The Transformer-less Unified Power Flow Controller (TUPFC) for Power Flow Control at Normally-Open Primary-Ties

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Agenda

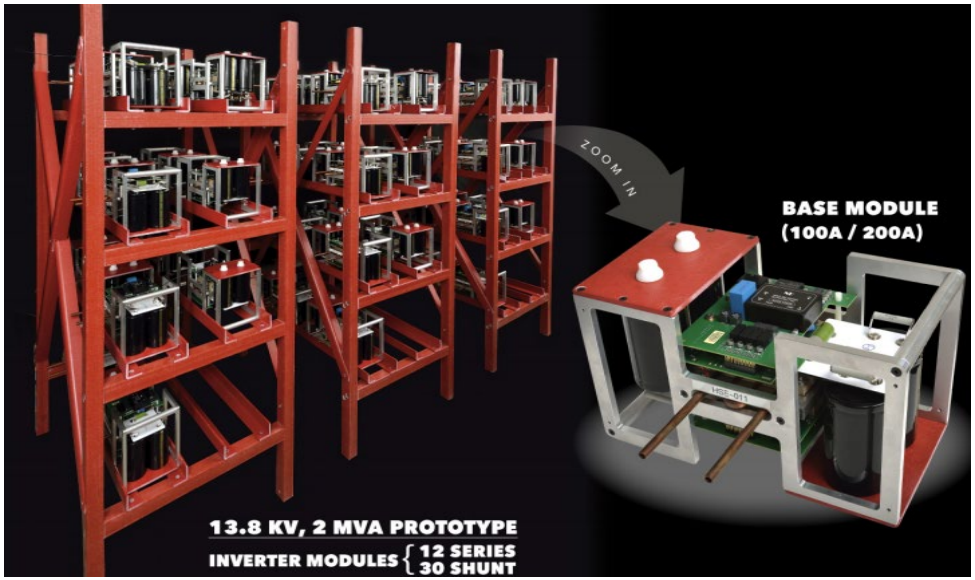
- Southern Company R&D Interest Background
- ARPA-E Background
- Application Background
- Technology Summary
- Georgia Power System Location Characteristics
- General Studies
- Site specific Studies
  - Solar Hosting Benefits
  - Volt-VAr Benefits

