RADIANCE DESIGN IPT

SAND2020-3530PE

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The design team has been focused on validating the various levels fidelity models (PSLF, PSCAD, Hypersim) using captured PMU data of events on the Cordova distribution system. Fault simulations using PSLF modeling have resulted in slight adjustments on line parameters and these changes have been incorporated in the HyperSim model.

Hardware work continues with the ABB PCS100ESS inverter and efforts are focused on ac simulator and PCS-100 interactions.

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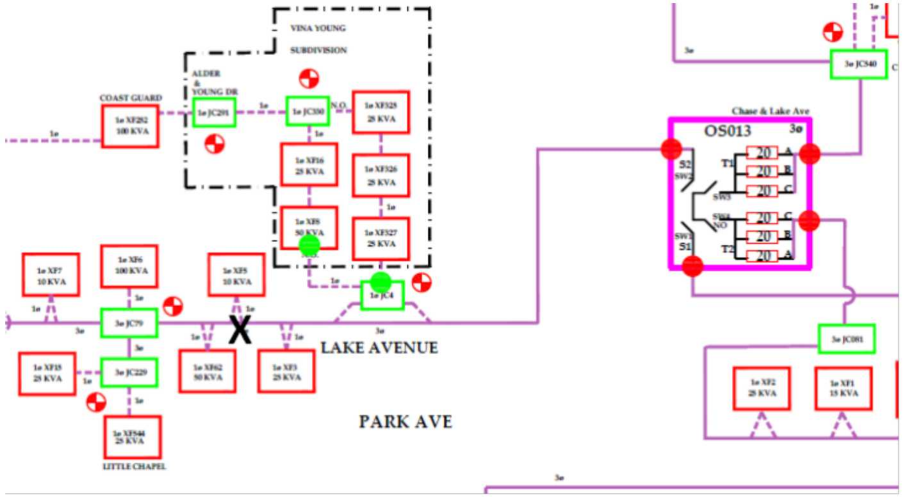
NMSU Update
Dr. Satish Ranade

Lake Avenue A phase Fault Simulation



Description

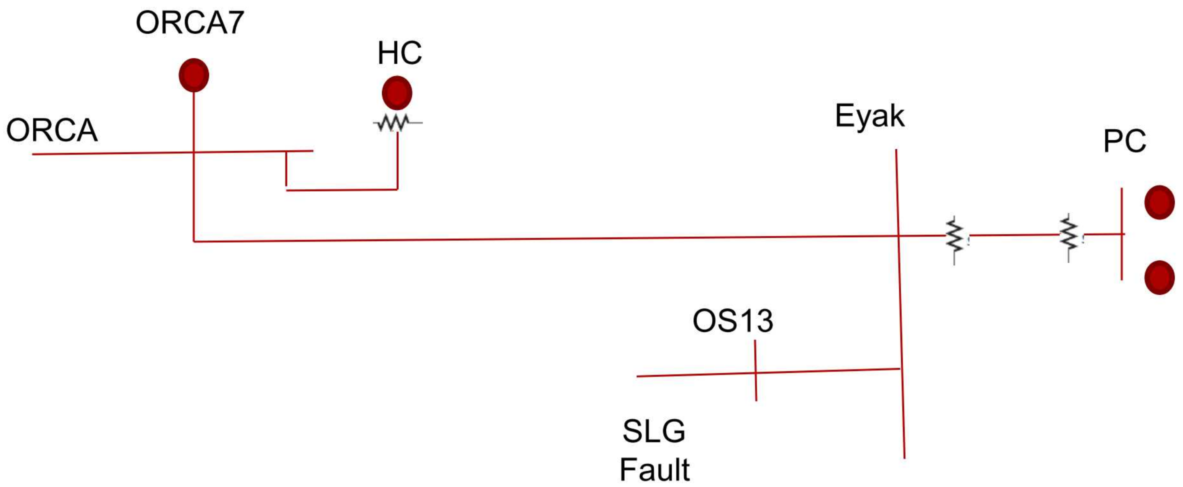
Phase A to G fault occurred on Lake Avenue feeder and was cleared by recloser in 8 cycles (August 14, 2019)

Total Generation	**6.637 MW**
Total Load	6.54 KW (Feeders Only) No auxiliaries at Plants
Generation on line (Unit, MW, MVAR)	ORCA 7 2600 KW HBC G3 100 A (80KW) PWRC H4 Real P 1763 KW ORCA 5 Blank PWRC H5 Real P 1594 KW ORCA 6 600 KW
Loads (Feeder, KW, KVAR, V)	LAKE 250KW -37 KW 13 Mile 400 KW 90 KVAR MT 2.2 MW -0.9 MVAR NT 510 KW -113 KVAR AUX 3.181 MW 1.24MVAR

- Created a model and calculation in Matcad/Matlab’
  - Reduced system shown above

- Table shows comparison (Measured v. Model)
- Original data does not match well
- Adjusted data has a closer match (trial and error adjustment)

- Following up on PSLF
- Double checking line data
- Checking ORCA PMU current issue
- Formal estimation
- Dynamic simulation



Fault PSLF Bus # 613 Downstream of OS13

Assumptions Ignore HC and ORCA G6
Ignore prefault current
Traditional assumption VPF=1

Original Data Orca G7 Z1=Z2= 0.2j Zo=0.1j 5MVA base
PC Z1=Z2=0.02+0.2j Zo=0.02+0.1j 3.8 MVA base

Adjusted Data Orca G7 Z1=Z2= 0.1j Zo=0.05j 5MVA base
PC Z1=Z2=0.025+0.25j Zo=0.025+0.125j 3.8 MVA base

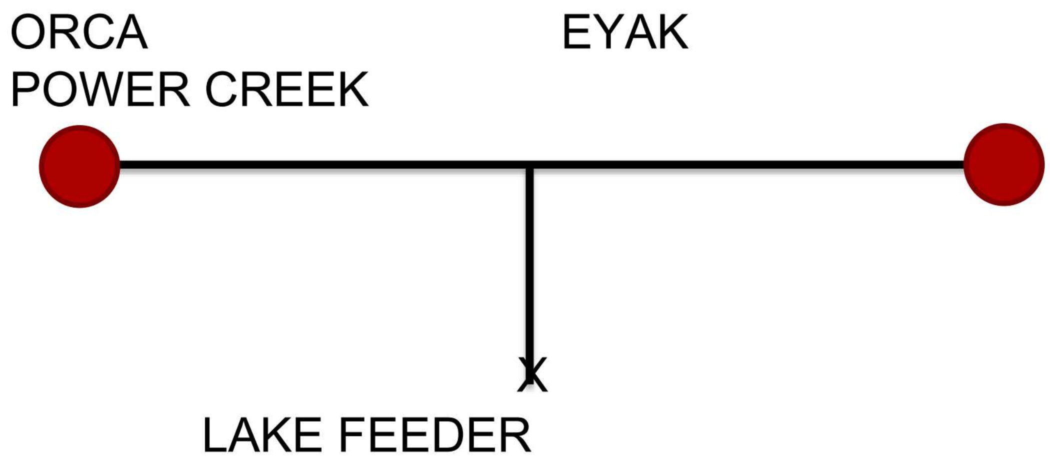
Notes PC PMU PTs are open delta on 4160V bus
ORCA PMU looks at 12470V line to HBC

	Measured at	Magnitude	Model	Comment
Fault Current	Lake Recloser	2475A	1849A	Original Model
Eyak Voltage	Lake Recloser	3147V	1449V	
ORCA Voltage	PMU	4000V	2666V	
PC Voltage	PMU – Open Delta	3100V	3182V	
Express Current	PMU	??	1286A	
PC Cable current	PMU	1100A	1740A	

	Measured at	Magnitude	Model	Comment
Fault Current	Lake Recloser	2475A	2553	Adjusted ORCA and PC Impedance
Eyak Voltage	Lake Recloser	3147V	2008	
ORCA Voltage	PMU	2666V	3941	
PC Voltage	PMU – Open Delta	3100V	3206V	
Express Current	PMU	??	2427A	
PC Cable current	PMU	1100A	1191A	

Model Validation from Fault data

Modified State Estimation Approach



Model

- Mixed sequence/phase domain
- Only ORCA, PC, EYAK and fault nodes modeled
- Prefault load and cable charging ignored
- ORCA and HC generators combined model E’’ behind Xd”; X2 and Xo

