Real-Time Simulation of Microgrid Protection Schemes under Dominion Energy's Locks Microgrid

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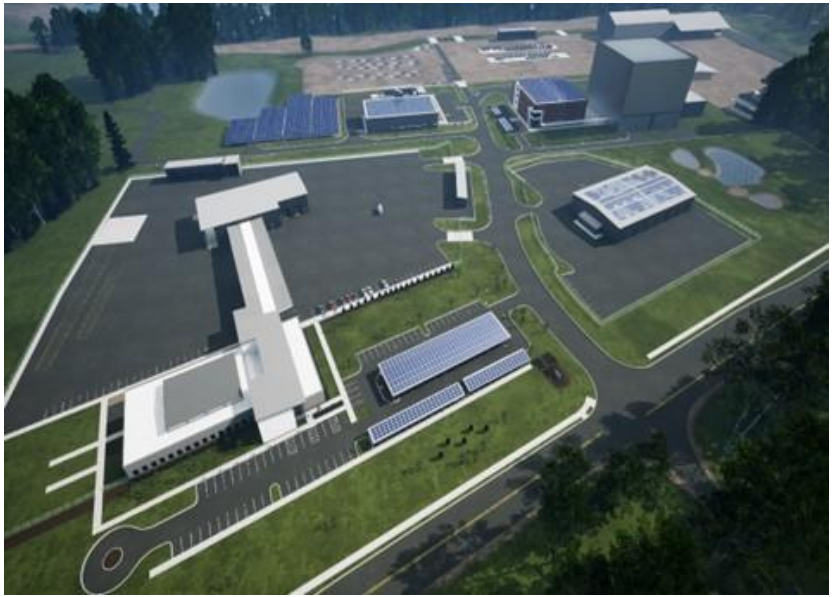
Locks Microgrid Overview

- **Virginia's Grid Transformation and Security Act**
  - Resilient and secured grid.
- **The Virginia Clean Economy Act of 2020**
  - 100 percent renewable electricity by 2045.
- **Dominion's Net Zero Commitment**
  - Net Zero greenhouse gas emissions by 2050.

Locks Microgrid

- Integrate distributed energy resources (DERs), such as solar, into the existing grid.
- Increase the system resiliency of the grid segments should disaster strike.
- Test different operation scenarios in real time.



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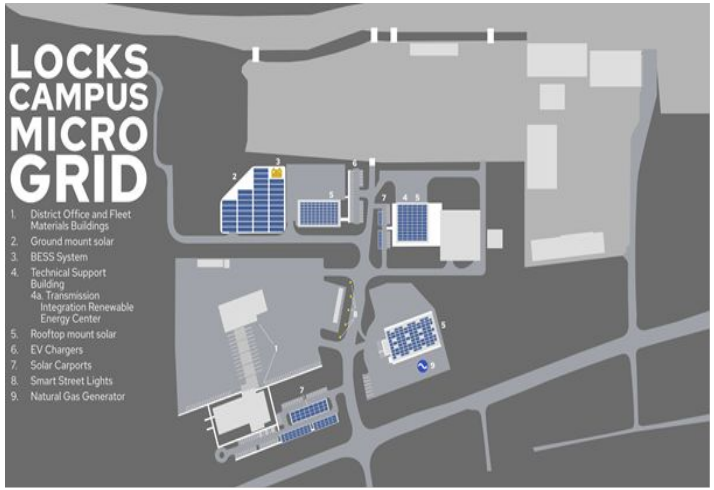
Locks Microgrid System

- Locks Microgrid has around 2 MW distributed energy resources (DERs) and serves around 0.3 MW buildings.



