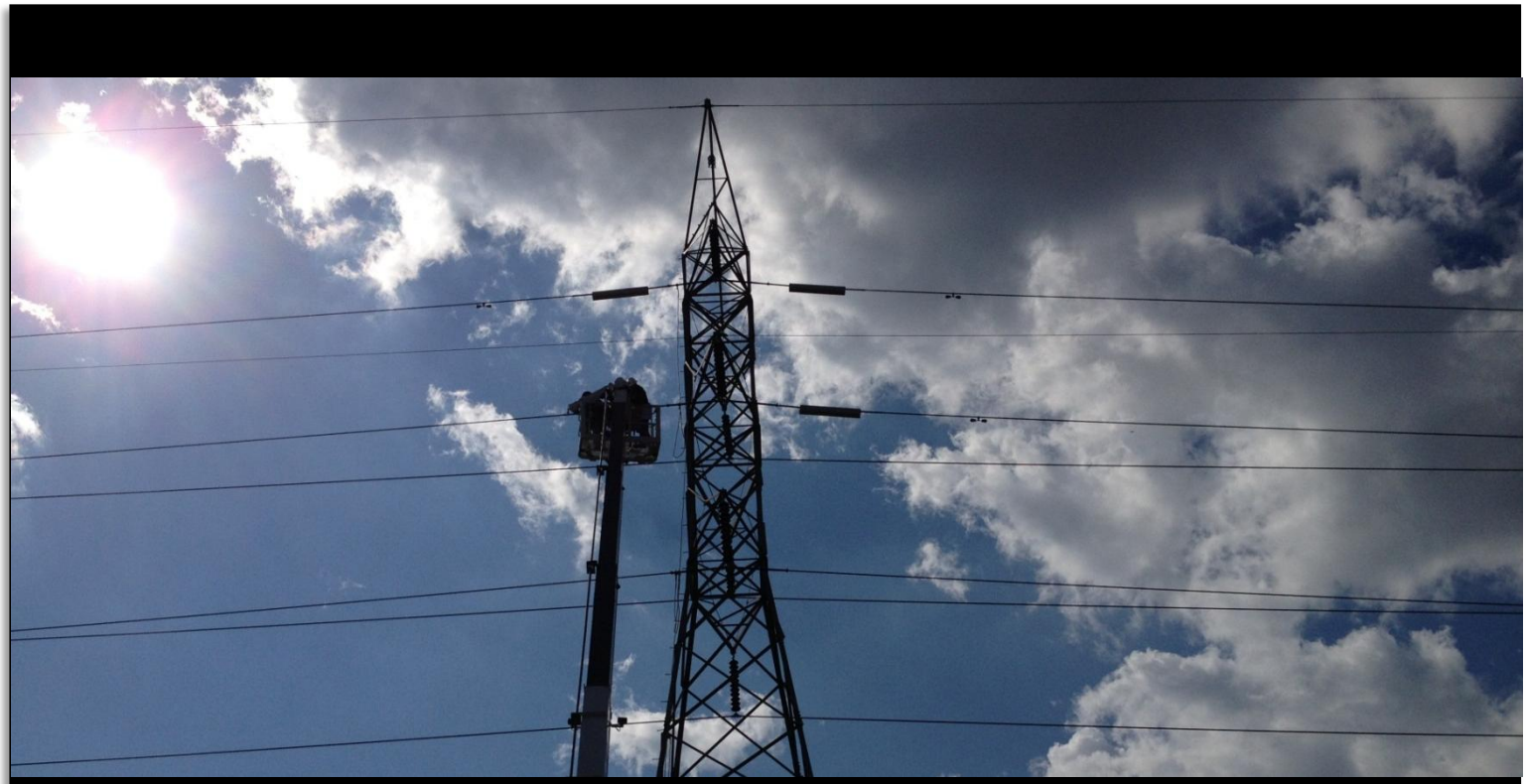
Power flow control for the Grid

Smart Wire Grid

Distributed FACTS Devices

for Transmission & Distribution Power Grids



Smart Grid Forum at Hannover Fair 2014

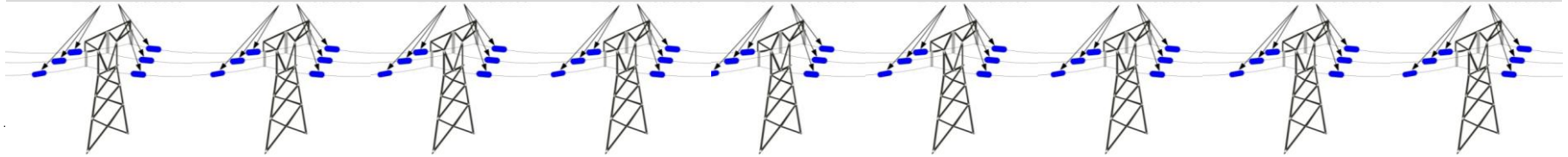
March 11th, 11:20-11:40am

Our Vision of Distributed FACTS …

Volatile power flow from intermittent generation and demand require intelligent grid operation and physical networks with flexible topologies.

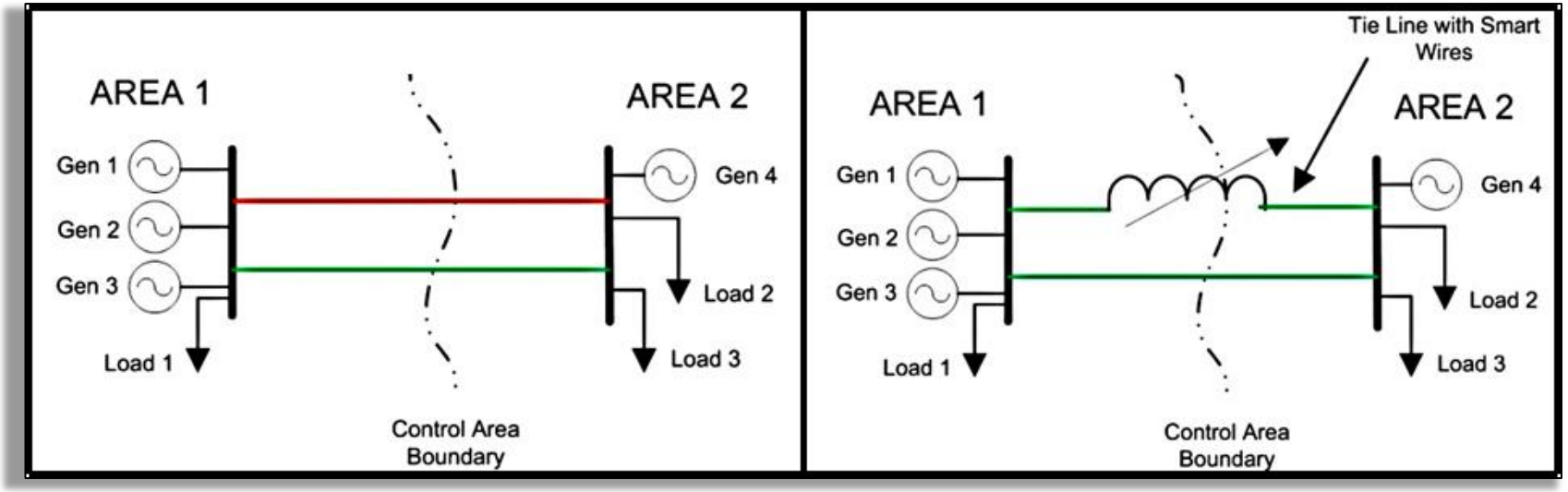
Our Distributed FACTS system adresses both the operation and the physical network design of power lines:

- **It varies line impedance autonomously and under remote control.**
- **It has high reliability and security.**
  - It is powered from the line itself.
  - It has no single point of failure.
  - It is maintenance-free.
  - It configures itself and under remote control.
- **It is easy to install with significantly less outage time and avoids lengthy permission procedures.**
- **It defers investments in network capacity and saves money.**



