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.

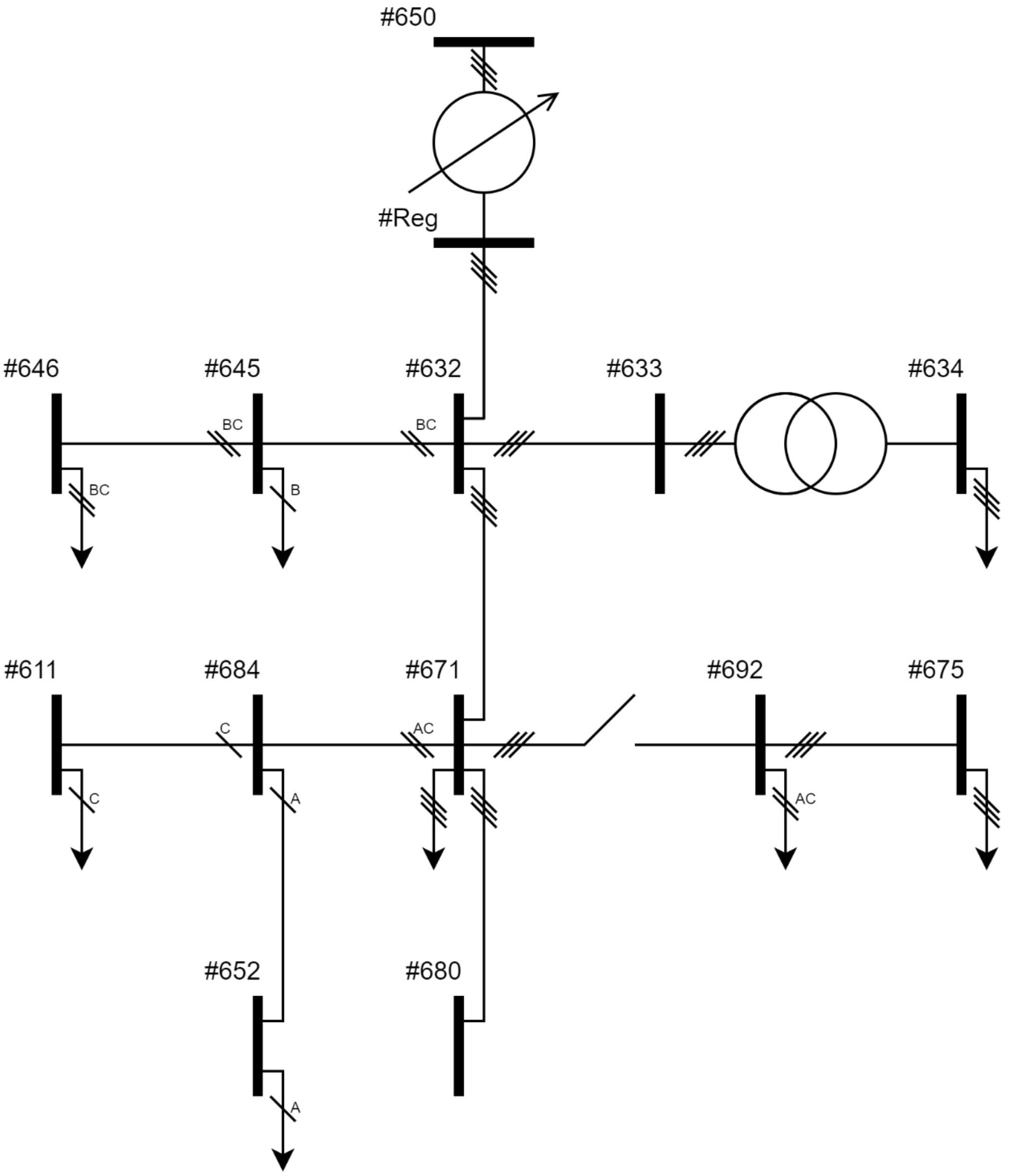

Figure 1 – Single Line diagram of the IEEE 13 Bus Feeder.