DERs	Location	Rating
BESS	3. BESS system	1 MW / 4 MWh
Solar1	5. Rooftop Mount Solar	180 kW
Solar2	5. Rooftop Mount Solar	96 kW
Solar3	2. Ground Mount Solar	400 kW
Solar4	5. Rooftop Mount Solar at 3.	240 kW
Solar5	7. Solar Carports	200 kW
Total		2116 kW

Loadings	Location	Demand
Load1	1. Fleet Materials building	64 kW
Load2	1. District Office	98 kW
Load3	Additional Buildings	124kW
Total		286 kW

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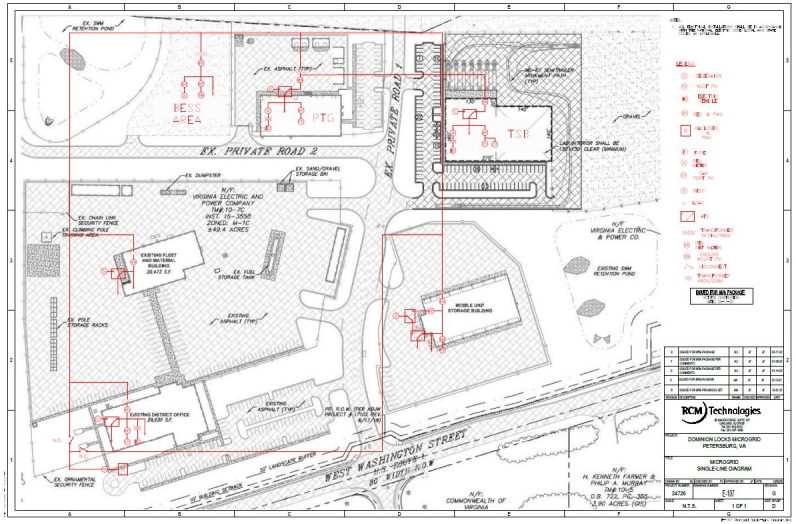
Locks Microgrid Modeling - Cable

- This RTDS model is based on real data and design

One-Line Diagram



Vendor's Specification of Cable

	Real	Imag.	Impedance	
Pos. & Neg. Seq. Impedance (Met. Shield):	0.222	0.097	0.242	Ω/kft
Zero Seq. Impedance (Earth & Met. Shield):	0.462	0.162	0.490	Ω/kft

Line Impedances in RTDS

Name	Description	Value	Unit
f	Line frequency	60.0	Hz
Rp	+ve sequence series resistance	0.442	ohms
Xp	+ve sequence series inductive react.	0.193	ohms
Xcp	+ve sequence shunt cap. reactance of line	1	Mohms
Rz	Zero sequence series resistance	0.92	ohms
Xz	Zero sequence series inductive react.	0.323	ohms
Xcz	Zero sequence shunt cap. react. of line	1	Mohms

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Locks Microgrid Modeling – PV Systems

- Model PV systems based on real data and design

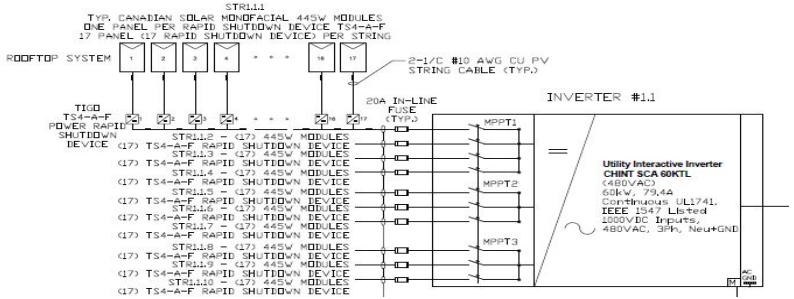
Vendor's Specification of PV Panel

CS3W	435MS	440MS	445MS	450MS	455MS	460MS	465MS
Nominal Max. Power (Pmax)	435 W	440 W	445 W	450 W	455 W	460 W	465 W
Opt. Operating Voltage (Vmp)	40.5 V	40.7 V	40.9 V	41.1 V	41.3 V	41.5 V	41.7 V
Opt. Operating Current (Imp)	10.75 A	10.82 A	10.89 A	10.96 A	11.02 A	11.09 A	11.16 A
Open Circuit Voltage (Voc)	48.5 V	48.7 V	48.9 V	49.1 V	49.3 V	49.5 V	49.7 V
Short Circuit Current (Isc)	11.42 A	11.48 A	11.54 A	11.60 A	11.66 A	11.72 A	11.78 A