Smart Wires Concept …

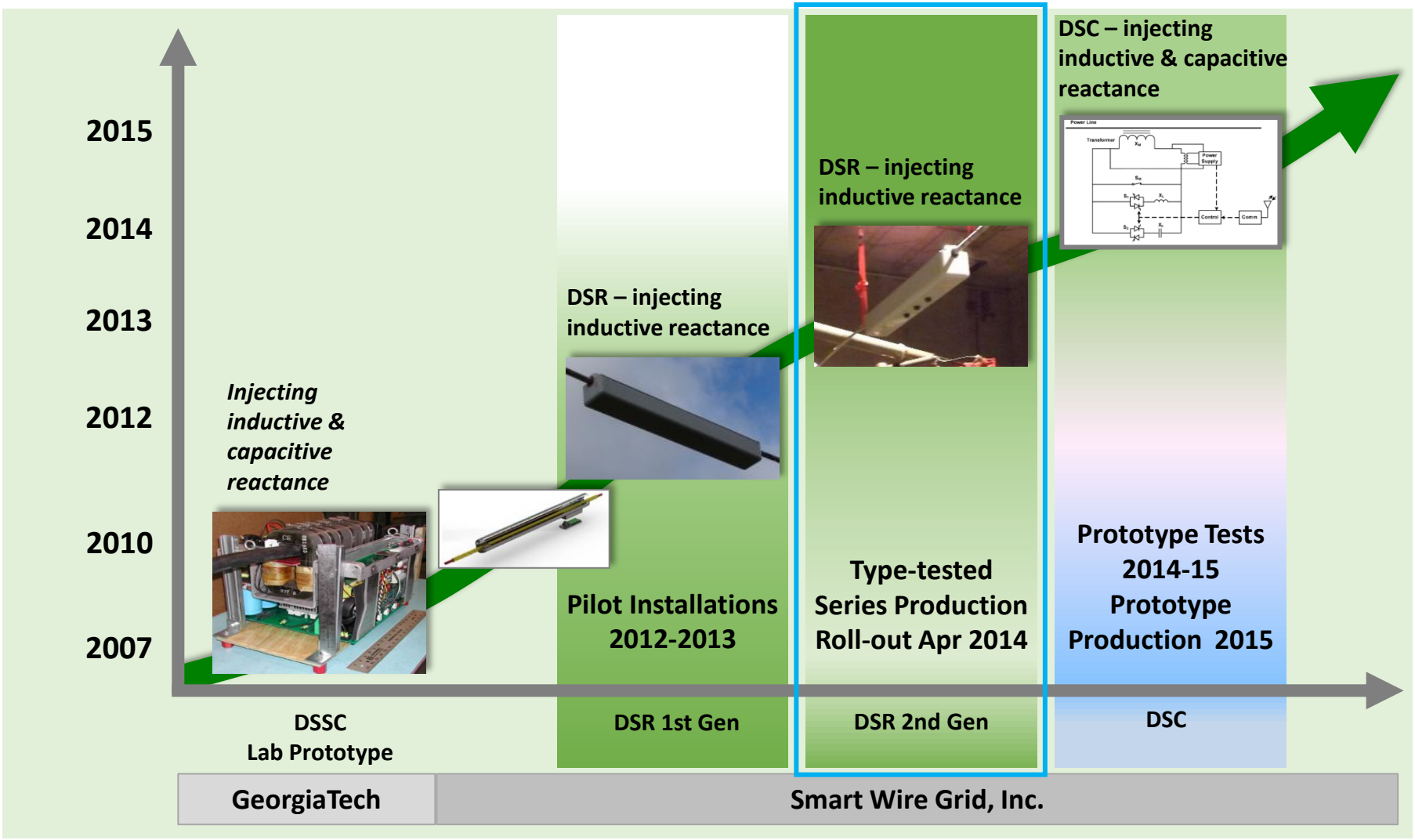
- **Rapidly deployable technology to convert overhead lines with fixed impedance into transmission lines with variable impedance**
  - which monitors line parameters
  - and is capable of self-controlling line impedance and diverting power flows
- **Simplified schematic showing basic principle:**