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	1177.700	1135.211	977.332	1037.700	1016.234	1348.461	1301.500	1377.268
kvar	681.570	650.500	648.132	373.418	407.200	400.899	669.784	705.300	764.008
kVA	1424.968	1345.400	1307.203	1046.241	1114.700	1092.452	1505.642	1480.300	1574.984
PF	0.8782	0.8753	0.868	0.9341	0.9309	0.9302	0.8956	0.8792	0.8745

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	1.0021	**#671**	Va	0.9900	0.9454	0.9295
	Vb	1.0000	1.0002	0.9999		Vb	1.0529	1.0536	1.0356
	Vc	1.0000	0.9998	0.9979		Vc	0.9778	0.9901	1.0197
#632	Va	1.0210	0.9928	0.9929	**#652**	Va	0.9825	0.9382	0.9182
	Vb	1.0420	1.0451	1.0140		Vb	--	--	--
	Vc	1.0174	1.0176	1.0444		Vc	--	--	--
#634	Va	0.9940	0.9668	0.9332	**#611**	Va	--	--	--
	Vb	1.0218	1.0239	0.9962		Vb	--	--	--
	Vc	0.9960	0.9963	1.0558		Vc	0.9738	0.9862	1.0156
#645	Va	--	--	--	**#692**	Va	0.9900	0.9453	1.0190
	Vb	1.0329	1.0355	1.0298		Vb	1.0529	1.0536	--*
	Vc	1.0155	1.0157	--*		Vc	0.9777	0.9900	0.9288
#646	Va	--	--	--	**#675**	Va	0.9835	0.9394	0.9215
	Vb	1.0311	1.0337	1.0240		Vb	1.0553	1.0557	1.0385
	Vc	1.0134	1.0136	1.0333		Vc	0.9758	0.9881	1.0182

Table 3. Power Flow – Load Voltages Errors.

Bus/Node	Phase	DSS	SCADA	Bus/Node	Phase	DSS	SCADA
#650	Va	0.01%	-0.21%	**#671**	Va	4.51%	6.11%
	Vb	-0.02%	0.01%		Vb	-0.07%	1.64%
	Vc	0.02%	0.21%		Vc	-1.26%	-4.29%
#632	Va	2.76%	2.75%	**#652**	Va	4.50%	6.54%
	Vb	-0.30%	2.69%		Vb	--	--
	Vc	-0.02%	-2.65%		Vc	--	--
#634	Va	2.74%	6.12%	**#611**	Va	--	--
	Vb	-0.21%	2.51%		Vb	--	--
	Vc	-0.03%	-6.00%		Vc	-1.27%	-4.29%

Bus/Node	Phase	DSS	SCADA	Bus/Node	Phase	DSS	SCADA
#645	Va	--	--	**#692**	Va	4.52%	-2.93%
	Vb	-0.25%	0.30%		Vb	-0.07%	--*
	Vc	-0.02%	--*		Vc	-1.26%	5.00%
#646	Va	--	--	**#675**	Va	4.49%	6.30%
	Vb	-0.25%	0.69%		Vb	-0.04%	1.59%
	Vc	-0.02%	-1.96%		Vc	-1.26%	-4.35%

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/)

CIGRE SYSTEMS

CIGRE EUROPEAN MEDIUM VOLTAGE (DISTRIBUTION SYSTEMS)

The CIGRE Medium Voltage distribution network is derived from a physical network in southern Germany [2], which supplies a small town and the surrounding rural area. In the European version, the modeling does not include unbalances on lines and loads.

Figure 2 shows the topology of the feeder. The system operates at 20 kV 50 Hz via separate transformers (T1 and T2) from the 110 kV transmission network. The topology can be modified between radial/radial/meshed configurations through S1, S2, and S3 switches.

The data modeling is presented in the following subsections. All lines are symmetrical, and the loads are represented as constant impedance. A fixed tap at the transformers T1 and T2 is set manually on the transformer parameterization (without voltage regulator).

The power flow results in the Results subsection show a good match between the OpenDSS and SCADA models compared to the reference.