PV Panel Model in RTDS

Name	Description	Value	Unit
Nc	Number of series connected cells per string per module	72	
Ncp	Number of parallel strings of cells (Note: Total cells per module= nsc*np	2	
Voc...	Open circuit voltage (Voc @ STC Tref, INSref)	48.9	Volts
Iscref	Short circuit current (Isc @ STC Tref, INSref)	5.77	Amps
Vm...	Voltage at Pmax (@ STC Tref, INSref)	40.9	Volts
Impr...	Current at Pmax (@ STC Tref, INSref)	5.445	Amps

Actual Design of PV Configuration



PV Configuration Model in RTDS

Name	Description	Value
Ns	Number of modules in series	17
Np	Number of modules in parallel	10

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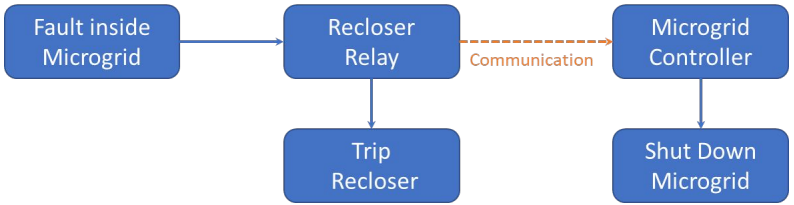
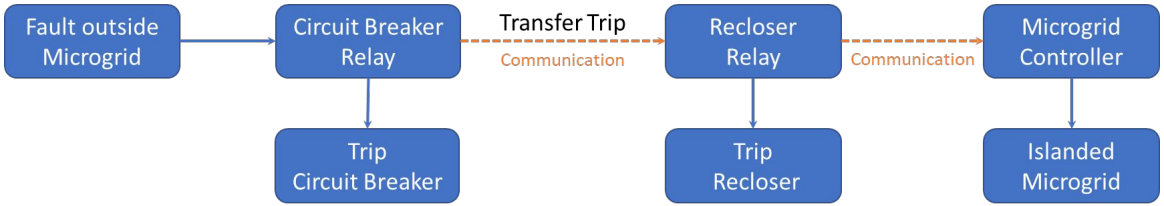
Protection Schemes