Imbalanced impedances leads to overload (red)

Smart Wires increases or decreases impedance to resolve overload (green)

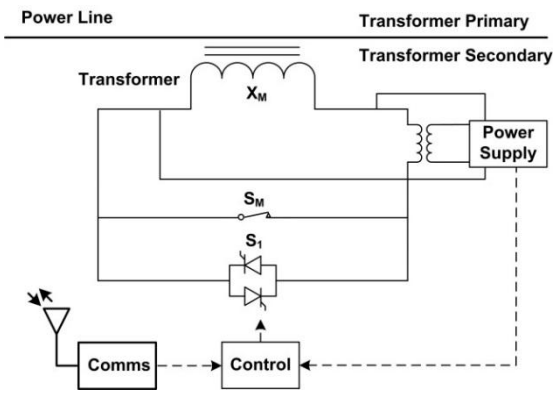
Smart Wire Grid Milestones



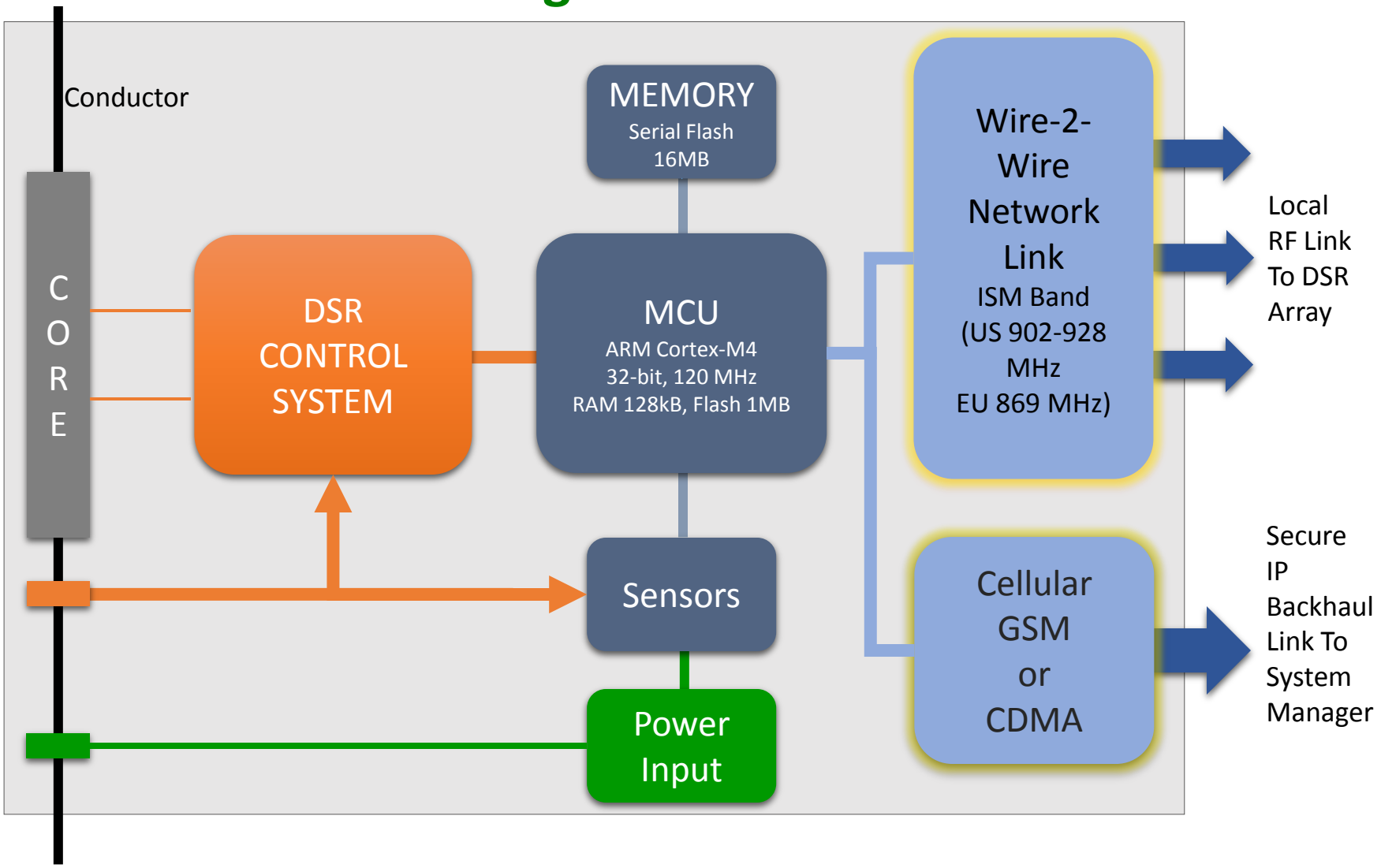
DSSC Distributed Static Series Compensator - **DSR** Distributed Serie Reactor - **DSC** Distributed Series Compensator