Model Validation from Fault data

Modified State Estimation Approach

Measurements

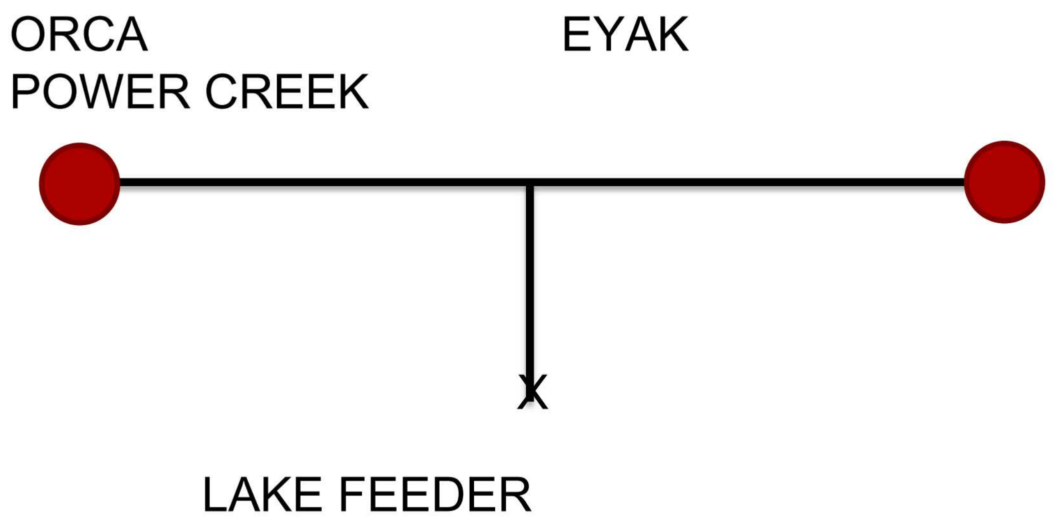
- ORCA PMU, voltage only
- EYAK Recloser unsynchronized
- PC PMU Open-delta Voltage, Current in 1 unit
-     (zero-sequence current=0)

Challenge

- Not enough measurements

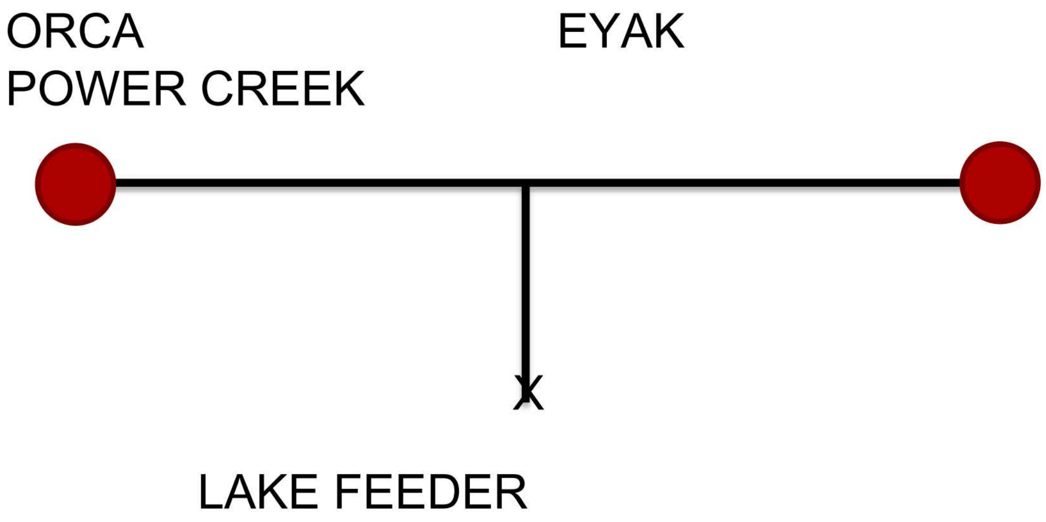
Pseudomeasurements

- Generator internal voltage is balanced
- Orca generator current ~= Express current
- PC generator positive/negative sequence current ~= Positive/negative Current from PC to Eyak at Eyak
- Express current = Lake current – PC to EYAK Current at EYAK



Model Validation from Fault data

Modified State Estimation Approach



Objective to minimize

- Measurement error
- Mismatch at ORCA and PC generator

Model Validation from Fault data

Modified State Estimation Approach

Note: Since EYAK voltage
Is not synchronized only relative angles
are of significance

As we found in our ad hoc attempt to match fault data, the estimation process suggests the impedances in model may be 5-10% HIGH

Based on complex power calculation from measurements:

ORCA Inertia H~2 S

PSLF Model H=1.38

Results

Units = PU<deg

		Measured	Calculated
ORCA	Va	0.55611<8.24	0.61282<1.7686
	VB	0.84139<-81.39	0.85185<-87.2504
	Vc	0.85528<150.7	0.81752<143.0764
	Ia	0.396<-9.8659	0.35776<-15.3412
	Ib	0.068<46	0.062492<118.2616
	IC	0.11<-29	0.091298<-92.0712
Lake	Va	0.41814<-0.23001	0.47431<8.24
	VB	0.83165<-90.0542	0.86222<-81.39
	Vc	0.92014<143.2682	0.86319<150.7
	Ia	0.539<172.24	0.52752<160.8085
	Ib	6.2063e-17<153.4349	5.5943e-17<-97.125
	IC	1.1189e-16<82.875	5.5511e-17<-90
	Va	.74581<30.7736	0.74964<37.7865
	VB	0.85354<-80.2456	0.85134<-73.0053
	Vc	0.90163<150.002	0.91305<157.1307
	Ia	0.144<-1.96	0.14112<-30.5016
	Ib	0.068<-134	0.072549<-69.089
	IC	0.11<151	0.026536<-94.9743