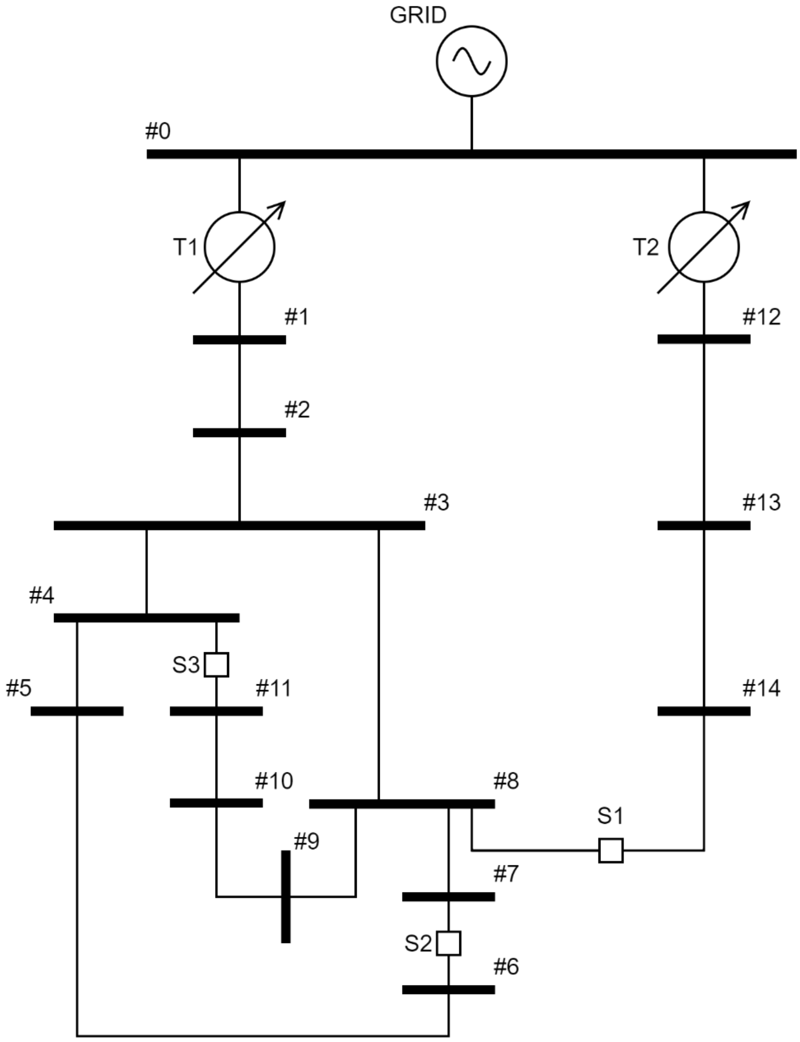

Figure 2 – Single Line diagram of the CIGRE European MV Feeder.

Results

Table 14. Power Flow – Load Voltages Magnitudes.

Bus	CIGRE	DSS	SCADA	Bus	CIGRE	DSS	SCADA
#0	1.0000	1.0007	1.0004	**#8**	0.9665	0.9625	0.9643
#1	1.0260	1.0213	1.0227	**#9**	0.9655	0.9616	0.9634
#2	1.0045	1.0003	--	**#10**	0.9645	0.9605	0.9623
#3	0.9715	0.9674	0.9675	**#11**	0.9645	0.9603	0.9621
#4	0.9700	0.9657	0.9697	**#12**	1.0020	1.0004	1.0036
#5	0.9690	0.9646	0.9664	**#13**	0.9970	0.9956	0.9986
#6	0.9675	0.9632	0.9651	**#14**	0.9940	0.9929	0.9958
#7	0.9665	0.9622	0.9640				

Table 15. Power Flow – Load Voltages Errors.

Bus	DSS	SCADA	Bus	DSS	SCADA
#0	-0.07%	-0.04%	**#8**	0.42%	0.23%
#1	0.46%	0.32%	**#9**	0.41%	0.22%
#2	0.42%	--	**#10**	0.42%	0.23%
#3	0.43%	0.41%	**#11**	0.44%	0.25%
#4	0.44%	0.03%	**#12**	0.16%	-0.16%
#5	0.46%	0.27%	**#13**	0.14%	-0.16%
#6	0.44%	0.25%	**#14**	0.11%	-0.18%
#7	0.44%	0.26%			

Table 16. Power Flow – System Input.