SWITCHED SOURCE

Southern Company R&D Background

SWITCHED SOURCE

Switched Source Background



2012 → 2016 → Today

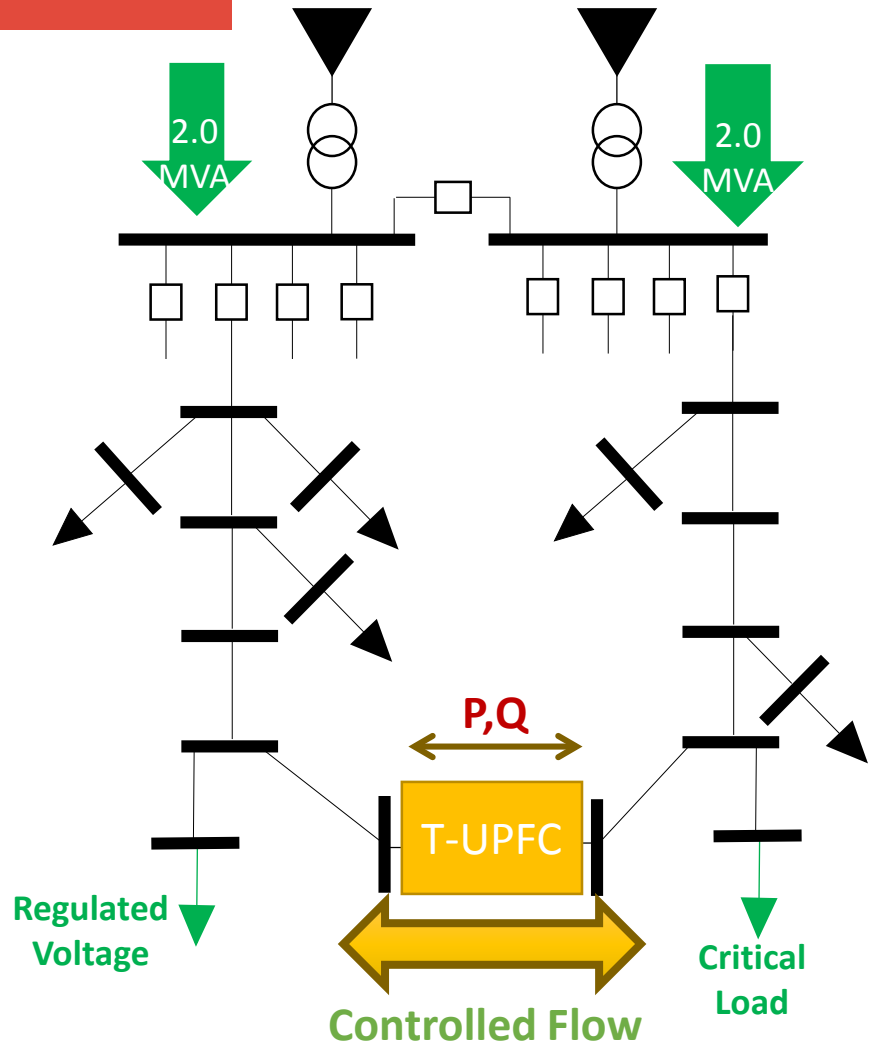
MICHIGAN STATE UNIVERSITY

SWITCHED SOURCE

U.S. DEPARTMENT OF ENERGY arpa·e

The power flow controller can tie feeders together at normally open tie locations: increasing reliability, efficiency, and management of distributed generation

- By coupling these feeders with the power flow controller, loads can be balanced better through the substation transformers
- Reactive power can be supplied for Volt-Var Optimization
- More reliable power can be supplied to critical loads
- Loop flows are eliminated by the device's power flow control



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System is a cascaded modular design, paired with switchgear and enclosure design from existing utility equipment providers.

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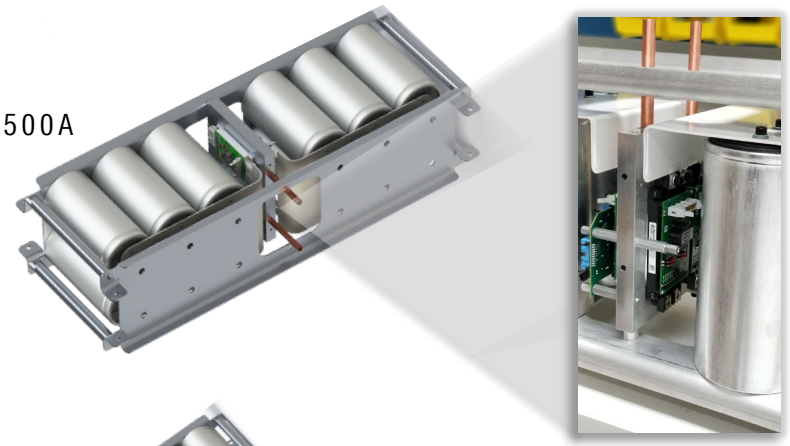
POWER MODULE