Next Steps

Updated PSLF based on revised physical parameters

-Shikhar updated Hypersim

Will update Express, PC and generator parameters based on estimation

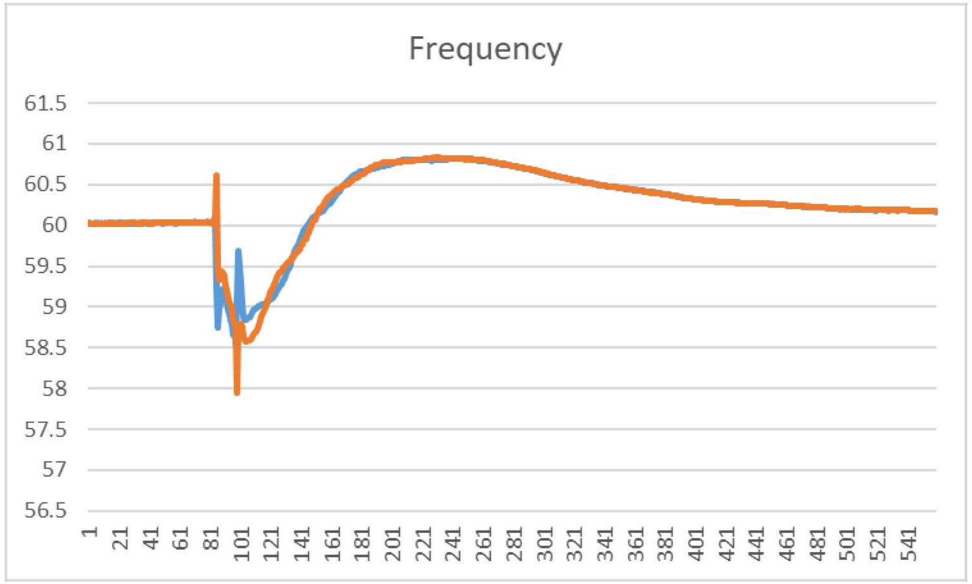
-Separate (sensitivity) case

Will complete this and look at second fault case

PMU's are being added

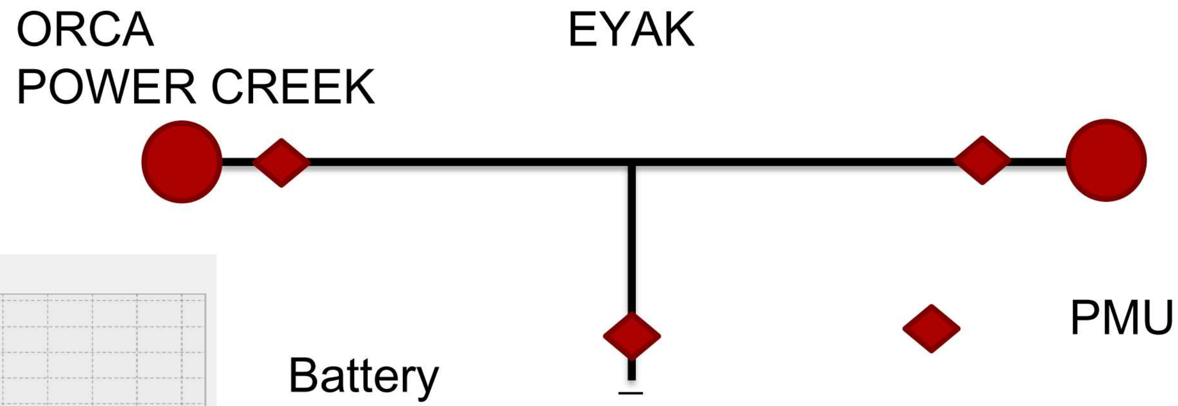
Validating dynamics

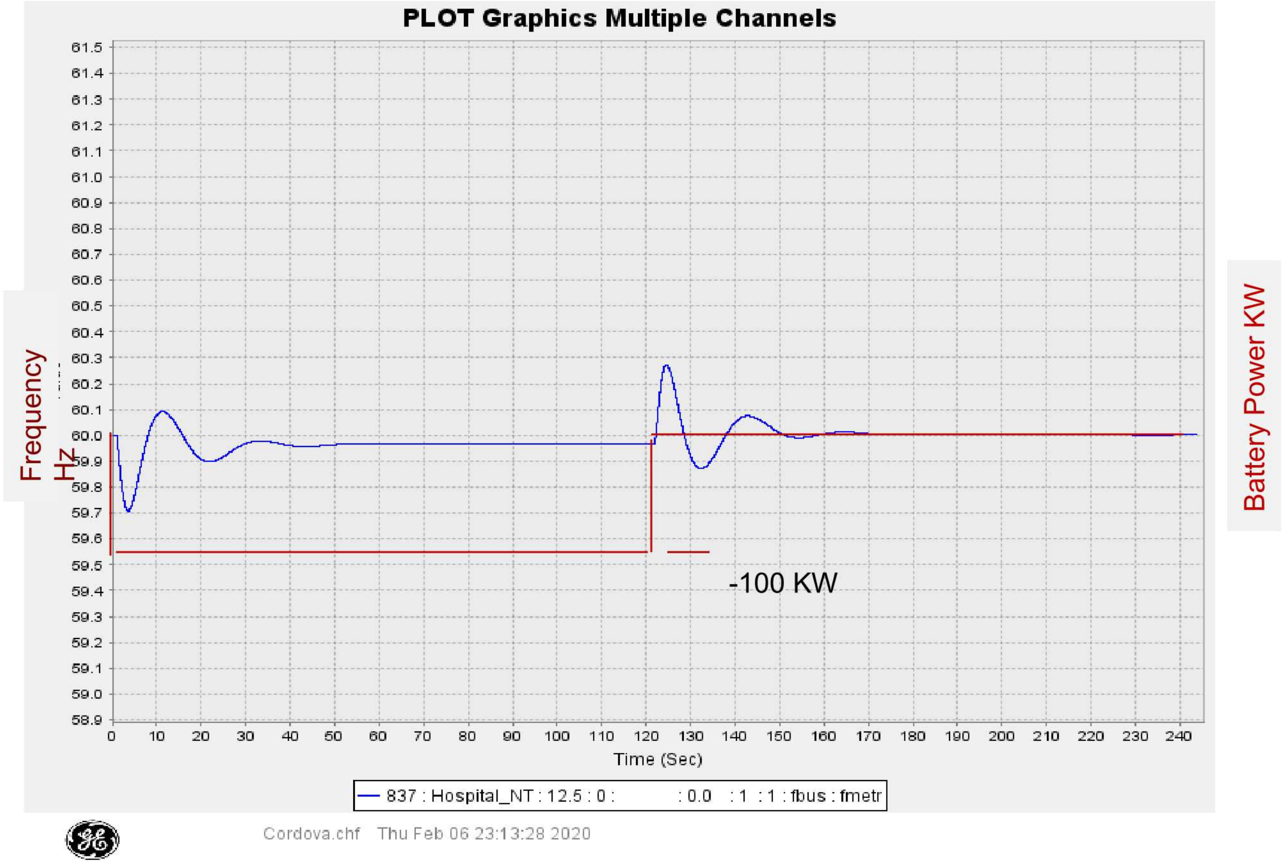
- During a fault (electrical) dynamics governs voltage phasors and dominates initial part of frequency measurement
- Actual generator field and electromechanical dynamic envelope is buried in measured frequency and can be extracted
- May get better results if we could conducted experiments in which we modulate battery output
- May not need more than 100 KW or so of modulation at the allowed rate if done when load is fairly steady



Validating dynamics using Battery

Response to step change in battery power (PSLF)





Measure voltage frequency response to change in battery power

- Step @ allowed ramp rate

- Frequency sweep

System identification of reduced order model
- Inertia
- Regulation
- Machine reactances

EMTP Modeling and Protection Coordination of the CEC System

By
Munim Bin Gani
Advisor: Dr Sukumar Brahma
Clemson University

Power System Modeling

❑ Network

- Lines and feeders are modeled with pi-sections.
- Oil switches are represented with buses in PSCAD

❑ Generators

- Values of different parameters in Hydro generator components (e.g., alternator, exciter, turbine, governors) are matched with the corresponding values from PSLF dynamic model.
- For diesel generators, alternators and exciter data are matched with PSLF. Engine data were kept default and governor was modeled by a simple PI controller.

❑ Loads

- Loads are modeled as lumped loads according to the PSLF model.
- Power System is simulated in PSCAD for healthy condition and power flow results match with PSLF model which is already validated against field data.

Modeled Protective Equipment in PSCAD

- Line and Feeder protection Relays
- Generator Protection Relays

Line and Feeder Relay Models Transferred to Hypersim

- ❑ EYAK Substation-
  - Lake Avenue Feeder- SEL 351-R
  - Main Town Feeder- SEL 351-R
  - New Town Feeder- SEL 351-R
  - 13 Mile Feeder- SEL 351-R
- ❑ ORCA Substation
  - Auxiliary Feeder- ABB CO-11
  - Express Feeder- ABB CO-11
- ❑ Humpback Creek Substation
  - ORCA/Main Feeder- SEL 351

Model Validation

- The model is currently under validation process against the data captured for fault on 08/14/2019.
- Loads are matched to reflect the pre-fault condition.
- Revised impedances provided by NMSU have been incorporated in PSCAD model.
- Generator data will be incorporated once they become available.

Future Work

- Relay settings to be checked and if needed revised using the PSCAD model.
- All relay settings which are not implemented yet in Hypersim to be provided to the Hypersim model development team, with guidance.
- Collaboration in protection-related issues during HIL testing of emergency scenarios.
- Energy storage and associated inverter in PSCAD will be modeled upon receiving the required data and their effect on the protection scheme will be analyzed.

Opal-RT Power Hardware-in-the-loop Modeling Efforts and Status Updates

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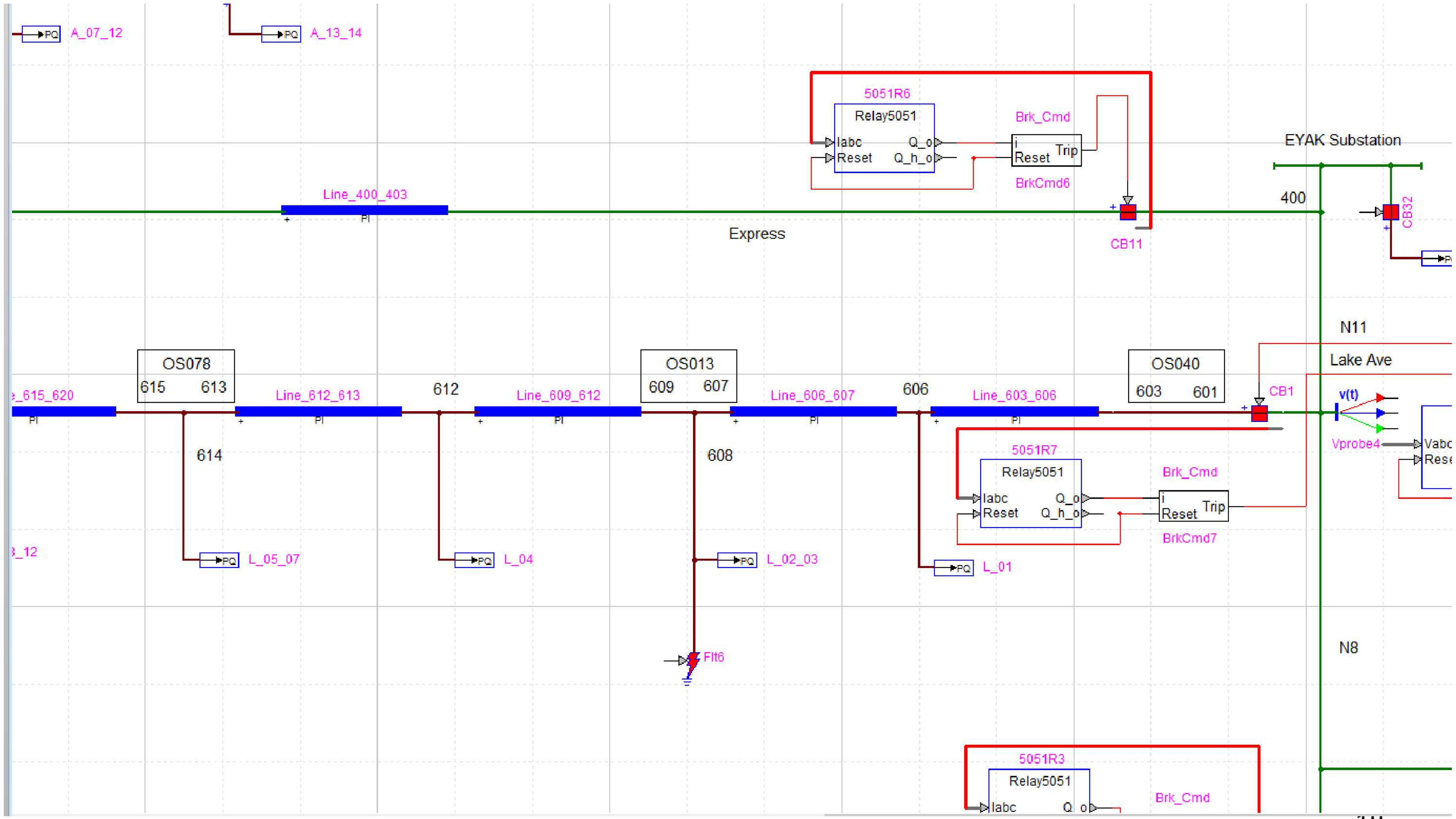
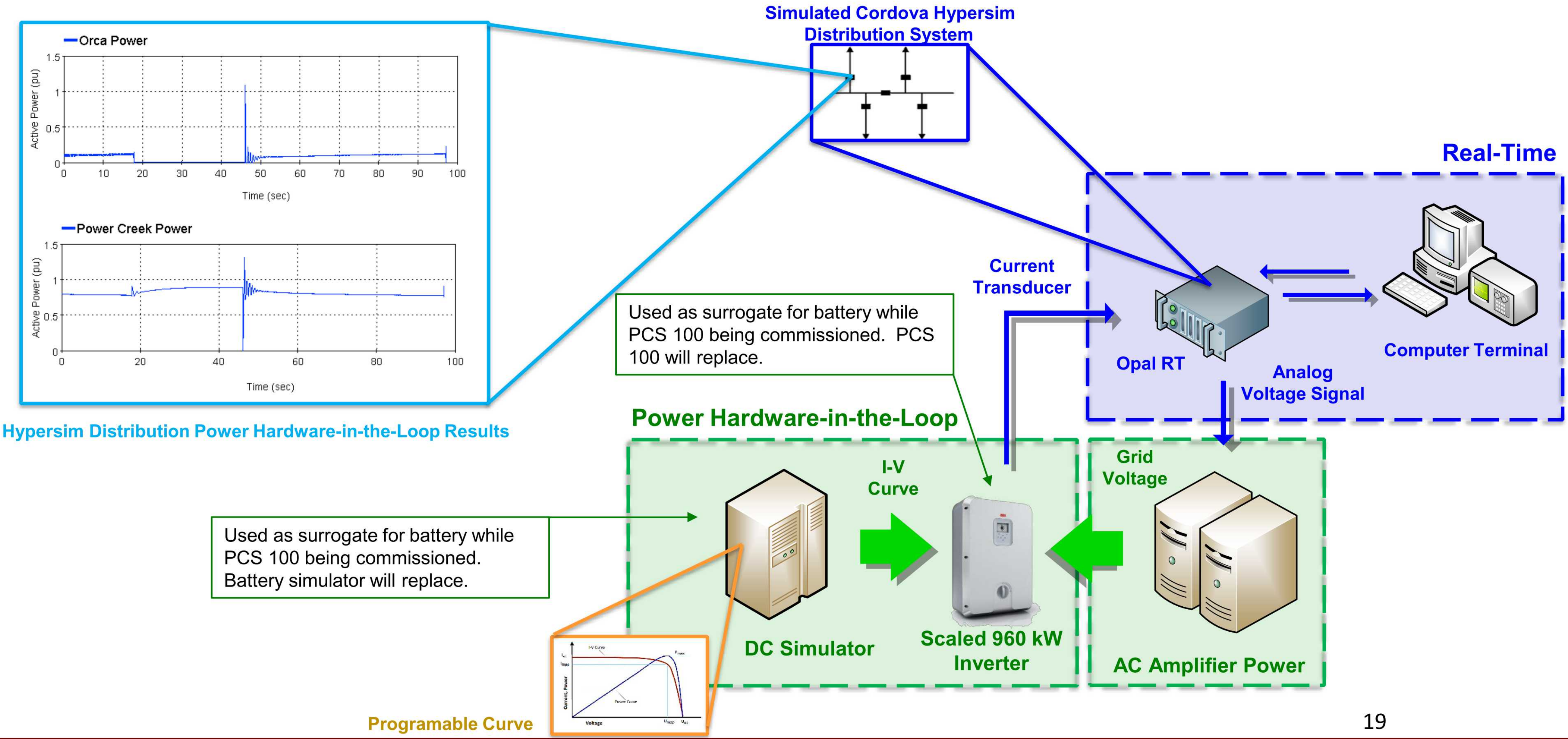
HyperSim Cordova Fault Simulation