- Overcurrent Protection



- Transfer Trip Protection



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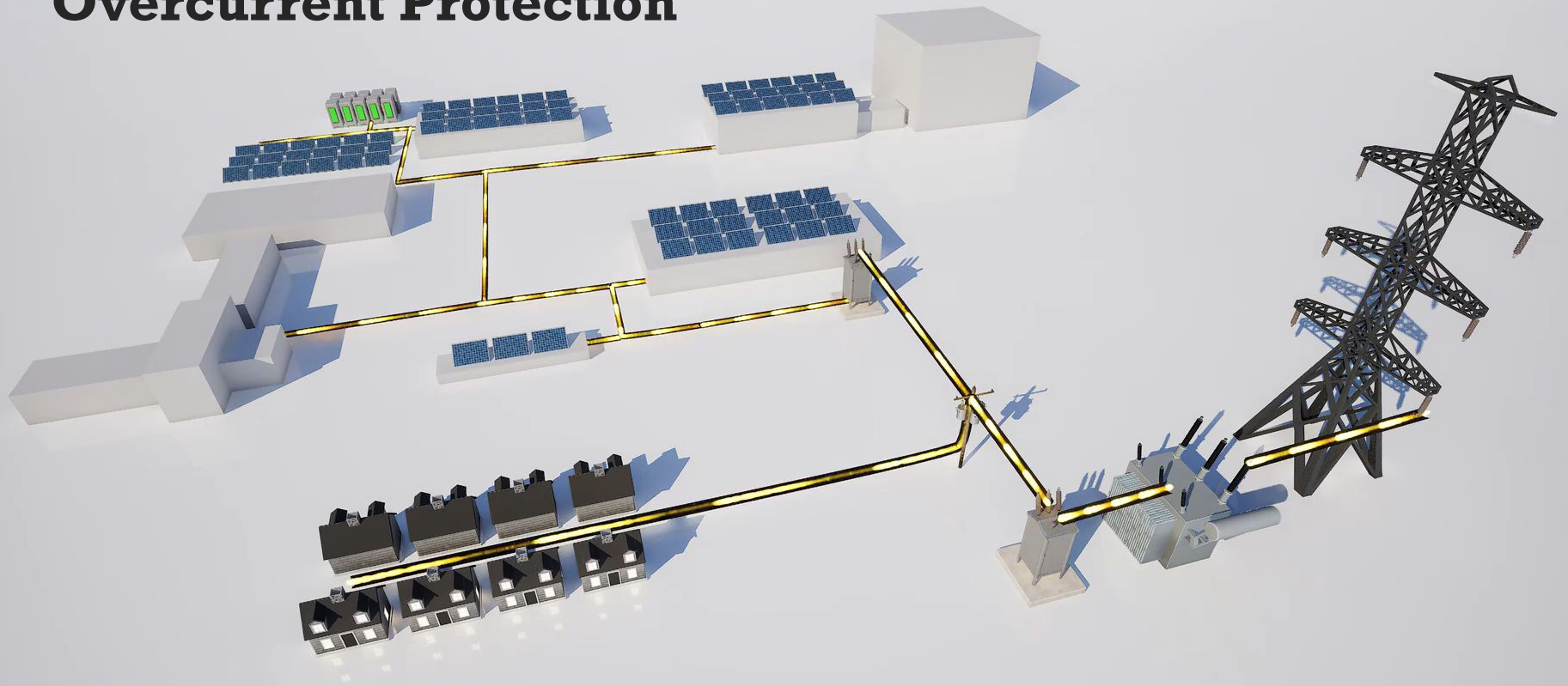
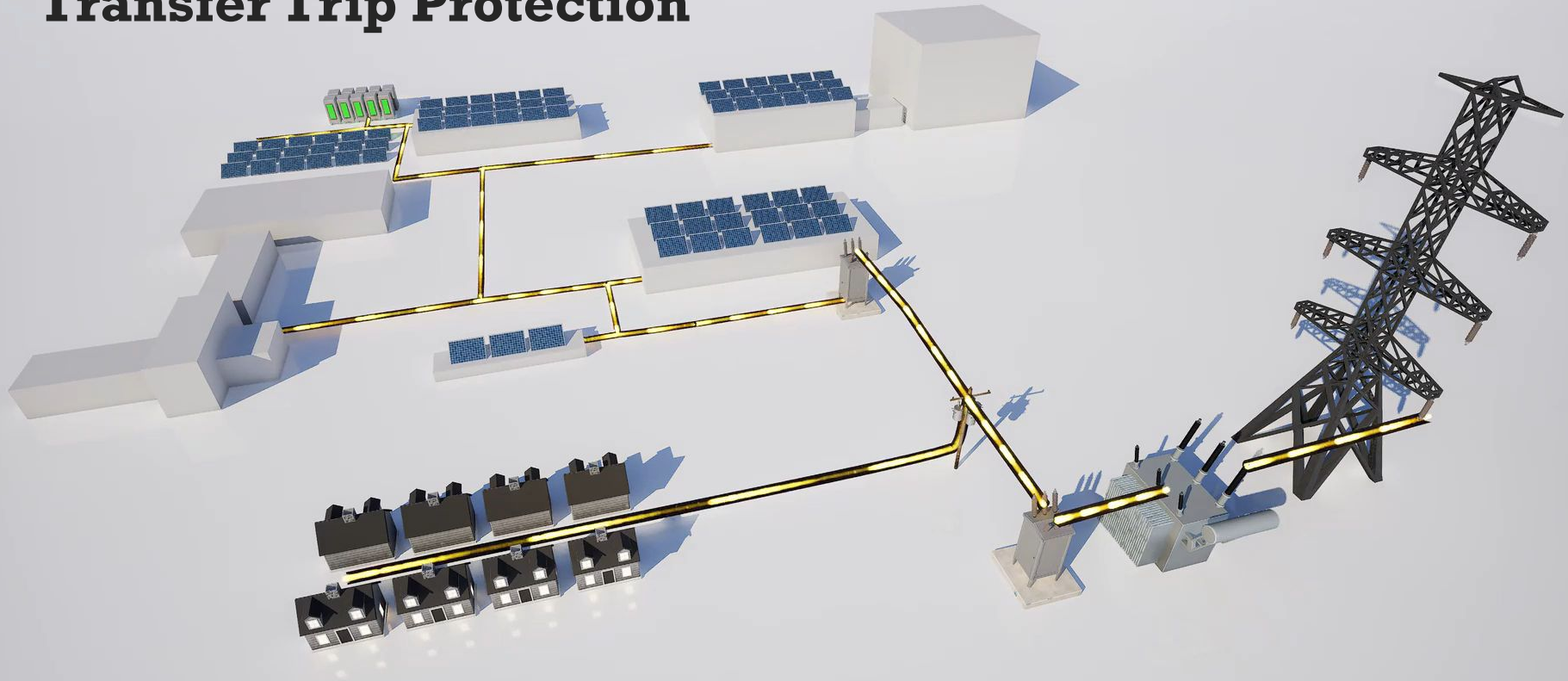
Overcurrent Protection