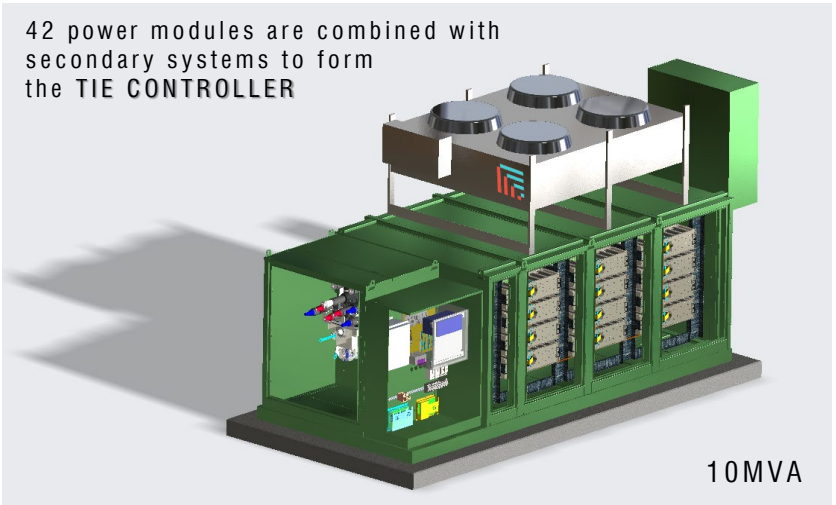
500A



266A

133A

42 power modules are combined with secondary systems to form the TIE CONTROLLER



10MVA

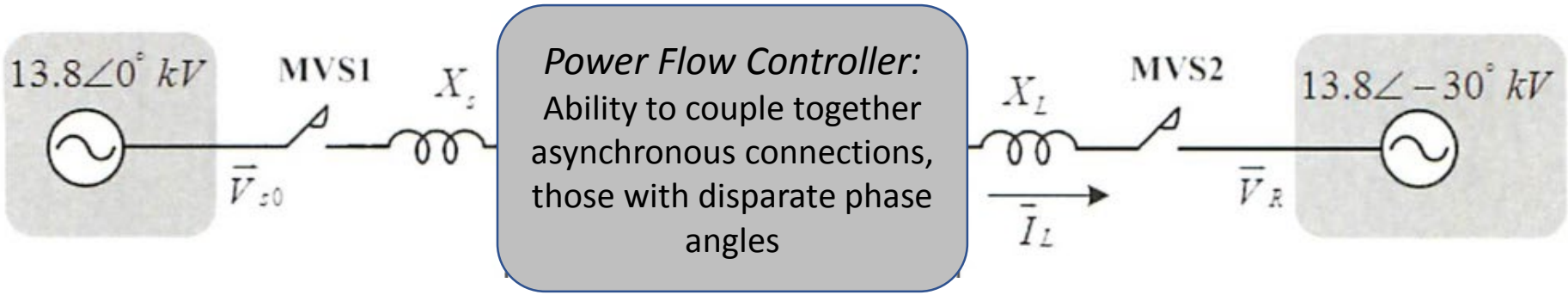
Outer enclosure with cabinets for systems access

10MVA

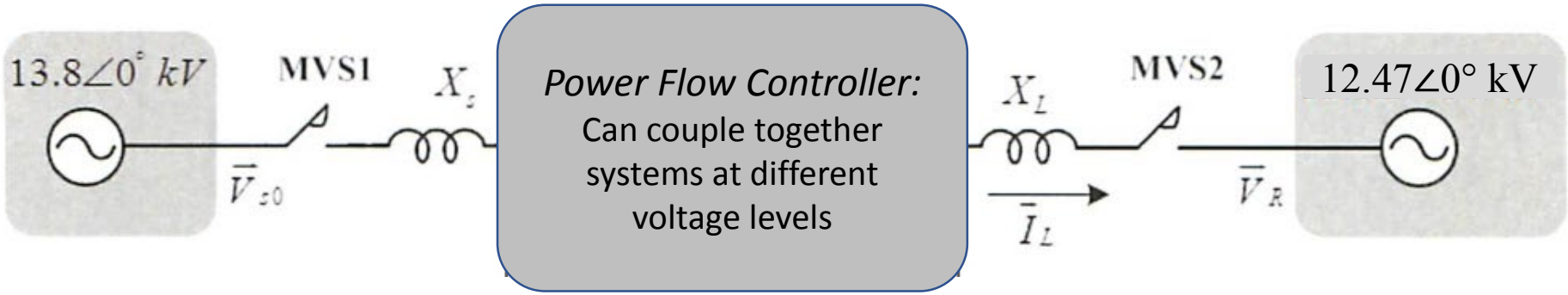
SWITCHED SOURCE

The device can connect out of phase or differing magnitude voltage feeds and control real and reactive power flow, designed to support an entire 15kV 10MVA circuit