Meas.	CIGRE	DSS		SCADA	
		Value	Error	Value	Error
P (MW)	45.9076	45.5472	0.79%	46.5141	-1.32%
Q (Mvar)	16.5096	16.8198	-1.88%	15.7301	4.72%
S (MVA)	48.7860	48.5536	0.48%	49.1018	-0.65%
PF	0.9410	0.9381	0.31%	0.9473	-0.67%

Modeling Data

Table 17. Line Segment Data.

Line	From (#Bus)	To (#Bus)	R1 (Ω/km)	X1 (Ω/km)	C1 (nF/km)	R0 (Ω/km)	x0 (Ω/km)	C0 (nF/km)	km
Line_1	#1	#2	0.501	0.716	151.175	0.817	1.598	151.175	2.82
Line_2	#2	#3	0.501	0.716	151.175	0.817	1.598	151.175	4.42
Line_3	#3	#4	0.501	0.716	151.175	0.817	1.598	151.175	0.61
Line_4	#4	#5	0.501	0.716	151.175	0.817	1.598	151.175	0.56
Line_5	#5	#6	0.501	0.716	151.175	0.817	1.598	151.175	1.54
Line_6	#6	#7	0.501	0.716	151.175	0.817	1.598	151.175	0.24
Line_7	#7	#8	0.501	0.716	151.175	0.817	1.598	151.175	1.67
Line_8	#8	#9	0.501	0.716	151.175	0.817	1.598	151.175	0.32
Line_9	#9	#10	0.501	0.716	151.175	0.817	1.598	151.175	0.77
Line_10	#10	#11	0.501	0.716	151.175	0.817	1.598	151.175	0.33
Line_11	#11	#4	0.501	0.716	151.175	0.817	1.598	151.175	0.49
Line_12	#3	#8	0.501	0.716	151.175	0.817	1.598	151.175	1.30
Line_13	#12	#13	0.510	0.366	10.097	0.658	1.611	4.0743	4.89
Line_14	#13	#14	0.510	0.366	10.097	0.658	1.611	4.0743	2.99
Line_15	#14	#8	0.510	0.366	10.097	0.658	1.611	4.0743	2.00

Table 18. Transformers T1 and T2 data.

Rated Primary Voltage:	110 kV
Rated Secondary Voltage:	20 kV
Connection:	Dyn
Rated Power:	25 MVA
R:	1 %
X:	12 %

Table 19. Load Data.

Bus	Residential		Industrial	
	S [kVA]	PF	S [kVA]	PF
#1	15300	0.98	5100	0.95
#2	---	---	---	---
#3	285	0.97	265	0.85
#4	445	0.97	---	---
#5	750	0.97	---	---
#6	565	0.97	---	---
#7	---	---	90	0.85
#8	605	0.97	---	---
#9	---	---	675	0.85
#10	490	0.97	80	0.85
#11	340	0.97	---	---
#12	15300	0.98	5280	0.95
#13	---	---	40	0.85
#14	215	0.97	390	0.85

References

[2] - TF C6.04.02 : TB 575 -- Benchmark Systems for Network Integration of Renewable and Distributed Energy Resources.

OTHER SYSTEMS

BANSHEE DISTRIBUTION NETWORK (MICROGRID)

The Banshee benchmark corresponds to a real-life small industrial facility, which reproduces typical microgrid challenges worldwide. Three utility feeders service the power plant at 13.8 kV levels (Figure 1) that may interconnect through normally open tie switches. Twenty-two (22) distribution transformers reduce the 13.8 kV to service voltages of 4.16 kV, 480 V, and 208 V.

Eighteen (18) aggregated low voltage loads (480 V and 208 V) are classified as critical, priority, or interruptible (all loads are modeled as constant power mode). In that way, several circuit breakers perform a load-shedding logic on the microgrid controller according to the load classification. All circuit breakers on the power plant are modeled as static switches, although they should be changed to controlled switches according to the model applications.