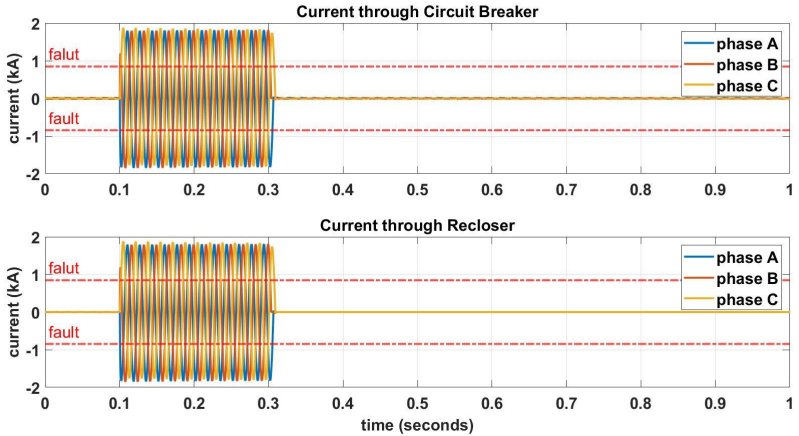
Transfer Trip Protection

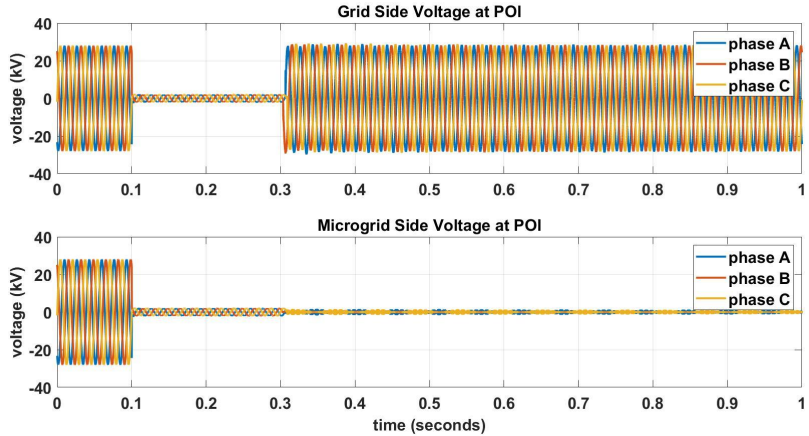


Simulation Result – Overcurrent Protection

- Fault currents and system voltages

Fault inside Microgrid





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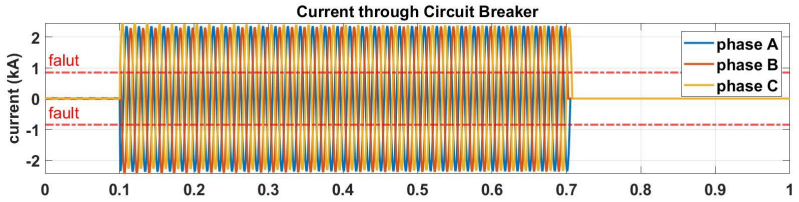
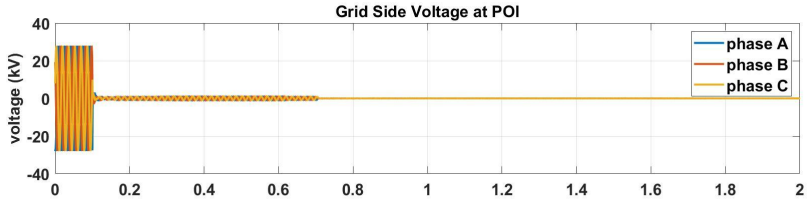
