0.1610	0.3060
6	9	0.0390	0.1700	0.3580
7	8	0.0085	0.0720	0.1490
8	9	0.0119	0.1008	0.2090

Table 3: Transformer Data

From BUS	To BUS	R (pu)	X (pu)	Tap Ratio[1]
1	4	0.0	0.0576	1.0
2	7	0.0	0.0625	1.0
3	9	0.0	0.0586	1.0

1.2.2 Dynamic Data

The dynamic data available in [1] does not contain the sub-transient data for generators. Therefore, to suppress the sub-transient effect, the following assumptions were made when choosing missing data.

- To satisfy condition, Xq" < Xd' for typical data [3], Xd" and Xq" are chosen to be $\leq$ Xd'
- Tdo" = Tqo" $\simeq$ 0.0
- The Xa was assumed to be 10 % of Xd
- In [1], the Xq and Xq' data of Generator-1 are same. To satisfy condition Xq > Xq' for typical data [3], the Xq of Generator-1 is used as 0.1 pu on 100 MVA base
- The synchronous machine model in RSCAD has a minimum value for Ra. Therefore, the ‘Ra’ is set to the minimum allowed value, which is 0.000125 pu on generator MVA

The exciter information provided in [1] correspond to the 'IEEE Type DC1A' excitation system [2]. The 'TGOV' type thermal governor [4] is used for frequency regulation of all generators.

NOTE:
It was assumed that the branch data provided in [1] is compensated for long line effects. The transmission lines in RSCAD simulation case is modelled using Bergeron line which is simulated using distributed line parameters. Therefore, the long line compensation was removed [5] to obtain the uncompensated data, which is used in the RSCAD case.

[1] Tap ratio is set to the from bus side of the transformer

Table 4: Generator Data-1 (100 MVA Base)

GEN	BUS	Xa (pu)	Xd (pu)	Xd' (pu)	Xd" (pu)	Xq (pu)	Xq' (pu)	Xq" (pu)
1	5	0.01460	0.1460	0.0608	0.06	0.1000	0.0969	0.06
2	7	0.08958	0.8958	0.1198	0.11	0.8645	0.1969	0.11
3	9	0.13125	1.3125	0.1813	0.18	1.2578	0.2500	0.18

Table 5: Generator Data-2 (100 MVA Base)

GEN	BUS	Ra (pu)[2]	Tdo' (s)	Tdo" (s)	Tqo' (s)	Tqo" (s)	H (s)	D(pu/pu)
1	5	0.000125	8.96	0.01	0.310	0.01	23.64	0.0
2	7	0.000125	6.00	0.01	0.535	0.01	6.40	0.0
3	9	0.000125	5.89	0.01	0.600	0.01	3.01	0.0

Table 6: Exciter Data-1 (IEEE Type DC1A)

GEN	KA	TA	VRmin	VRmax	KE	TE	KF	TF
1	20.0	0.2	-5.0	5.0	1.0	0.314	0.063	0.35
2	20.0	0.2	-5.0	5.0	1.0	0.314	0.063	0.35
3	20.0	0.2	-5.0	5.0	1.0	0.314	0.063	0.35

Table 7: Exciter Data-2 (IEEE Type DC1A)

GEN	EX1	S(EX1)	EX2	S(EX2)
2	3.3	0.6602	4.5	4.2662
3	3.3	0.6602	4.5	4.2662
4	3.3	0.6602	4.5	4.2662

Table 8: Governor Data (TGOV1)

GEN	R	T1	Vmax	Vmin	T2	T3	Dt
1	0.05	0.05	5.00	-5.00	2.1	7.0	0.0
2	0.05	0.05	5.00	-5.00	2.1	7.0	0.0
3	0.05	0.05	5.00	-5.00	2.1	7.0	0.0

[2] The stator resistance (Ra) is given as 0 pu in [1]. However, the synchronous machine model in RSCAD has a minimum value for this entry. Therefore, the 'Ra' is set to the minimum allowed value, which is 0.000125 pu on generator MVA.

1.3 COMPARISON OF LOADFLOW RESULTS

Table 9: Load Flow Results of Generator Buses

BUS	|V| (pu)		∠V (deg)[3]		P_G (MW)		Q_G (MVAr)	
	RTDS	PSSE	RTDS	PSSE	RTDS	PSSE	RTDS	PSSE
1	1.0400	1.0400	-30.0000	0.0000	71.722	71.642	27.042	27.052
2	1.0250	1.0250	-20.7264	9.2805	163.000	163.000	6.654	6.659
3	1.0250	1.0250	-25.3422	4.6651	85.000	85.000	-10.857	-10.856

Table 10: Load Flow Results of Load Buses

BUS	|V| (pu)		∠V (deg)	
	RTDS	PSSE	RTDS	PSSE
4	1.0258	1.0258	-2.2193	-2.2168
5	0.9956	0.9956	-3.9930	-3.9890
6	1.0127	1.0127	-3.6921	-3.6875
7	1.0258	1.0258	3.7133	3.7200
8	1.0159	1.0159	0.7209	0.7277
9	1.0322	1.0323	1.9598	1.9669

1.4 REFERENCES

[1] P.W. Sauer and M.A. Pai, "Power System Dynamics and Stability," *IEEE Press.* 1998.
[2] "Excitation System Models for Power System Stability Studies," *IEEE Trans. Power App. Syst.*, Vol. PAS-100, pp.494-509, 1981.
[3] P.S. Kundur, Power System Stability and Control, *New York, McGraw−Hill*, 1983.
[4] "Dynamic Models for Steam and Hydro Turbines in Power System Studies," *IEEE Trans. Power App. Syst.*, Vol. PAS-92, No. 6, pp.1904-1915, 1973.
[5] J.J. Grainger and W.D. Stevenson, Power System Analysis, *McGraw−Hill Inc.*, 1994.

[3] The 30 degree difference in voltage angle is due to the Y-Δ step-up transformers at the generator buses in RSCAD.