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

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 2 show how to execute a snapshot simulation from the OpenDSS engine by clicking the “Run” button on the “Simulation” tab of the SimDSS component. The power flow results are accessed by the “Show” properties tab (Figure 2.b). After compiling and loading the model into the HIL, the user can observe a similar operational point as shown in the Results section. The power flow results compared in Table 1 – Table 3 show the match between the Typhoon model and the reference. The DSS column refers to the results obtained from the SimDSS component from the Schematic Editor, and the SCADA column is the steady state voltages from the runtime simulation. Figure 3 shows the SCADA Panel running the Banshee simulation on Typhoon HIL SCADA.

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 1 and Table 3, 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.

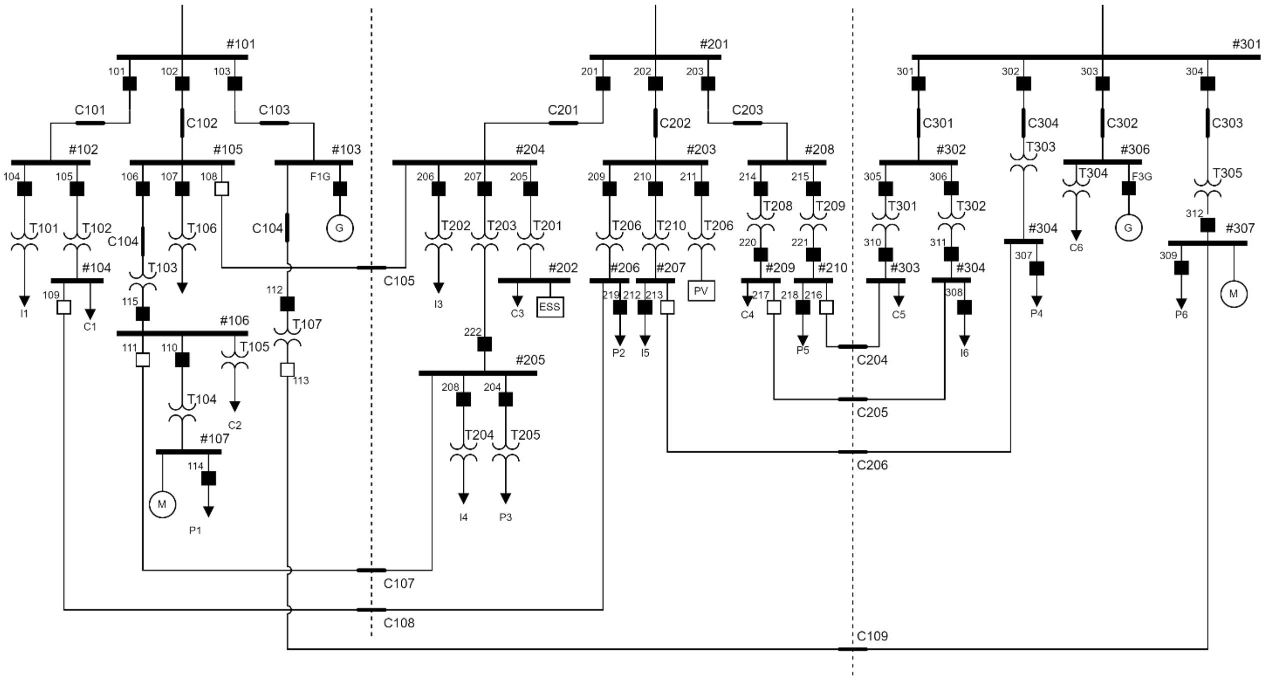
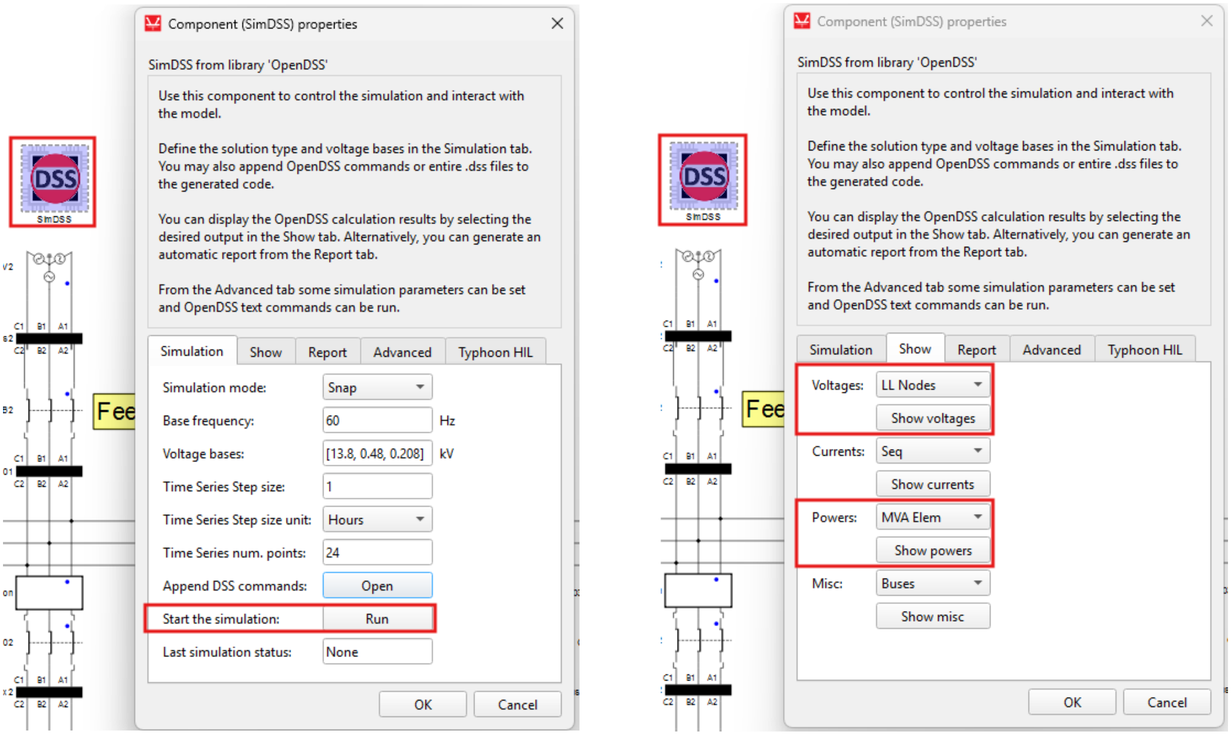