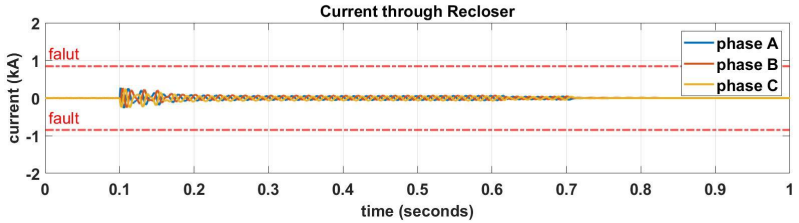
Simulation Result – Transfer Trip Protection

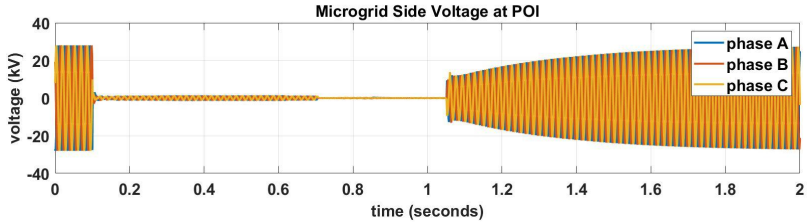
- Fault currents and system voltages

Fault outside Microgrid









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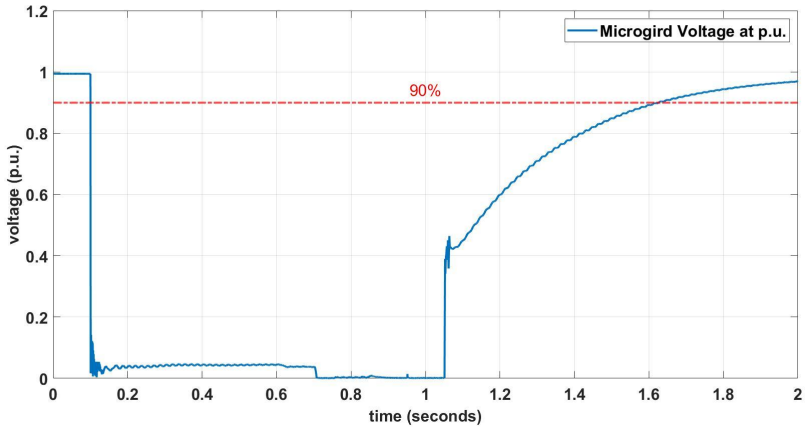
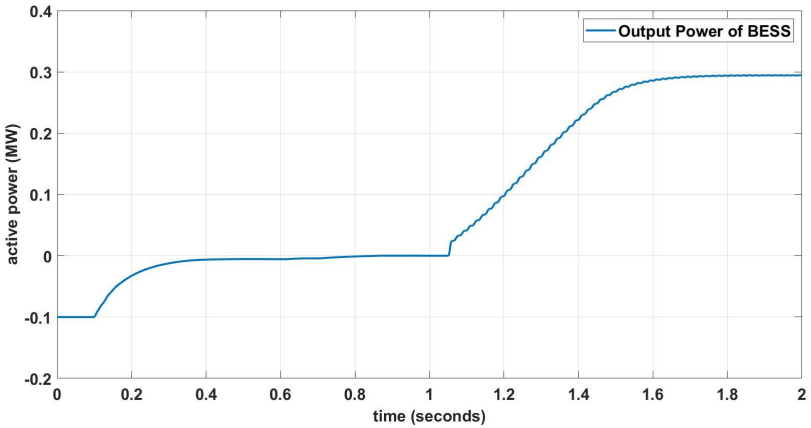
Simulation Result – Transfer Trip Protection (cont'd)