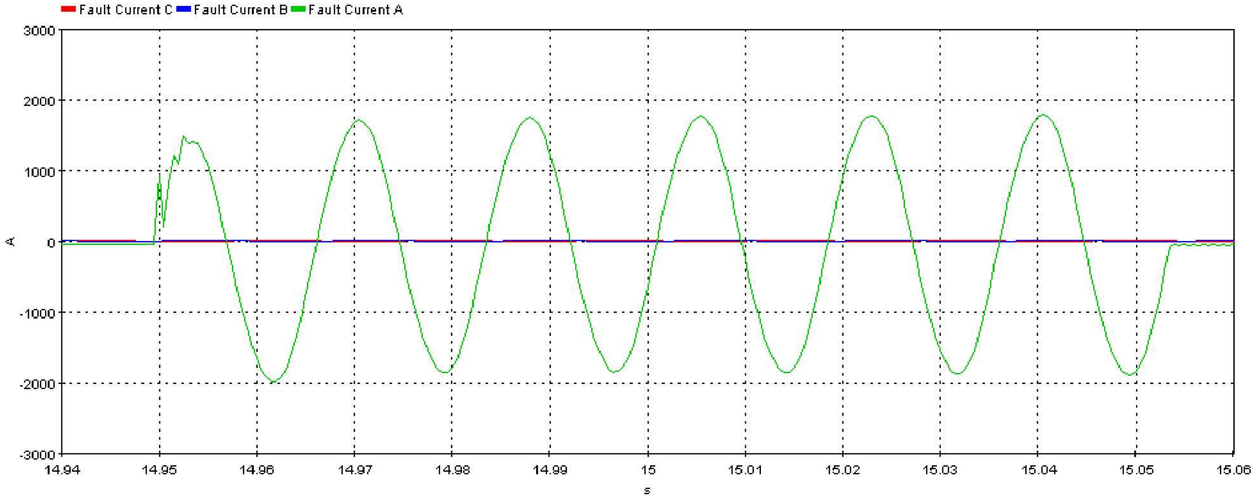


Real Time Power Hardware-in-the-Loop Setup

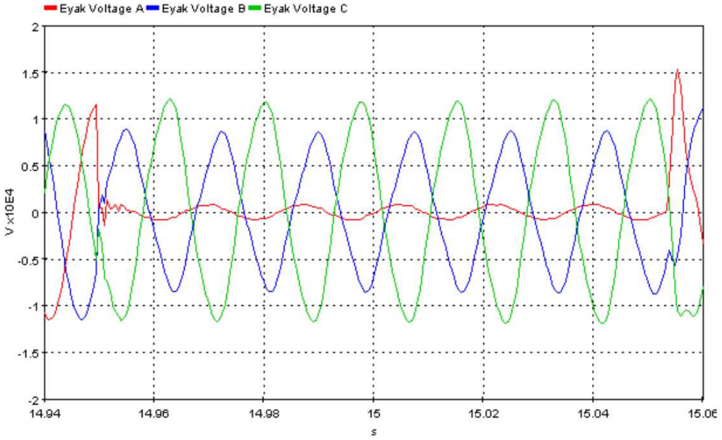


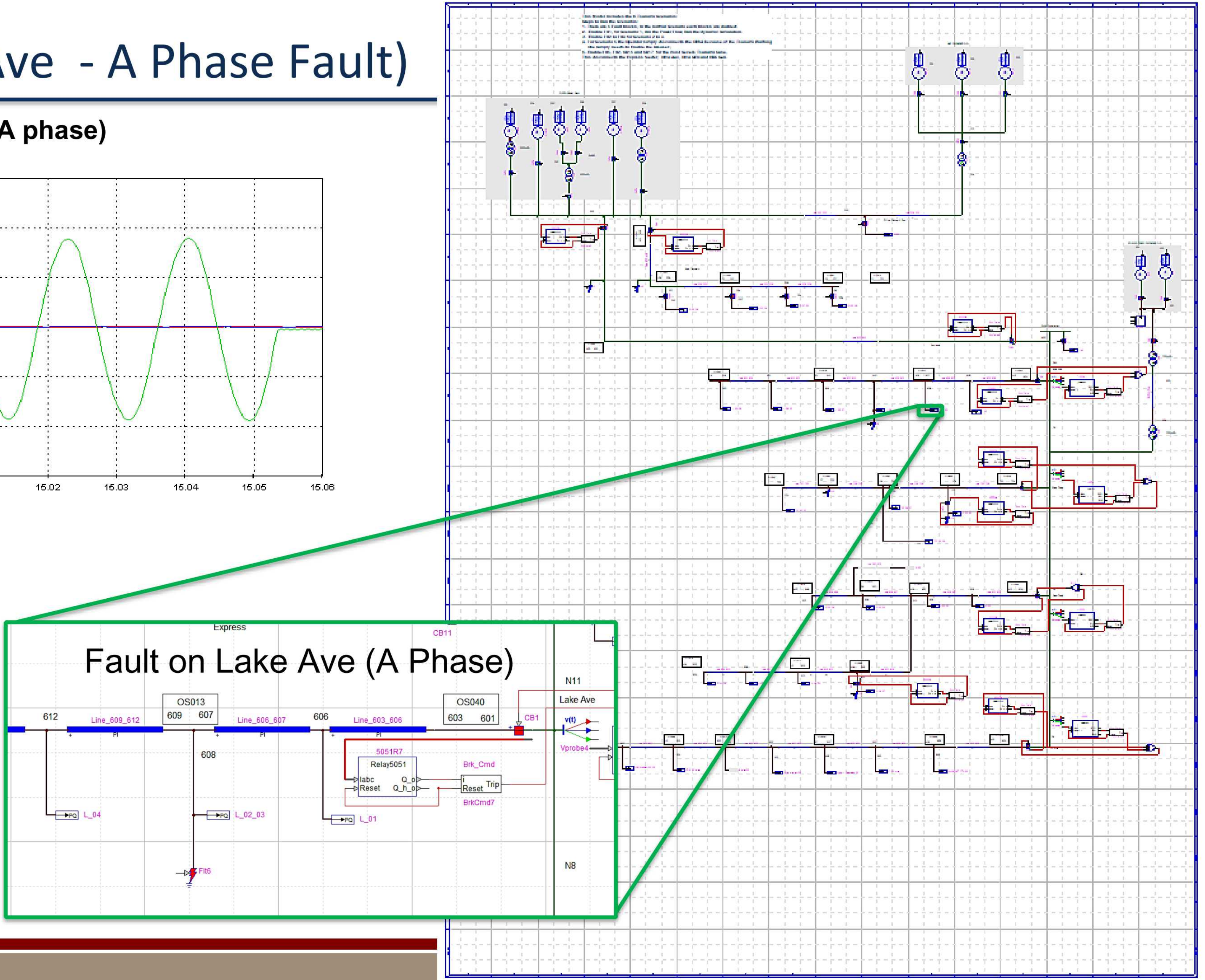
Hypersim Results (Lake Ave - A Phase Fault)