Banshee also includes two large induction motors (200 HP) connected with the P1 and P6 loads. However, as motors are not present in the current Typhoon OpenDSS library, it still needs to be considered on the model in future versions. The same is applied to the PV generation connected to bus #202. In this context, BESS and synchronous generators of the power plant also are not used in this modeling version.

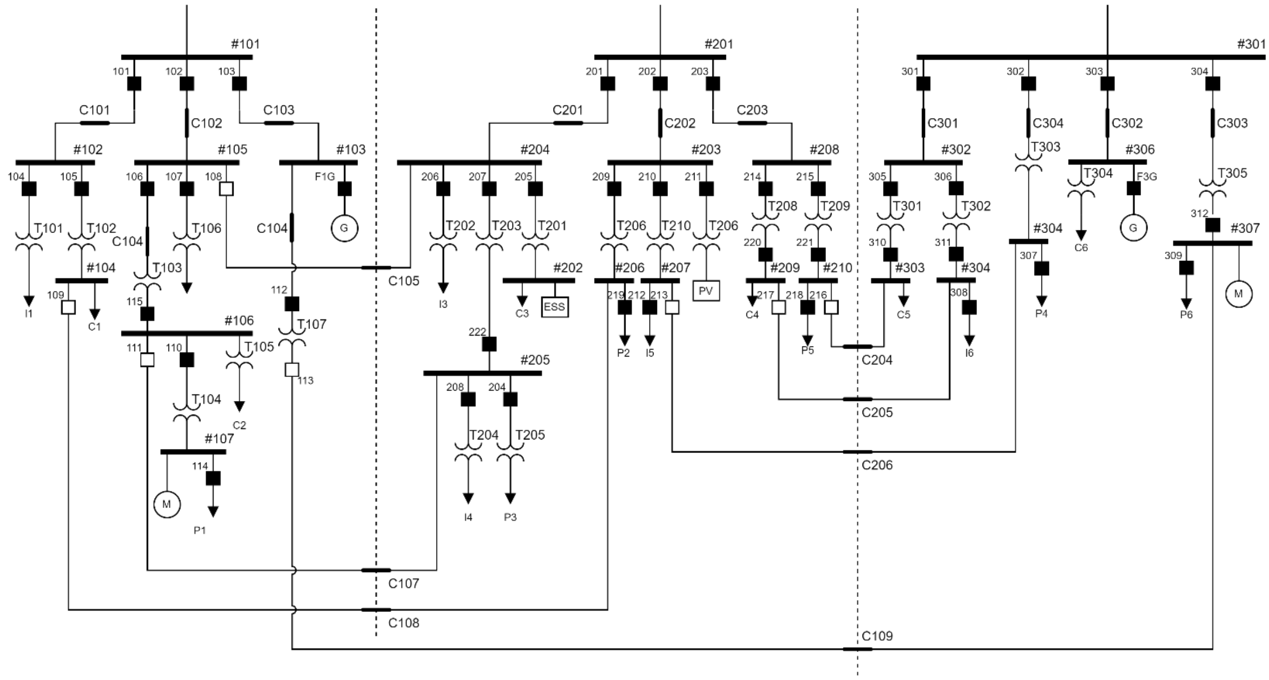

Figure 3 – Single Line diagram of the Banshee Microgrid.

The power flow results compared in Table 20 – Table 22 show the match between the Typhoon model and the reference. 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.

It’s worth mentioning two points about the results:

- Several TLM core coupling components divide the model resources due to the power plant size. That kind of core coupling has some advantages in terms of stability compared to the ITM method, but it adds shunt capacitance to the model, which can be significant if the inductance of the TLM is small. To minimize that behavior, all TLM is placed inside the transformers. Even though those capacitors impact the system, as shown in Table 20 and Table 22, when significative errors are observed only on the SCADA tab. On the power flow impact, it is possible to see differences of around 30% in the reactive power flowing in some circuits. From the voltage viewpoint, it is also possible to check the capacitors' impact in over-voltages in some buses, in the worst cases, assuming values greater than 1.0 pu.
- CB102 flow has significant errors in both DSS and SCADA tabs. Comparing the data entry of the source code from the reference was noted a different input for the reactive power in a load of this branch. The model will use the load value from the reference paper instead.