- Microgrid voltage and output power of BESS

Fault outside Microgrid





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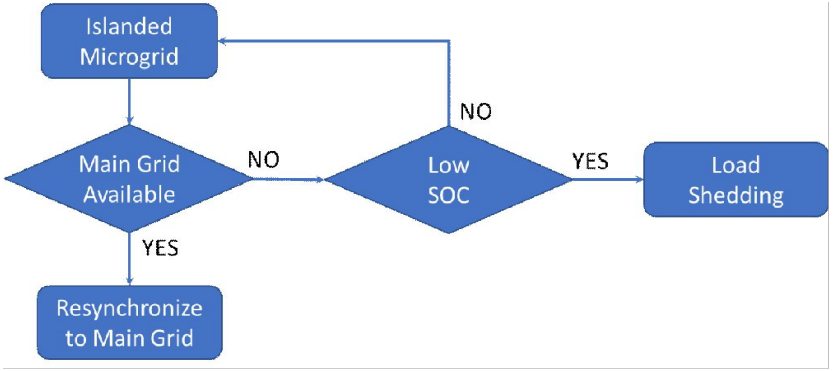
Islanded Microgrid Resynchronization or Load Shedding

- To operate as an islanded microgrid, the BESS will function in grid-forming mode to establish the microgrid's voltage and frequency.
- The microgrid will resynchronize once the main grid becomes available.
- Otherwise, if the BESS's state of charge (SOC) drops below 40%, load will be shed.