Figure 1 – Single Line diagram of the Banshee Microgrid.



a) b)

Figure 2 – a) Running the OpenDSS simulation and b) getting the power flow results.

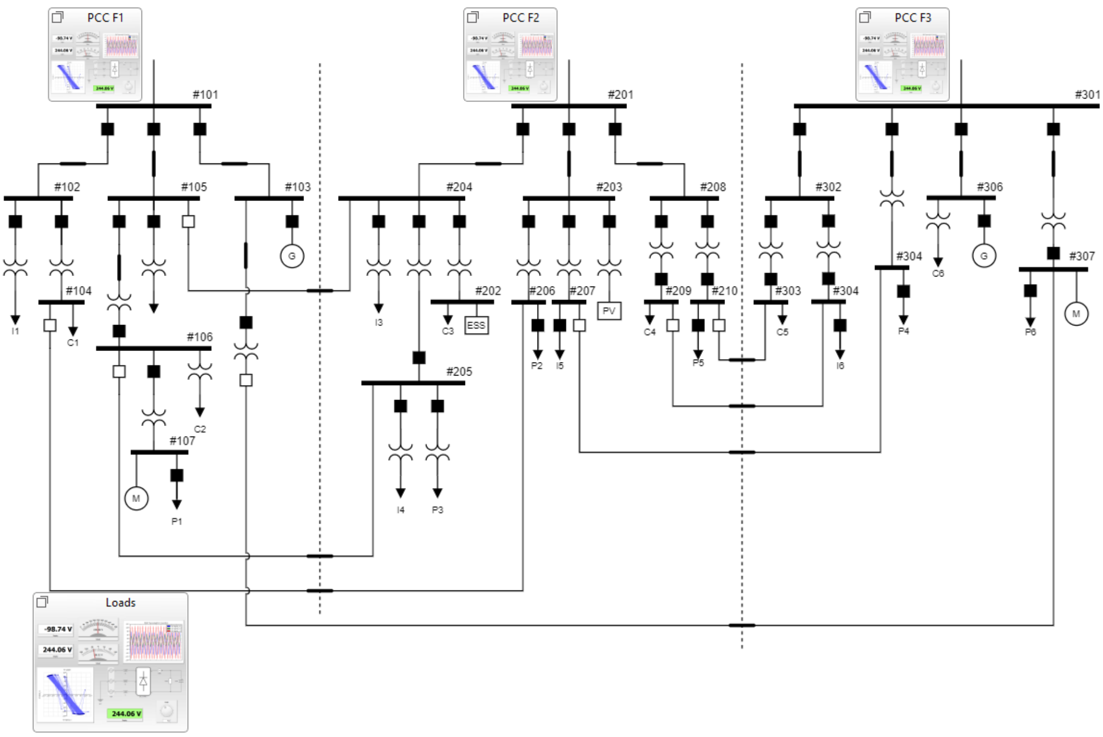


Figure 3 – HIL SCADA Panel.

Results

Table 1. 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	2.51	1.35
CB103	0.00	0.00	0.00	0.00	0.00	-0.02
CB201	2.67	1.40	2.64	1.41	2.65	1.41
CB202	1.28	0.65	1.27	0.65	1.27	0.86
CB203	1.55	0.76	1.54	0.79	1.54	0.92
CB301	1.46	0.74	1.46	0.75	1.46	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 2. Power Flow errors at feeders PCC.

Circuit Breaker	DSS		SCADA	
	MW	Mvar	MW	Mvar
CB101	0.39%	-0.81%	0.00%	2.86%
CB102	1.98%	-27.32%	0.79%	-23.85%
CB103	--	--		
CB201	1.01%	-0.36%	0.75%	-0.71%
CB202	0.58%	0.00%	0.78%	-32.31%
CB203	0.44%	-3.87%	0.65%	-21.05%
CB301	0.15%	-1.00%	0.00%	5.41%
CB302	0.55%	1.76%	0.00%	6.90%
CB303	1.39%	0.56%	0.00%	0.00%
CB304	-0.38%	-2.17%	0.00%	0.00%

Table 3. 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%	1.000	-1.83%
C4	0.976	0.971	0.52%	0.997	-2.15%
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%	1.035	-5.40%
P3	0.949	0.948	0.08%	0.953	-0.42%
P4	0.973	0.965	0.78%	0.970	0.31%
P5	0.984	0.990	-0.65%	1.048	-6.50%

Load ID	REF Voltage	DSS		SCADA	
		Voltage	Error	Voltage	Error
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%	0.993	-2.48%
I4	0.962	0.950	1.28%	0.956	0.62%
I5	0.982	0.972	0.98%	1.031	-4.99%
I6	0.986	0.973	1.28%	0.982	0.41%

Modeling Data

Table 4. 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 5. 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 6. 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
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 7. 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

[1] – 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

[2] – 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