Fault Current (Lake Ave – A phase)

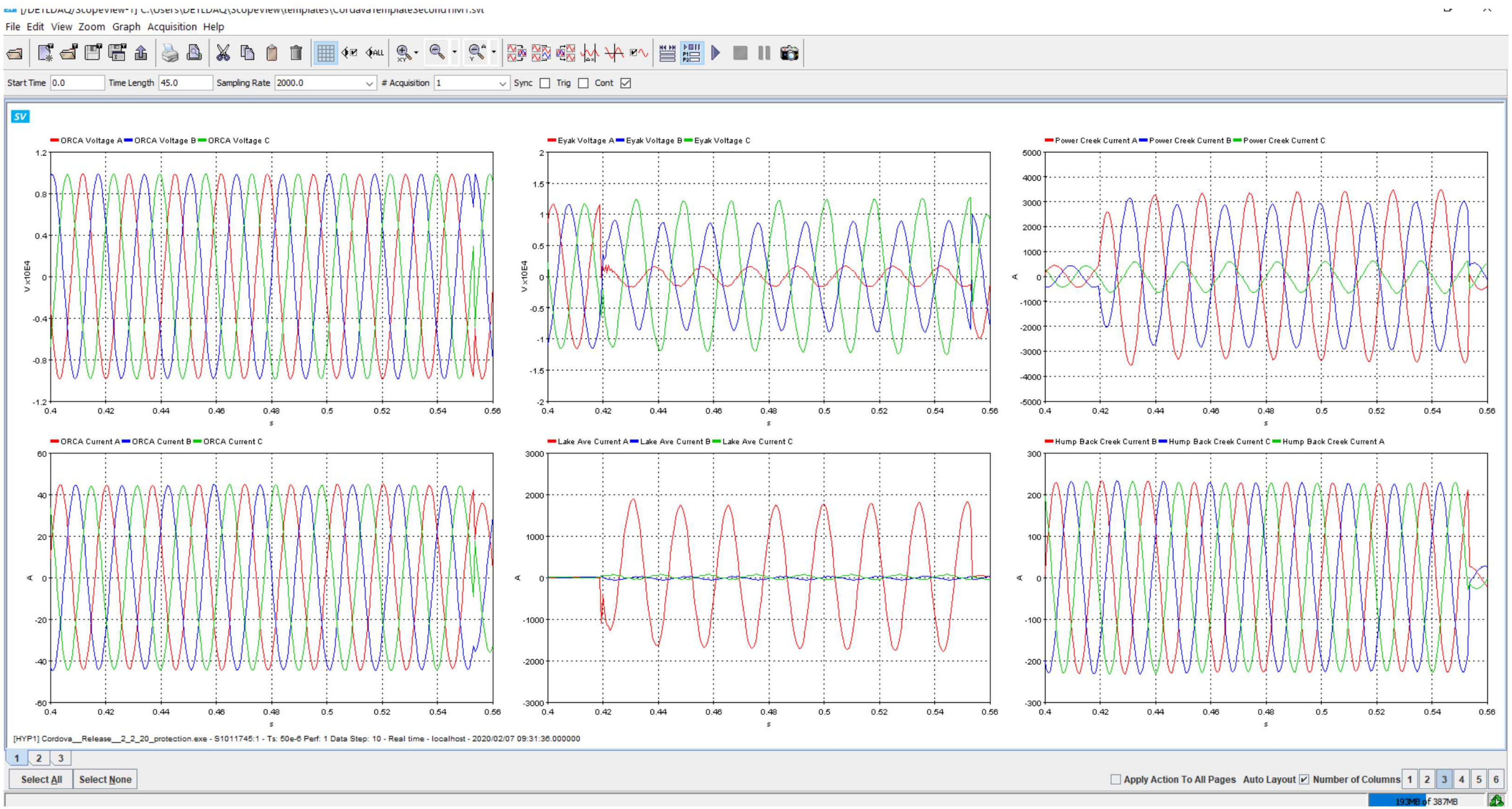


Eyak Voltage (Lake Ave)

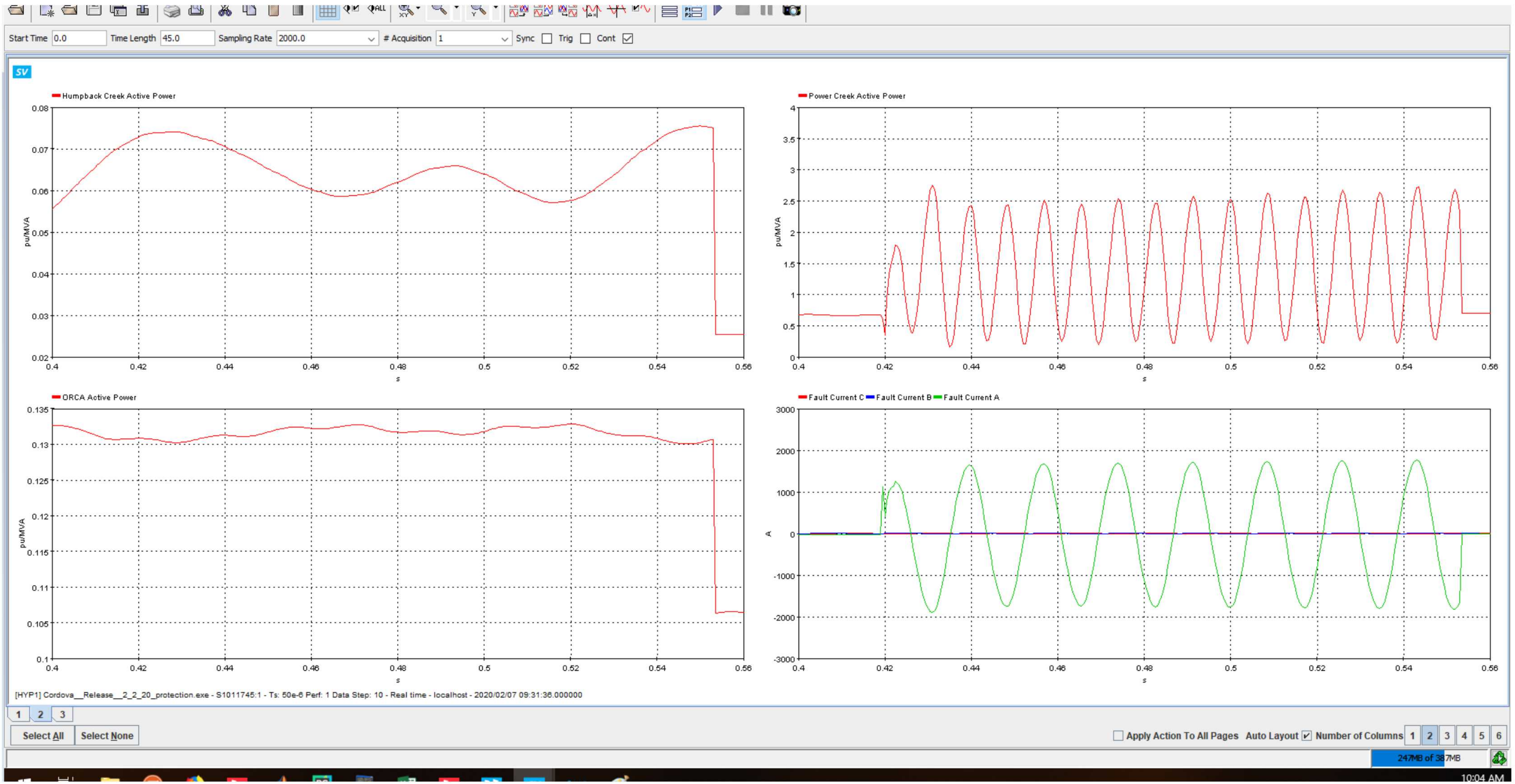




HyperSim Results (Orca, Lake Ave, PC: V&I)



