Benchmark Systems
Modeling Description

Abstract: This document describes the modeling of the Benchmark Examples using the OpenDSS Library from the Typhoon HIL toolchain. The main goal of these systems is to support a starting point for the usage of the library applying its key features. The library modeling technique/features are applied according to the electrical system characteristics in the study.

CONTENTS

IEEE SYSTEMS

IEEE 13 BUS FEEDER (DISTRIBUTION SYSTEMS)

The IEEE 13 Bus feeder is commonly employed in studies involving distribution systems. Despite being a small system, the feeder has interesting characteristics [1]:

- Short and relatively loaded for a 4.16 kV feeder:
  - Unbalanced spot and distributed loads (~3466 MW and 2102 MVAR);
- Variety Overhead and Underground lines topologies:
  - Ten branches (~2.5 km of lines)
- Voltage Regulation equipment:
  - One series voltage regulator (three single-phase transformers);
  - Shunt Capacitor banks (one single-phase and one three-phase bank).

The feeder topology is shown in Figure 1. The system mainly operates at 4.16 kV. The reference provides one substation transformer data operating at 115 kV, but it is not considered in the modeling. Three single-phase voltage regulators are used between the #650 and #632 buses. At the default configuration, the transformers are parameterized using a line voltage drop compensation, but the current stage of the library does not support this feature. A modification on the voltage reference of the regulator is implemented to match the secondary level of the voltage regulator.

The inherent unbalance of the feeder is preserved through the load connections and line representation. All the loads from the feeder are modeled using a constant impedance approach. The lines are modeled using a matrix representation from linecodes feature from the library. All modeling data is provided in the following subsections.

The power flow results compared in Table 2 and Table 1 show a close match between the model and the reference, even with the abovementioned modifications. Table 2 compares the voltages at the load nodes. The DSS column refers to the results obtained from the SymDSS component from the Schematic Editor, and the SCADA column is the steady state voltages from the runtime simulation.