Results

Table 20. Power Flow at feeders PCC.

Circuit Breaker	REF.		DSS		SCADA	
	MW	Mvar	MW	Mvar	MW	Mvar
CB101	1.37	0.70	1.36	0.71	1.37	0.68
CB102	2.53	1.09	2.48	1.39	2.52	1.40
CB103	0.00	0.00	0.00	0.00	0.01	-0.02
CB201	2.67	1.40	2.64	1.40	2.66	1.40
CB202	1.28	0.65	1.27	0.65	1.28	0.86
CB203	1.55	0.76	1.54	0.79	1.55	0.92
CB301	1.46	0.74	1.46	0.75	1.47	0.70
CB302	0.55	0.29	0.55	0.28	0.55	0.27
CB303	0.74	0.39	0.73	0.39	0.74	0.39
CB304	0.91	0.46	0.91	0.47	0.91	0.46

Table 21. Power Flow errors at feeders PCC.

Circuit Breaker	DSS		SCADA	
	MW	Mvar	MW	Mvar
CB101	0.73%	-1.43%	0.00%	2.86%
CB102	1.98%	-27.52%	0.40%	-28.44%
CB103	--	--		
CB201	1.12%	0.00%	0.37%	0.00%
CB202	0.78%	0.00%	0.00%	-32.31%
CB203	0.65%	-3.95%	0.00%	-21.05%
CB301	0.00%	-1.35%	-0.68%	5.41%
CB302	0.00%	3.45%	0.00%	6.90%
CB303	1.35%	0.00%	0.00%	0.00%
CB304	0.00%	-2.17%	0.00%	0.00%

Table 22. Load Voltages Magnitudes and errors.

Load ID	REF Voltage	DSS		SCADA	
		Voltage	Error	Voltage	Error
C1	0.978	0.967	1.08%	0.976	0.20%
C2	0.950	0.941	0.94%	0.942	0.84%
C3	0.982	0.971	1.10%	0.997	-1.53%
C4	0.976	0.971	0.52%	0.993	-1.74%
C5	0.977	0.967	1.03%	0.974	0.31%
C6	0.964	0.961	0.33%	0.961	0.31%
P1	0.960	0.944	1.63%	0.952	0.83%
P2	0.982	0.970	1.20%	1.036	-5.50%
P3	0.949	0.948	0.08%	0.954	-0.53%
P4	0.973	0.965	0.78%	0.970	0.31%

Load ID	REF Voltage	DSS		SCADA	
		Voltage	Error	Voltage	Error
P5	0.984	0.990	-0.65%	1.048	-6.50%
P6	0.982	0.966	1.61%	0.979	0.31%
I1	0.974	0.972	0.20%	0.973	0.10%
I2	0.976	0.973	0.34%	0.974	0.20%
I3	0.969	0.966	0.34%	0.995	-2.68%
I4	0.962	0.950	1.28%	0.956	0.62%
I5	0.982	0.972	0.98%	1.032	-5.09%
I6	0.986	0.973	1.28%	0.982	0.41%

Modeling Data

Table 23. Cable Type Impedances.

Cable Type	R1 (Ω/km)	X1 (Ω/km)	R0 (Ω/km)	X0 (Ω/km)
15kV Shielded 4/0 AWG 3C CU	0.1668	0.1286	1.3302	0.9830
15kV Shielded 500KCMIL SR 3C CU	0.0749	0.1167	1.1405	0.7559

Table 24. Line Segment Data.