Voltage Angle Mismatch



Voltage Magnitude Mismatch



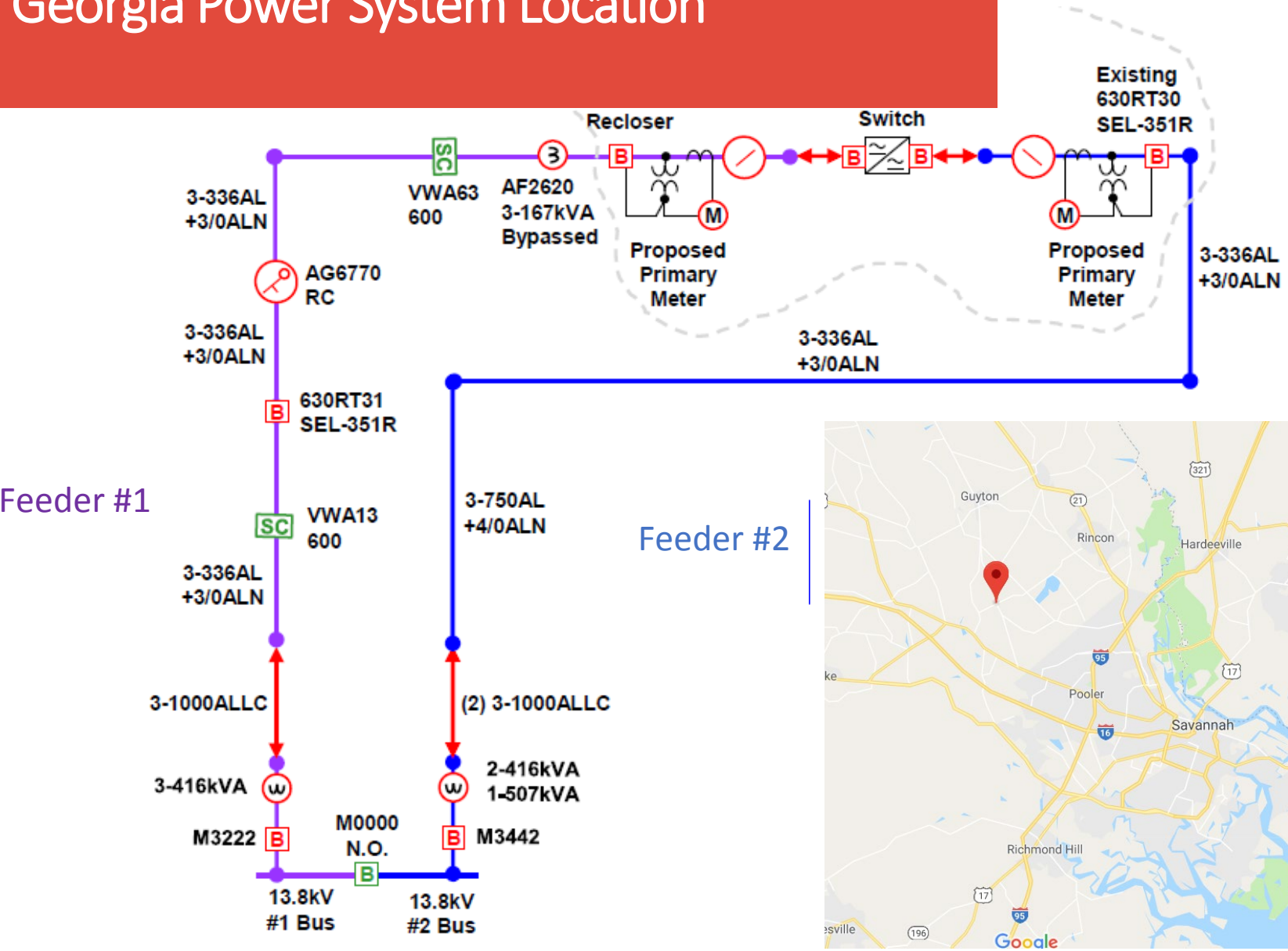
SWITCHED SOURCE

The Transformer-less UPFC has been evaluated alongside other potential power electronics solutions for "Soft-Open Points"

	STATCOM	B2B	MT	SSSC	UPFC	TUPFC
Feeder Connection	None	DC-Link (async.)	DC-Link (async.)	Direct (sync.)	Direct (sync)	Direct (sync.)
Active Power Exchange	N	Y	Y	Limited	Y	Y
Post-Fault Restoration	N	Y	Y	Y	Y	Y
Reactive Power Support	Y	Y	Y	Limited	Y	Y
Partially Rated Converters	Y	N	N	Y	Y	Y
Additional Feeders Required	N	Y	Y	Y	Y	Y
No Transformer	N	N	N	N	N	Y
Isolates Circuit with Disturbance	N	Y	Y	N	N	Y
Limits Fault Current	N	Y	Y	N	N	Y
VSCs in Series	0	2	2	1	1	1
VSC in Shunt	1	0	0	0	1	1
VSCs per Device	1	2	>3	1	2	2