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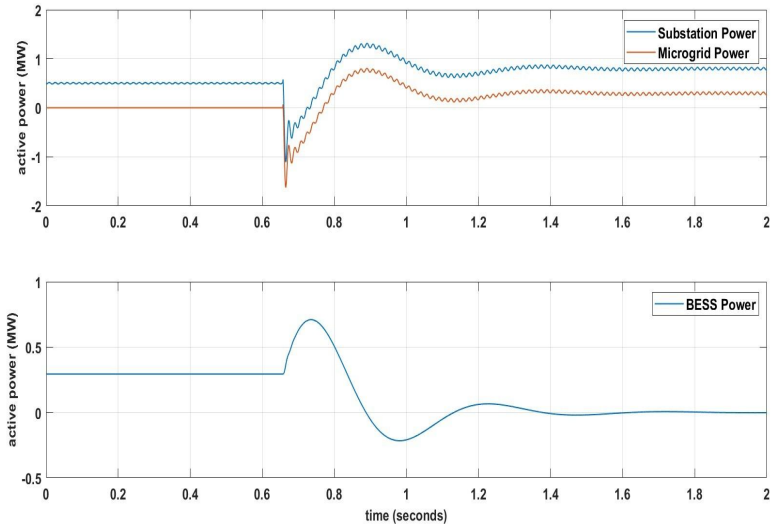
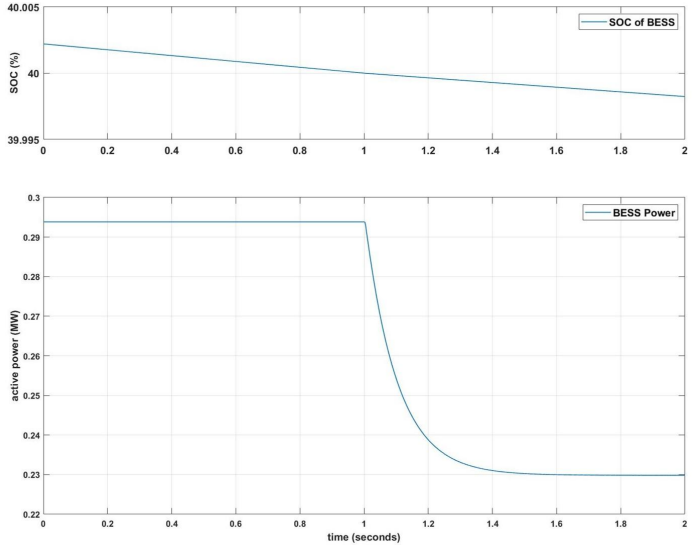
Simulation Result – Islanded Microgrid Operations

- Resynchronization or Load Shedding





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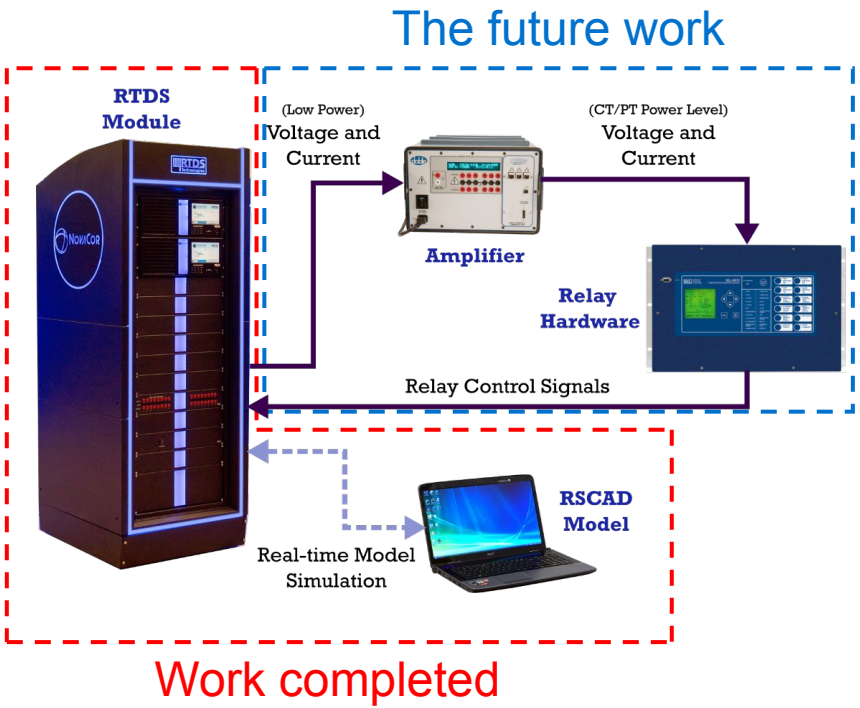
Conclusion and Future Work

Conclusion

- The Locks Campus Microgrid was modeled in RSCAD to evaluate microgrid protection and control.
- When a fault occurs inside a microgrid, the protection relay should isolate the microgrid while maintaining the distribution system.
- But if the fault occurs outside the microgrid, a transfer trip to the recloser will be activated. The microgrid will operate under the islanded mode, where the BESS works on grid-forming mode.

Future Work

- Verify the performance of the relay using the hardware-in-the-loop (HIL) simulation.



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Thank you

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