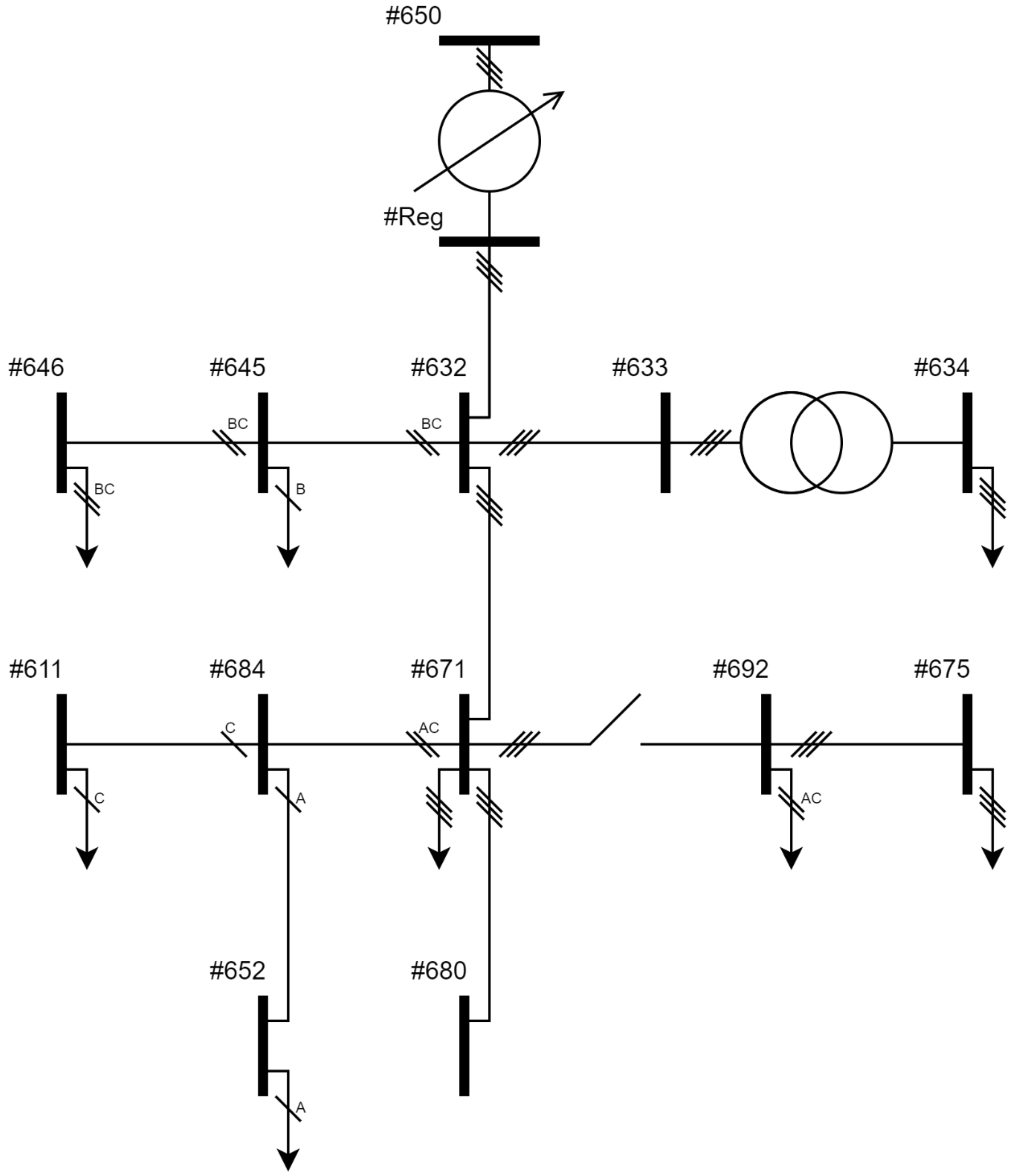

Figure 1 – Single Line diagram of the IEEE 13 Bus Feeder.

Results

Table 1. Power Flow – System Input.

#	IEEE Phase A	DSS Phase A	SCADA Phase A	IEEE Phase B	DSS Phase B	SCADA Phase B	IEEE Phase C	DSS Phase C	SCADA Phase C
kW	1251.398	1175.000	1148.630	977.332	1041.300	1017.119	1348.461	1288.100	1367.993
kvar	681.570	654.200	653.87.	373.418	409.700	398.557	669.784	772.600	751.164
kVA	1424.968	1344.800	1321.704	1046.241	1119.000	1092.419	1505.642	1502.000	1560.658
PF	0.8782	0.874	0.8691	0.9341	0.931	0.9311	0.8956	0.858	0.8765

Table 2. Power Flow – Load Voltages Magnitudes.

Bus/Node	Phase	IEEE	DSS	SCADA	Bus/Node	Phase	IEEE	DSS	SCADA
#650	Va	1.0000	0.9999	1.0017	**#671**	Va	0.9900	0.9448	0.9348
	Vb	1.0000	1.0003	1.0003		Vb	1.0529	1.0583	1.0358
	Vc	1.0000	0.9998	0.9979		Vc	0.9778	0.9818	1.0146
#632	Va	1.0210	0.9925	0.9968	**#652**	Va	0.9825	0.9377	0.9247
	Vb	1.0420	1.0483	1.0148		Vb	--	--	--
	Vc	1.0174	1.0134	1.0392		Vc	--	--	--
#634	Va	0.9940	0.9665	0.9433	**#611**	Va	--	--	--
	Vb	1.0218	1.0270	0.9906		Vb	--	--	--
	Vc	0.9960	0.9923	1.0502		Vc	0.9738	0.9762	1.0133
#645	Va	--	--	--	**#692**	Va	0.9900	0.9447	0.9319
	Vb	1.0329	1.0387	1.0188		Vb	1.0529	1.0583	--
	Vc	1.0155	1.0115	--		Vc	0.9777	0.9818	1.0173
#646	Va	--	--	--	**#675**	Va	0.9835	0.9388	0.9269
	Vb	1.0311	1.0369	1.0171		Vb	1.0553	1.0604	1.0390
	Vc	1.0134	1.0094	1.0387		Vc	0.9758	0.9799	1.0132

Table 3. Power Flow – Load Voltages Errors.

Bus/Node	Phase	DSS	SCADA	Bus/Node	Phase	DSS	SCADA
#650	Va	0.01%	-0.17%	**#671**	Va	4.56%	5.58%
	Vb	-0.03%	-0.03%		Vb	-0.51%	1.62%
	Vc	0.02%	0.21%		Vc	-0.41%	-3.76%
#632	Va	2.80%	2.37%	**#652**	Va	4.56%	5.88%
	Vb	-0.60%	2.61%		Vb	--	--
	Vc	0.39%	-2.14%		Vc	--	--
#634	Va	2.77%	5.10%	**#611**	Va	--	--
	Vb	-0.51%	3.05%		Vb	--	--
	Vc	0.38%	-5.44%		Vc	-0.25%	-4.06%
#645	Va	--	--	**#692**	Va	4.57%	5.87%
	Vb	-0.56%	1.37%		Vb	-0.51%	--
	Vc	0.39%	--		Vc	-0.41%	-4.05%
#646	Va	--	--	**#675**	Va	4.55%	5.75%
	Vb	-0.56%	1.36%		Vb	-0.48%	1.54%
	Vc	0.39%	-2.50%		Vc	-0.42%	-3.83%

Modeling Data

Table 4. Line Segment Data.