SWITCHED SOURCE

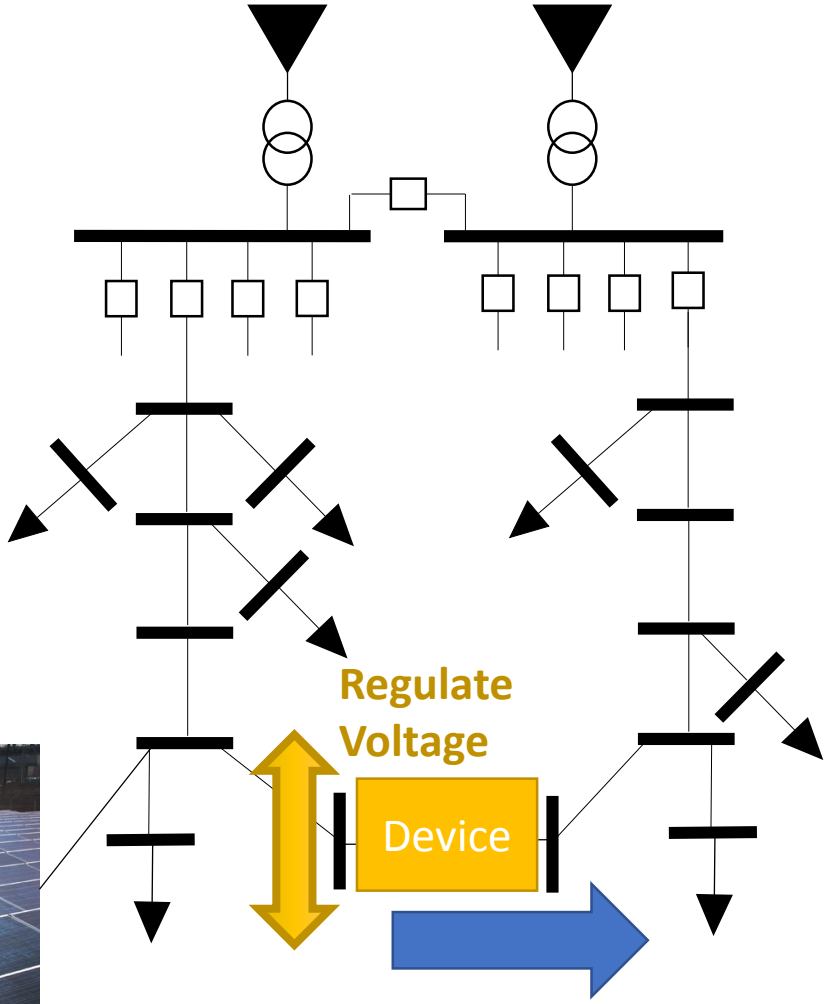
Georgia Power System Location



SWITCHED SOURCE

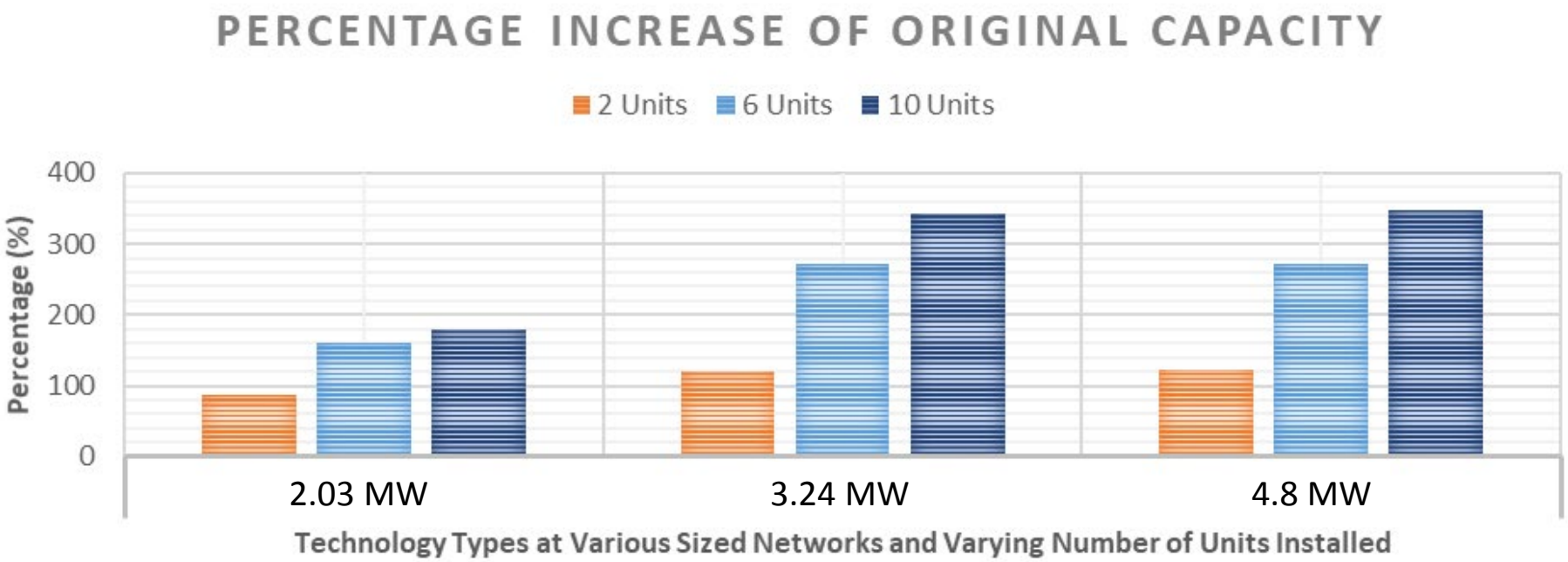
The Tie Controller can route excess solar generation to more load on adjacent feeders, increasing solar hosting capabilities to 50% penetration, at 5% of the cost of energy storage

