IEEE 9 Bus Power System

Contents

1. CASE INFORMATION

Case Name	IEEE 9 Bus Power System
Location	RSCAD\Example Cases\Benchmark Systems
Revision Date	01 – November, 2022
Created by	Arunprasanth Sakthivel
Target	PB5, NovaCor
Minimum Hardware	1 x NovaCor Chassis with at least 1 enabled core 1 x PB5 based rack with at least 2 PB5 cards
Keywords	Generator, Exciter, Governor, Fault, Transmission line
Purpose	To provide an RSCAD model of the IEEE 9 bus power system

2. 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 3. The power flow results from RSCAD® and PSS®E are compared in Section 4 to show that a close match can be achieved. Section 5 lists references related to the data and models used in the system.

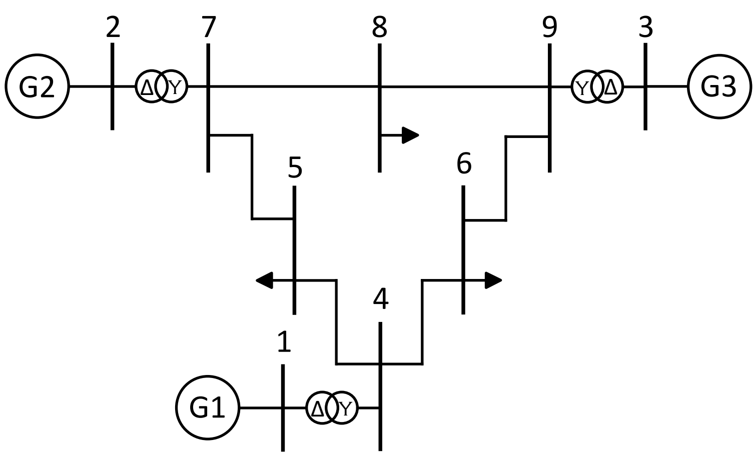

Figure 1 : One-Line Diagram of IEEE 9 Bus Power System

3. SYSTEM MODELLING

The power flow data of the system expressed in 100 MVA base are taken from [1]. 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 [2], Xd" and Xq" are chosen to be ≤ Xd'
- Tdo" = Tqo" ≃ 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 [2], the Xq of Generator-1 is increased 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. The 'TGOV' type thermal governor is used for frequency regulation of all generators. It was assumed that the line data provided in [1] is compensated for long line effects. The transmission lines in RSCAD simulation case is modelled using Bergeron model, which is simulated using distributed line parameters. Therefore, the long line compensation was removed [3] to obtain the uncompensated data, which is used in the RSCAD case.

Table 1 Bus 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

NOTE: The transmission lines in RSCAD case have been configured to read data from the tlines file located in the case folder. If required, tline data input files (.tli) of all transmission lines can be found inside the 'Tline Files' folder.

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

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

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

Table 5 Generator Data-2 (100 MVA Base)

GEN	BUS	Ra (pu)	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

4. LOADFLOW RESULTS

The loadflow results obtained using the embedded loadflow program in RSCAD is compared against the PSS/E loadflow results in Table 9 and Table 10. More details on benchmarking a standard power system can be found in [4].

Table 9 Load Flow Results of Generator Buses

BUS	|V| (pu)		∠V (deg)[2]		PG (MW)		QG (MVAr)	
	RTDS	PSS/E	RTDS	PSS/E	RTDS	PSS/E	RTDS	PSS/E
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	PSS/E	RTDS	PSS/E
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

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

5. REFERENCES

[1] P.W. Sauer and M.A. Pai, "Power System Dynamics and Stability," IEEE Press. 1998.

[2] P.S. Kundur, Power System Stability and Control, New York, McGraw−Hill, 1983.

[3] J.J. Grainger and W.D. Stevenson, Power System Analysis, McGraw−Hill Inc., 1994.

[4] S. Arunprasanth, H. Meiklejohn, and R. Wierckx, "Benchmarking Standard Power Test Systems for Real-Time Simulation Studies", CIGRE Sessions-2018