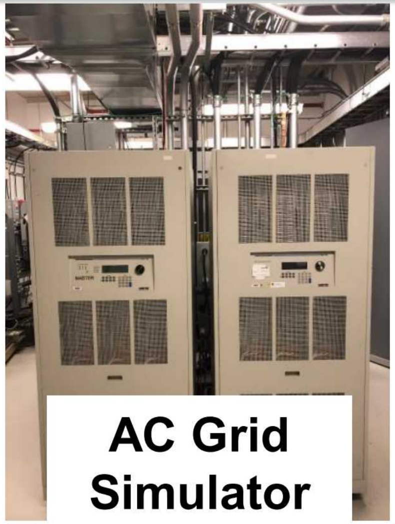
HyperSim Results (HC, Orca, PC: P)

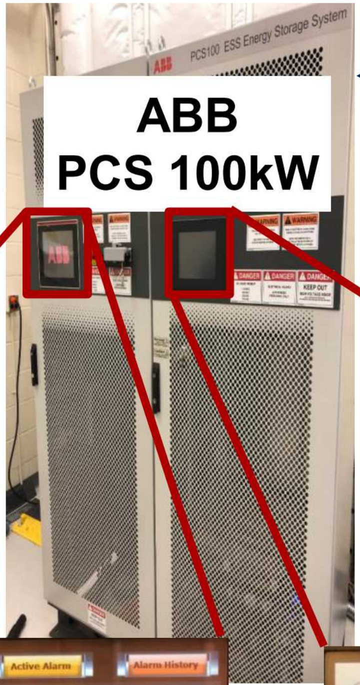


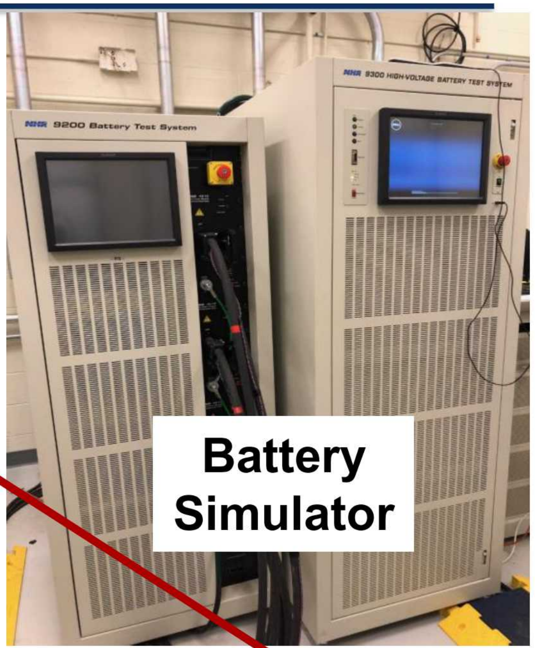
HyperSim Next Steps

- Work with NMSU (Satish), Clemson (Munim) and NREL (Shikhar) to compare Hypersim fault data results for Lake Ave fault event (short term)
  - Calibrate fault impedances and initial conditions to see how close the PSLF, PSCAD and Hypersim models match
  - Finalize the base working model we will use
- Work with same parties to incorporate model results to compare diesel and hydro dynamics to field data events
- If we can obtain battery event field data, compare Hypersim PHIL simulations to battery events
- Use Hypersim PHIL model to compare effect of use of battery to improve resilience to various tsunami, avalanche or other high consequence emergency scenarios

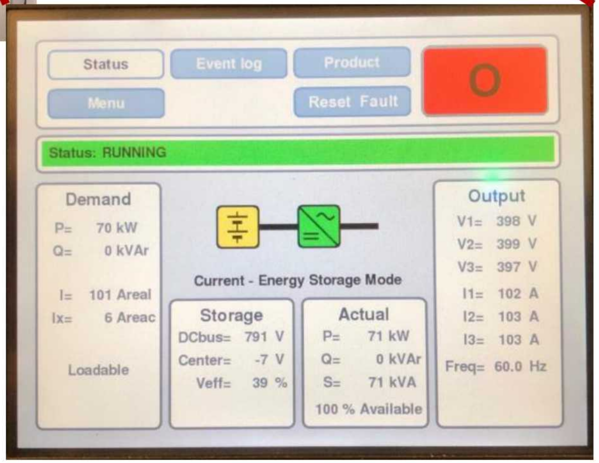
Sandia DETL Equipment for Real Time Power Hardware-in-the-Loop Setup





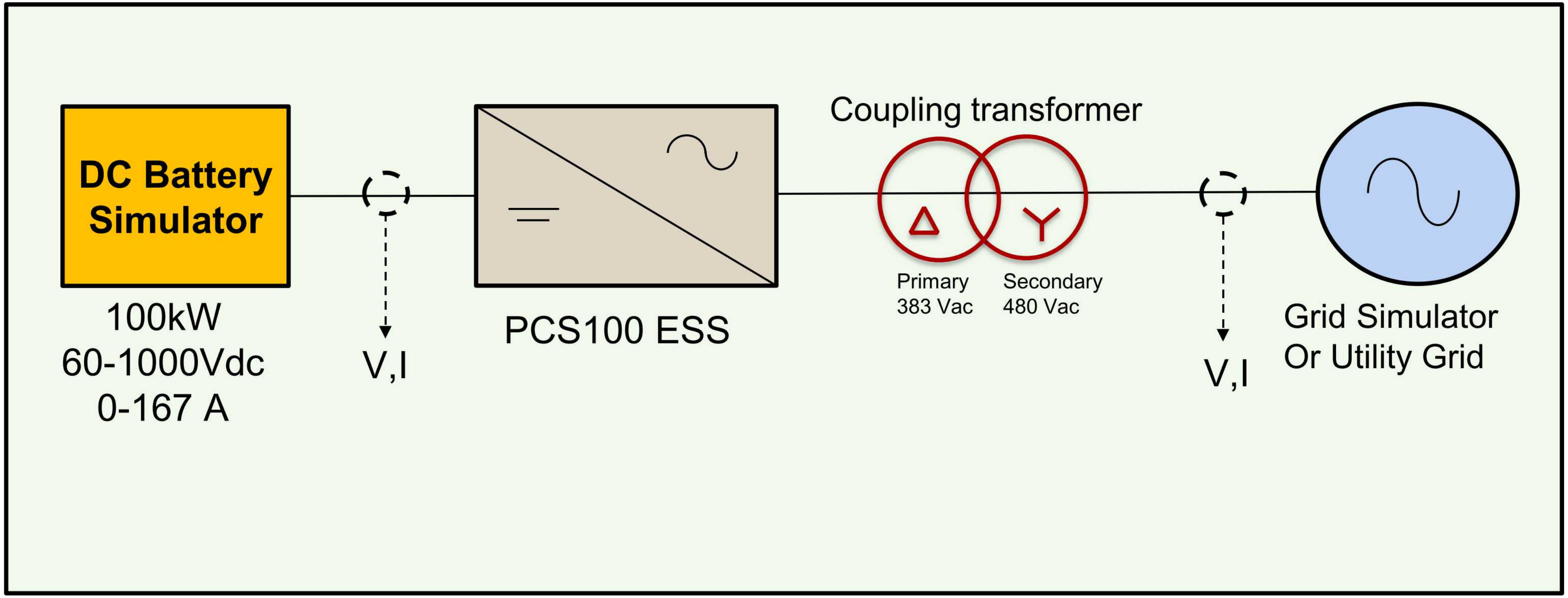


Opal RT
PHIL



PCS
output

PCS100 Hardware Configuration



Hardware Status

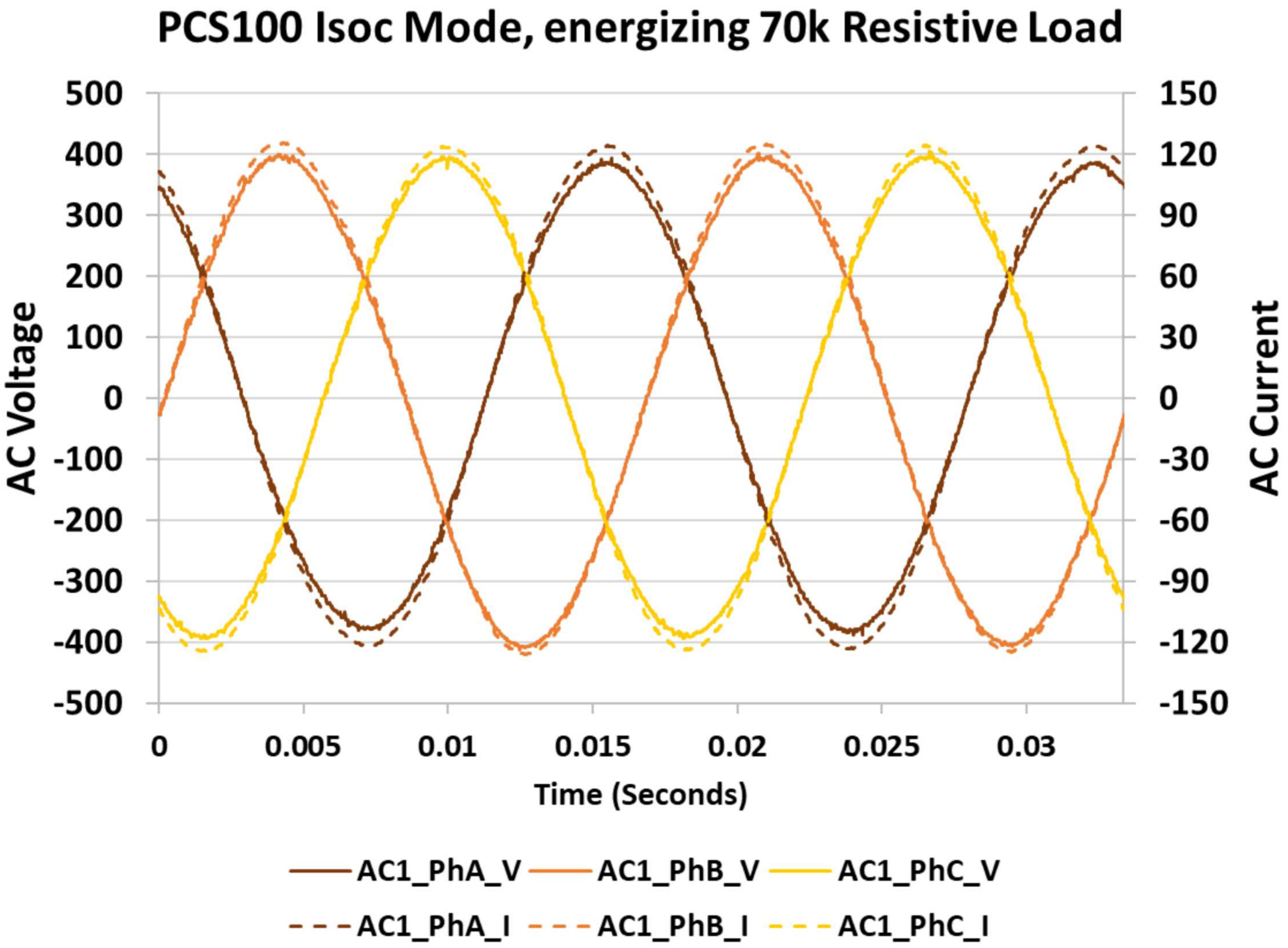
Re-configuration of ABB PCS-100ESS inverter