5 MW of Solar



SWITCHED SOURCE

Analysis of larger system wide studies highlight significant solar benefits.



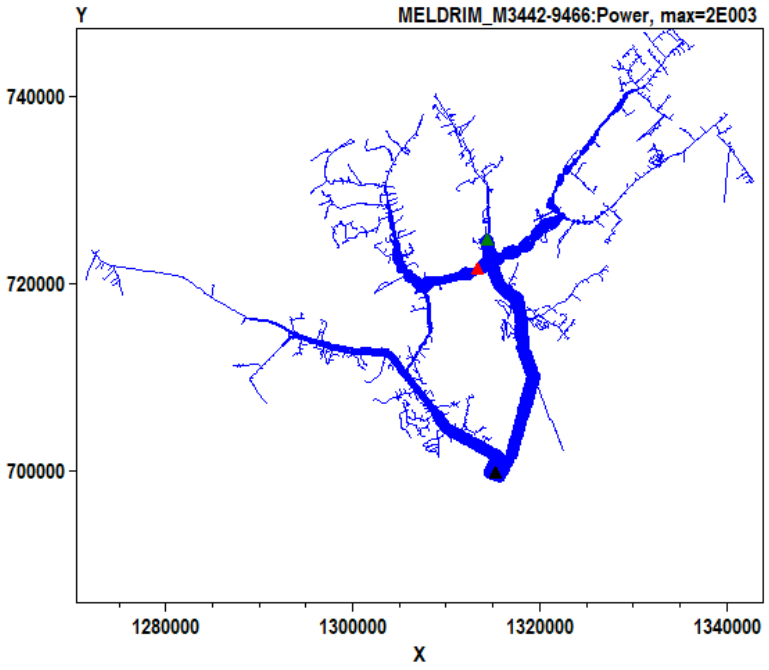
- Installation of 5 UPFCs at a network that originally hosts 4.88 MW of renewable energy can triple the initial hosting capacity.
- Installing 1 UPFC can double renewable energy hosting capacities.
- Other take-aways from larger analysis: UPFC performs significantly better than STATCOMS and performs similar to B2B.