Line	From (#node)	To (#node)	Config ID	km	Phases
Line_650632	#650	#632	601	0.610	ABC
Line_632645	#632	#645	603	0.152	BC
Line_632633	#632	#633	602	0.152	ABC
XFM-1	#633	#634	500 kVA – 4.16/0.48 kV (Ynyn); Z=1.1+2%		
Line_645646	#645	#646	603	0.091	BC
Line_632671	#632	#671	601	0.610	ABC
Line_671684	#671	#684	604	0.091	AC
Line_671680	#671	#680	601	0.305	ABC
Switch	#671	#692	Static Switch (ABC)		
Line_684652	#684	#652	607	0.244	A
Line_684611	#684	#611	605	0.091	C
Line_692675	#692	#675	606	0.152	ABC

Table 5. Load Data.

Node	S_A [kVA]	FP_A	S_B [kVA]	FP_B	S_C [kVA]	FP_C	Notes
#634	194.16	0.82	150.00	0.80	150.00	0.80	Spot Load (Y ABC)
#645	--	--	211.01	0.81	--	--	Spot Load (B)
#646	--	--	265.19	0.87	--	--	Spot Load (BC)
#652	154.21	0.83	--	--	--	--	Spot Load (A)
#671	443.42	0.87	443.42	0.87	443.42	0.87	Spot Load (D ABC)
#675	520.89	0.93	90.69	0.75	359.23	0.81	Spot Load (Y ABC)
#692	--	--	--	--	227.38	0.75	Spot Load (AC)
#611	--	--	--	--	187.88	0.90	Spot Load (C)
#632	19.72/2	0.86	76.16/2	0.87	135.33/2	0.86	Distr. Load (Y ABC)
#671	19.72/2	0.86	76.16/2	0.87	135.33/2	0.86	Distr. Load (Y ABC)
#675	200	--	200	--	200	--	Capacitor (Y ABC)
#611	--	--	--	--	100	--	Capacitor (C)

Table 6. Impedances for Configuration 601 (Linecode CONFIG_601).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
0.2153			0.6325			10.3836		
0.0969	0.2097		0.3117	0.6511		-3.2896	9.8230	
0.0982	0.0954	0.2121	0.0982	0.2392	0.6430	-2.0760	-1.2225	9.2938

Table 7. Impedances for Configuration 602 (Linecode CONFIG_602).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
0.4676			0.7341			9.3933		
0.0982	0.4645		0.2632	0.7446		-1.7829	8.5371	
0.0969	0.0954	0.4621	0.3117	0.2392	0.7526	-2.7864	-1.0859	8.9411

Table 8. Impedances for Configuration 603 (Linecode CONFIG_603).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
--			--			--		
--	0.8261		--	0.8371		--	7.7627	
--	0.1284	0.8226	--	0.2853	0.8431	--	-1.4833	7.6904

Table 9. Impedances for Configuration 604 (Linecode CONFIG_604).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
0.8226			0.8431			7.6904		
--	--		--	--		--	--	
0.1284	--	0.8261	0.2853	--	0.8371	-1.4833	--	7.7627

Table 10. Impedances for Configuration 605 (Linecode CONFIG_605).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
--			--			--		
--	--		--	--		--	--	
--	--	0.8259	--	--	0.8373	--	--	7.4489

Table 11. Impedances for Configuration 606 (Linecode CONFIG_606).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
0.4960			0.2773			159.6977		
0.1983	0.4903		0.0204	0.2511		--	159.6977	
0.1770	0.1983	0.4960	-0.0089	0.0204	0.2773	--	--	159.6977

Table 12. Impedances for Configuration 607 (Linecode CONFIG_607).

Resistance Matrix (Ω/km)			Reactance Matrix (Ω/km)			Capacitance Matrix (nF/km)		
0.8342			0.3184			148.3273		
--	--		--	--		--	--	
--	--	--	--	--	--	--	--	--

Table 13. Voltage Regulator Settings.

Regulator ID:	1		
Line Segment:	650 - 632		
Location:	50		
Phases:	A - B -C		
Connection:	3-Ph,LG		
Monitoring Phase:	A-B-C		
Bandwidth:	2.0 volts		
PT Ratio:	20		
Primary CT Rating:*	700		
Compensator Settings:*	Ph-A	Ph-B	Ph-C
R - Setting:*	3	3	3
X - Setting:*	9	9	9
Volltage Level:	122	122	122

References

[1] – IEEE 13 Bus Feeder (https://cmte.ieee.org/pes-testfeeders/resources/)