- Repaired transformer installed and commissioned
- Commissioned inverter isochronous mode energizing resistive load
- Characterize PCS in CSI mode energizing utility grid
- Investigate unbalanced currents (CSI mode) when connected to ac simulator. Conducted a calibration to remove dc offset on output

PCS100 in Isoc Mode energizing 70kW Resistive Load

PCS100 ESS Configuration

- Battery emulator provides dc
- Connected through Transformer
- Isochronous modes sets voltage and frequency

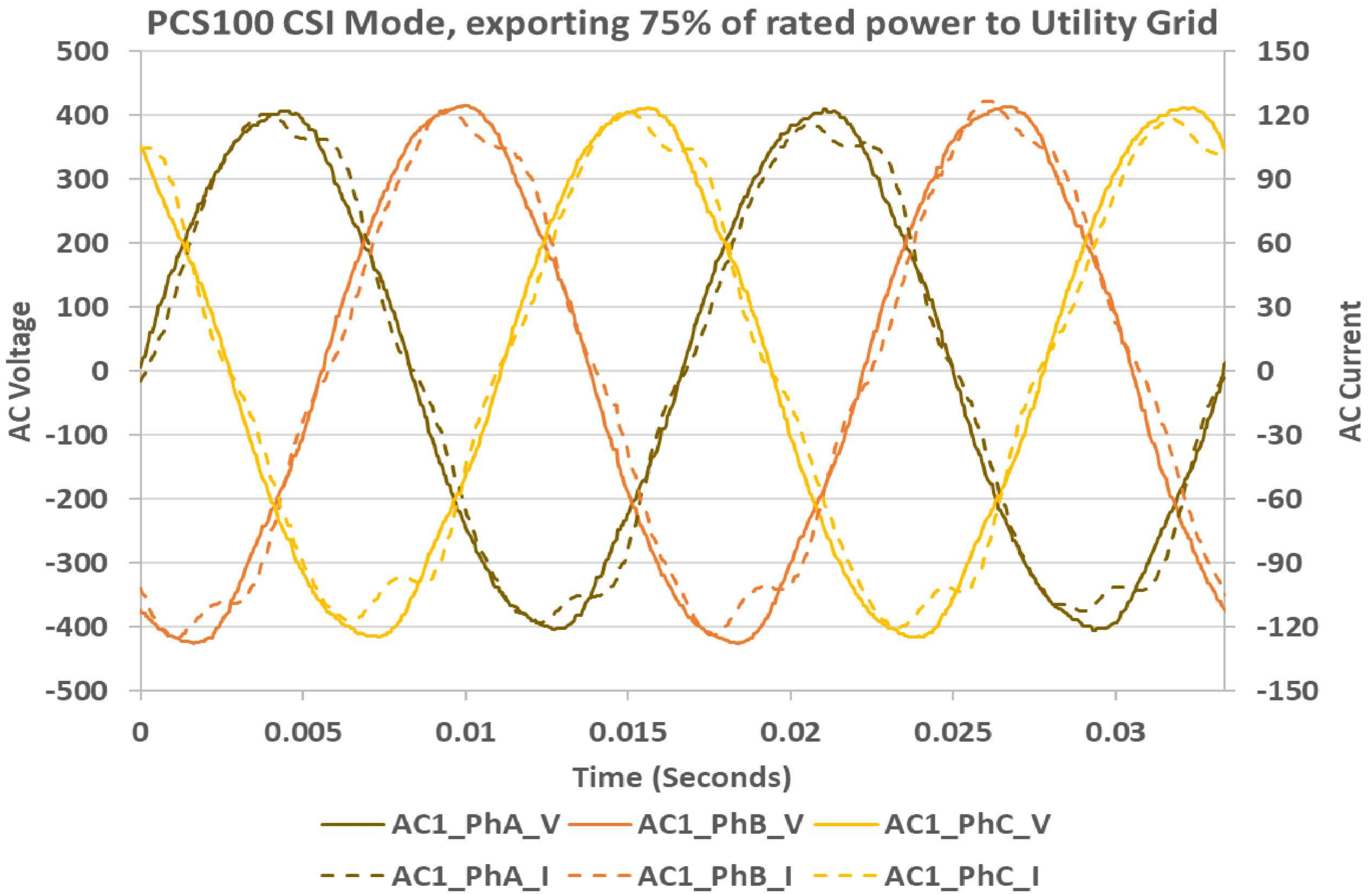


PCS100 in CSI Mode, 75kW to Utility Grid

PCS100 ESS Configuration

- Battery emulator provides dc
- Connected through Transformer
- CSI mode, 75kW active power

CSI should produce balanced and currents are balanced

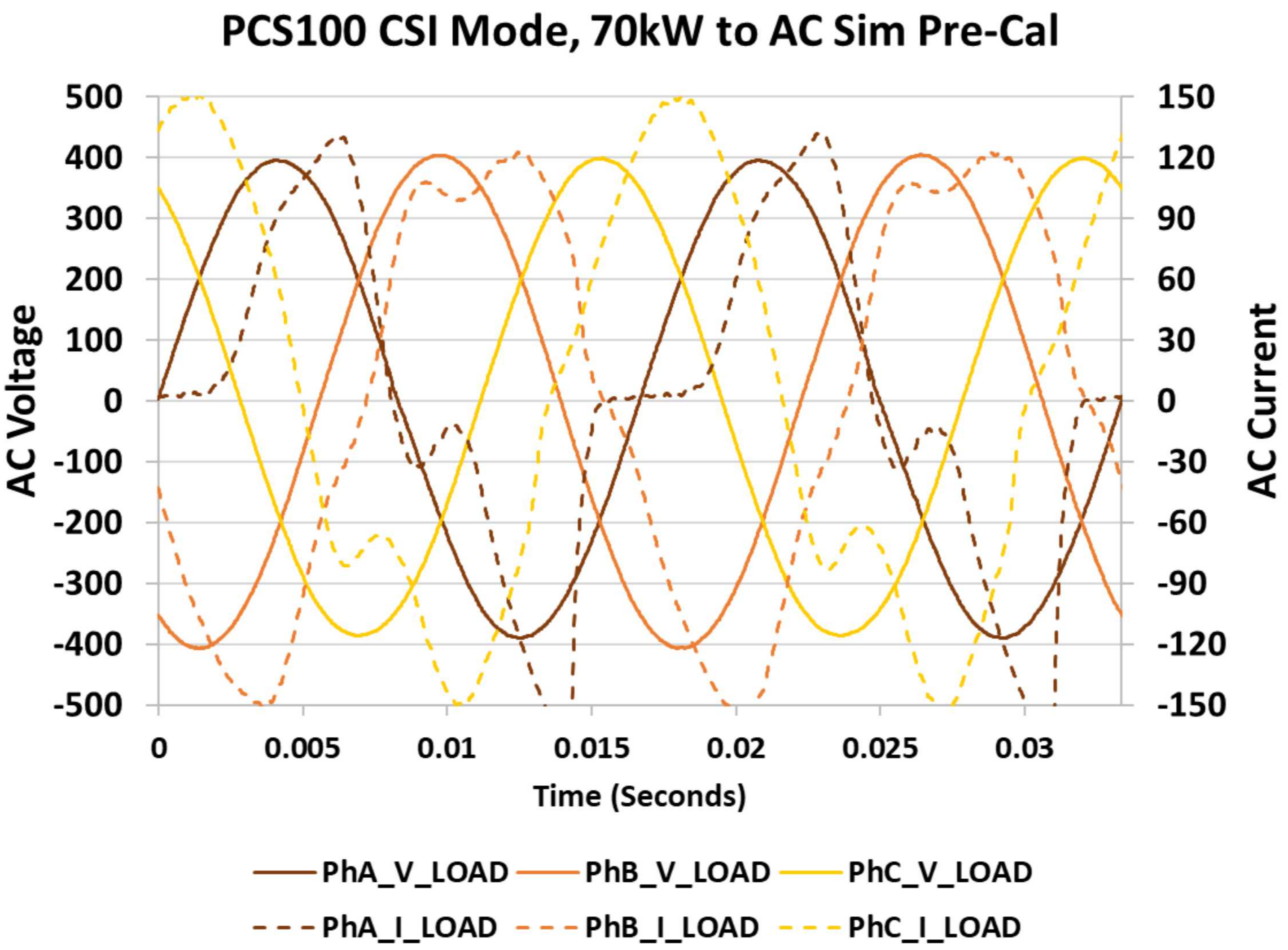


PCS100 in CSI Mode, 70kW to AC Sim Pre-Cal

PCS100 ESS Configuration

- Battery emulator provides dc
- Connected through Transformer
- CSI mode, 70kW active power