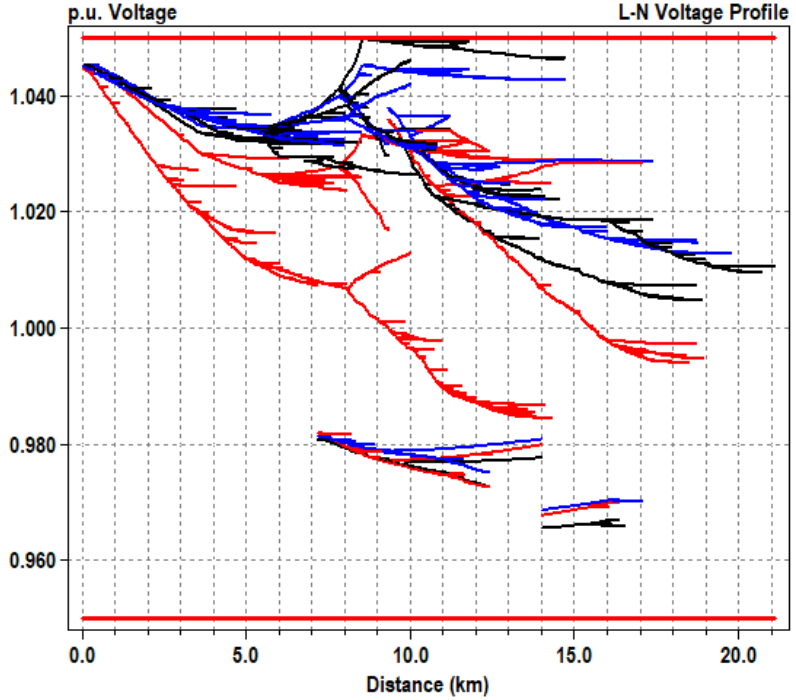
J. Bloemink and T. Green, "Benefits of Distribution-Level Power Electronics for Supporting Distributed Generation Growth". IEEE Transactions on Power Delivery, Vol. 28, No. 2, April 2013.

Southern Co feeder analysis was performed by Switched Source in OpenDSS.

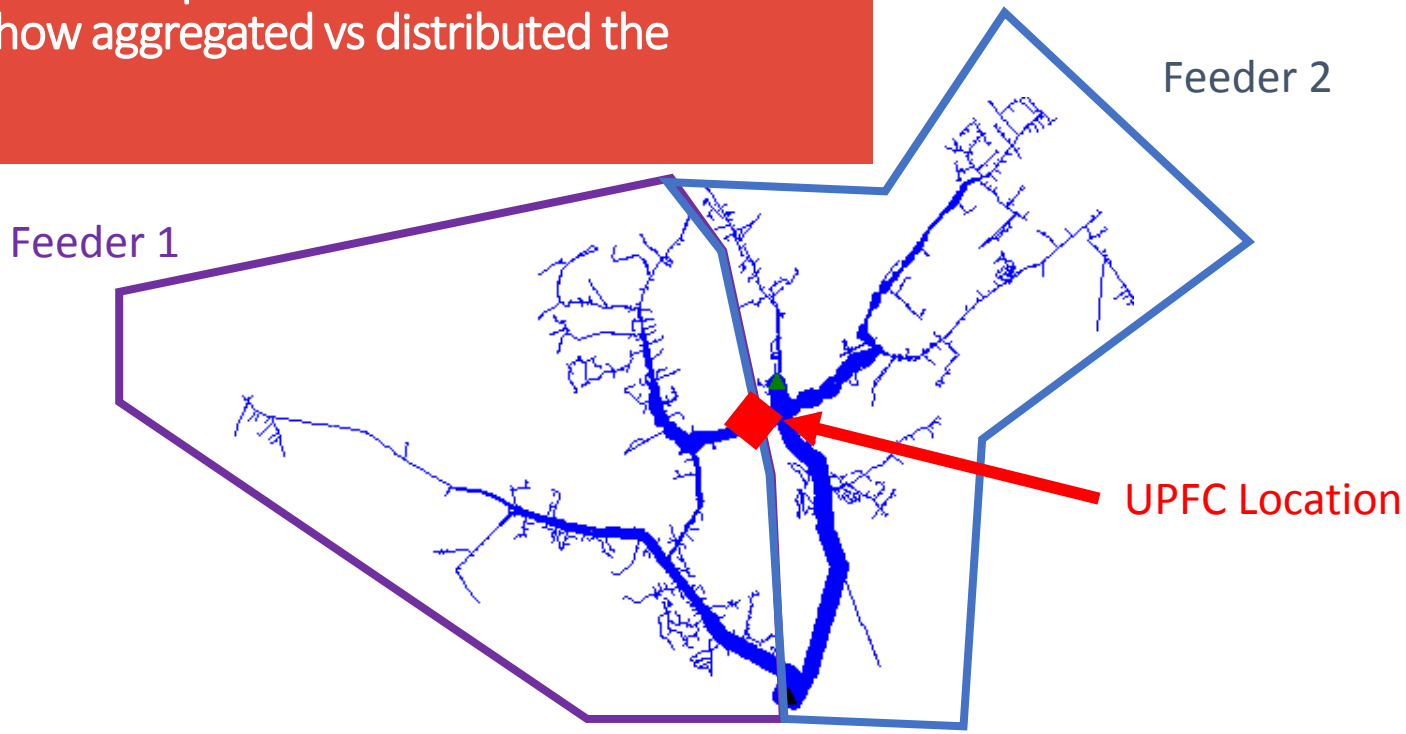
Maximum DG was assessed at peak load based upon three criteria:

1. Conductor ratings (thermal ratings)
2. Voltage Profile (ANSI Voltage Requirements)
3. No substation backfeed (potential relay complications/upgrades)





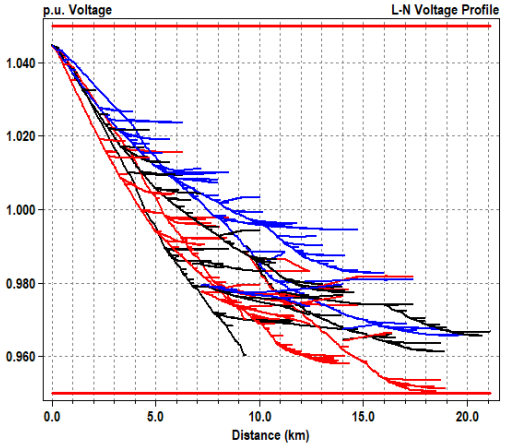
Results range based upon where the solar is located and how aggregated vs distributed the solar is.



Feeder	Node	Original Hosting Capacity	Hosting Capacity After TC
Feeder 1	188_12252	6 MW	14 MW
Feeder 1	221_456539	5 MW	13 MW
Feeder 1	226_408678	6 MW	18 MW
Both Feeders Distributed	Skip scheme	12 MW	18 MW
Feeder 2	189_3739212	9.35 MW	13.4 MW
Feeder 2	941_6315608	9.18 MW	14.2 MW
Feeder 2	195_2309522	9.2 MW	14.2 MW
Feeder 2	941_4777623	11.5 MW	16.1 MW

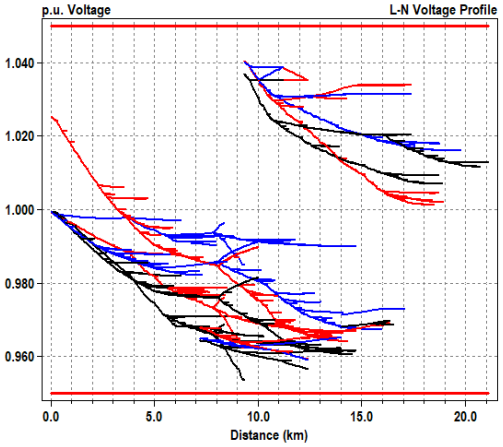
CVR and VVO benefits can also be increased with use of Soft-Open Points.

CVR without TC



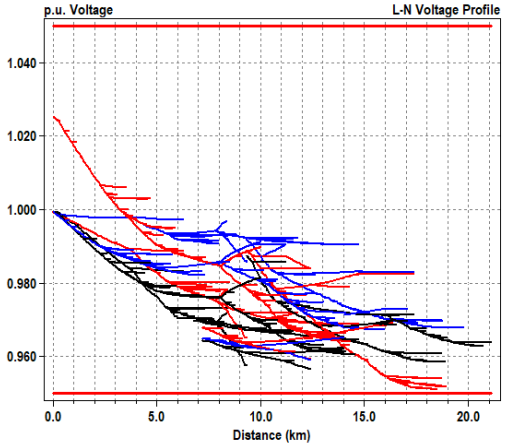
The power consumption difference is= 0.24452 MVA
The power losses difference is = 0.0594 MVA
Total Power Savings = 0.30392 MVA

CVR with TC



The power consumption difference is= 0.20923 MVA
The power losses difference is = -0.076691 MVA
Total Power Savings = 0.13254 MVA

Adjusting the other Regulators to do further CVR with TC



The power consumption difference is= 0.45012 MVA
The power losses difference is = -0.019662 MVA
Total Power Savings = 0.43046 MVA

- The Tic Controller increased CVR capability by 0.1265 MVA which is 46.6% increase of the original capability. The CVR benefit without the Tie Controller is 1.67% and with the Tie Controller it becomes 2.37% which is a 0.7% increase

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