Line	From (#Bus)	To (#Bus)	Cable Type	Length ft (km)	Line	From (#Bus)	To (#Bus)	Cable Type	Length ft (km)
C101	#101	#102	500 kcmil	1800 (0.549)	**C201**	#201	#204	4/0 AWG	5500 (1.676)
C102	#101	#105	500 kcmil	5500 (1.676)	**C202**	#201	#203	500 kcmil	2000 (0.610)
C103	#101	#103	4/0 AWG	1000 (0.305)	**C203**	#201	#208	500 kcmil	3000 (0.914)
C104	#101	#T107	500 kcmil	3000 (0.914)	**C204**	#210	#303	500 kcmil	1500 (0.457)
C105	#105	#204	500 kcmil	3000 (0.914)	**C205**	#209	#304	500 kcmil	1500 (0.457)
C106	#105	#106	500 kcmil	1500 (0.457)	**C206**	#207	#305	500 kcmil	1500 (0.457)
C107	#106	#205	500 kcmil	2000 (0.610)	**C301**	#301	#302	500 kcmil	2500 (0.762)
C108	#104	#206	500 kcmil	1000 (0.305)	**C302**	#301	#306	4/0 AWG	2000 (0.610)
C109	#T107	#307	500 kcmil	2000 (0.610)	**C303**	#301	#307	500 kcmil	2000 (0.610)
					C304	#301	#305	4/0 AWG	1500 (0.457)

Table 25. Load Data.

Classification	ID	Connection	Demand kVA	Classification	ID	Connection	Demand kVA
Critical	**C1**	#104	1200	**Critical**	**C4**	#209	1000
	C2	#106 (T105)	1500		**C5**	#303	1000
	C3	#202	1000		**C6**	#306 (T304)	800
Priority	**P1**	#107	1000	**Priority**	**P4**	#305	600
	P2	#206	1000		**P5**	#210	700
	P3	#205 (T205)	1000		**P6**	#307	1000

Classification	ID	Connection	Demand kVA	Classification	ID	Connection	Demand kVA
Interruptible	**I1**	#102 (T101)	300	Interruptible	**I4**	#205 (T204)	600
	I2	#105 (T106)	250		**I5**	#207	400
	I3	#204 (T202)	300		**I6**	#304	600

Table 26. Transformers Data.

ID	Nameplate					Computed	
	Rating [kVA]	Vpri [kV]	Vsec [kV]	Z [%]	X/R	X [%]	R [%]
T101	500	13.8	0.48	5.00	4.9	4.90	1.00
T102	2500	13.8	0.48	5.75	6.6	5.69	0.86
T103	3750	13.8	4.16	4.75	11.4	4.73	0.42
T104	2000	4.16	0.48	5.75	4.7	5.62	1.20
T105	2000	4.16	0.48	5.75	4.7	5.62	1.20
T106	500	13.8	0.208	5.00	4.9	4.90	1.00
T107	2500	13.8	0.48	5.75	6.6	5.69	0.86
T201	2500	13.8	0.48	5.56	5.5	5.47	0.99
T202	500	13.8	0.208	5.00	4.9	4.90	1.00
T203	3750	13.8	4.16	4.75	11.4	4.73	0.42
T204	1000	4.16	0.48	5.75	4.2	5.59	1.33
T205	1500	4.16	0.48	5.75	5.0	5.64	1.12
T206	2500	13.8	0.48	5.75	6.6	5.69	0.86
T207	5000	13.8	0.48	5.00	5.4	4.92	0.90
T208	2000	13.8	0.48	5.75	4.7	5.62	1.20
T209	2000	13.8	0.48	5.75	4.7	5.62	1.20
T210	1000	13.8	0.48	5.75	4.2	5.59	1.33
T301	2000	13.8	0.48	5.75	4.7	5.62	1.20
T302	2000	13.8	0.48	5.75	4.7	5.62	1.20
T303	1000	13.8	0.48	5.75	4.2	5.59	1.33
T304	1000	13.8	0.48	5.75	4.2	5.59	1.33
T305	2500	13.8	0.48	5.75	6.6	5.69	0.86

References

[3] – Banshee distribution network benchmark and prototyping platform for hardware-in-the-loop integration of microgrid and device controllers. The Journal of Engineering, 2019: 5365-5373. https://doi.org/10.1049/joe.2018.5174

[4] – Electric Power Hardware-in-the-loop Controls Collaborative. Available at https://github.com/PowerSystemsHIL/EPHCC/releases/download/BansheeBenchmark/Supporting.Data.for.Banshee.Benchmark.Paper.zip