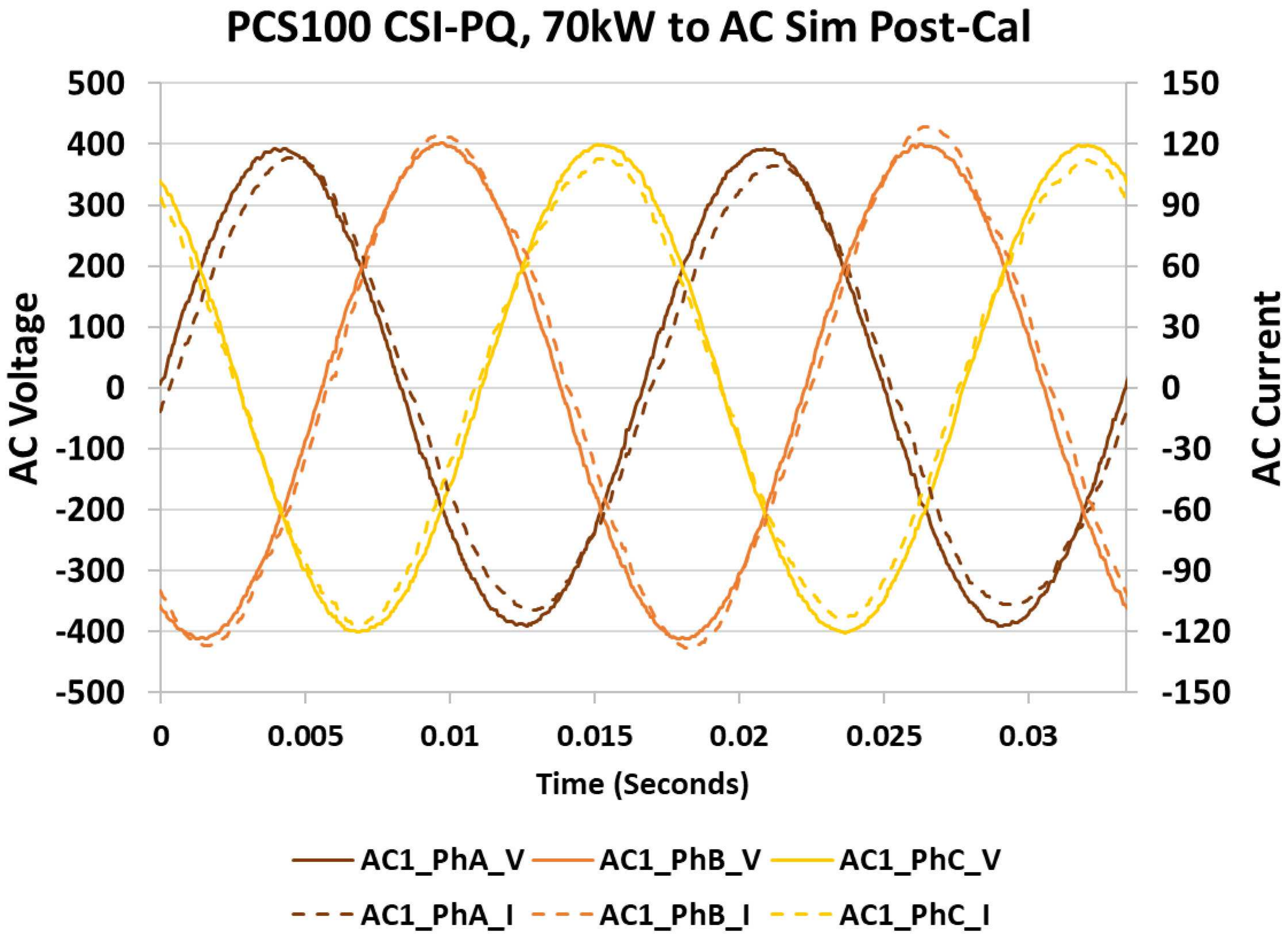
CSI should produce balanced and currents not balanced



PCS100 in CSI Mode, 70kW to AC Sim Post-Cal

PCS100 ESS Configuration

- Battery emulator provides dc
- Connected through Transformer
- CSI mode, 70kW active power and currents close to balanced



What's Next for Hardware

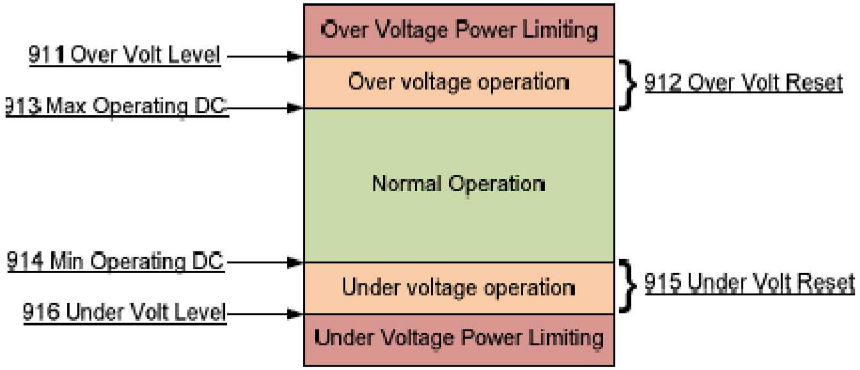
Conduct high resolution calibration on ac simulator

Operate the PCS100 in VSI and CSI mode with connected to the Utility Grid

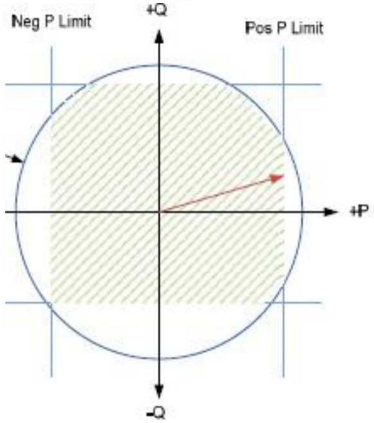
Obtain PCS ESS parameters from Cordova and implement in our inverter

Implement RTAC controls to optimize fault response of PCS in simulation

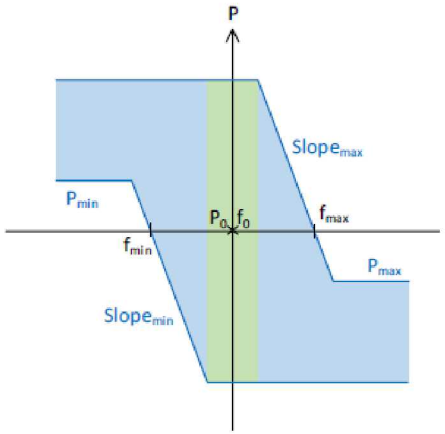
Voltage and Frequency Set Points for VSI VF and ISO	
These set points should be set before switching the inverters to VSI VF or VSI ISO base mode to avoid unwanted behavior.	
Frequency Set Point (Hz)	Frequency set points for VSI VF and VSI ISO.
Frequency Droop (%)	Frequency droop for VSI VF. Frequency droop allows power sharing between multiple ESS systems and power generators.
Voltage Set Point (V)	Voltage set point for VSI VF and VSI ISO.
Voltage Droop (%)	Voltage droop for VSI VF. Voltage droop allows power sharing between multiple ESS systems and power generators.



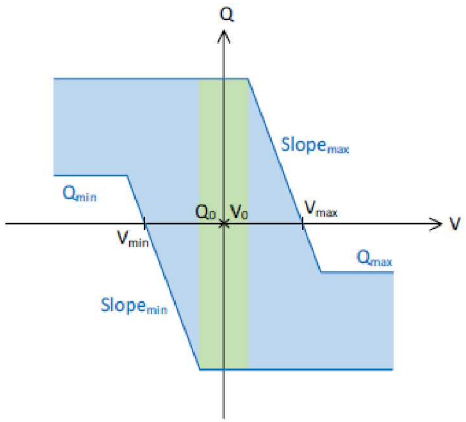
State of charge limiter



Absolute power limiter



Frequency regulator



Voltage regulator