DSR Distributed Series Reactor

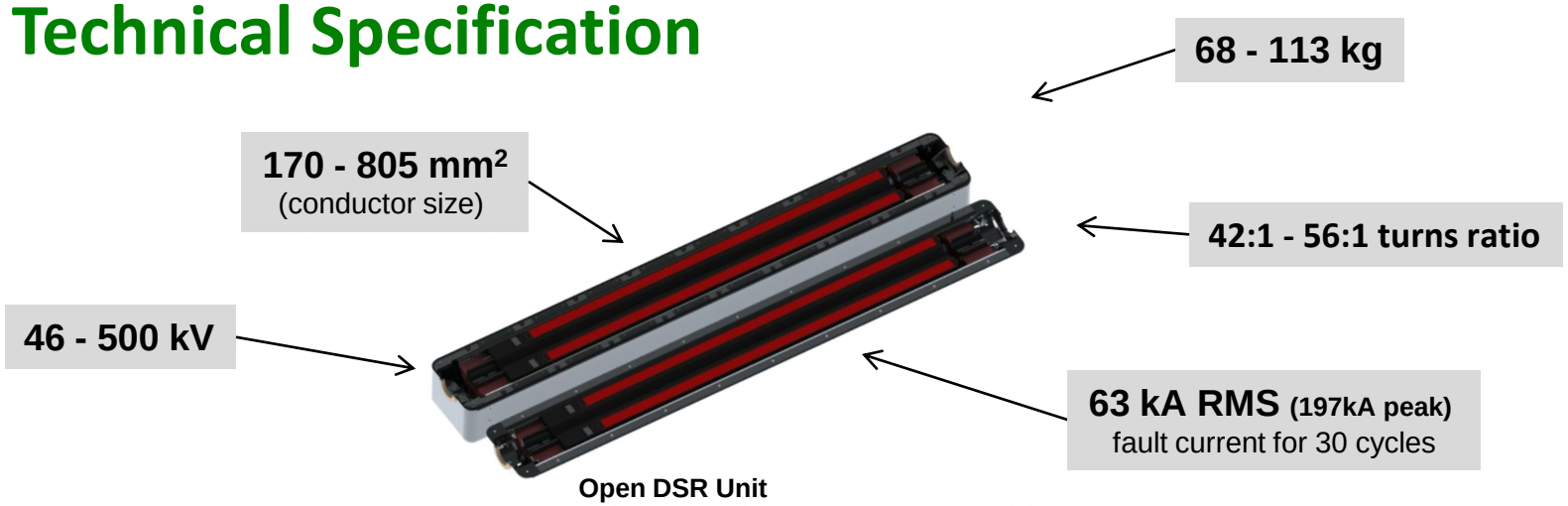
- **Actuator part:**
  - Each device can increase the line impedance by injecting a pre-tuned value of magnetizing inductance into the conductor
- **Sensor part:**
  - Each device has sensors for line monitoring
- **Two modes of operation:**
  - The “fleet” of devices can operate autonomously with pre-set tripping points to inject impedance
  - Each device has radio communications for remote control to enable sophisticated grid operation and dynamic line rating by the grid control center



DSR Hardware & Intelligence …



DSR Technical Specification

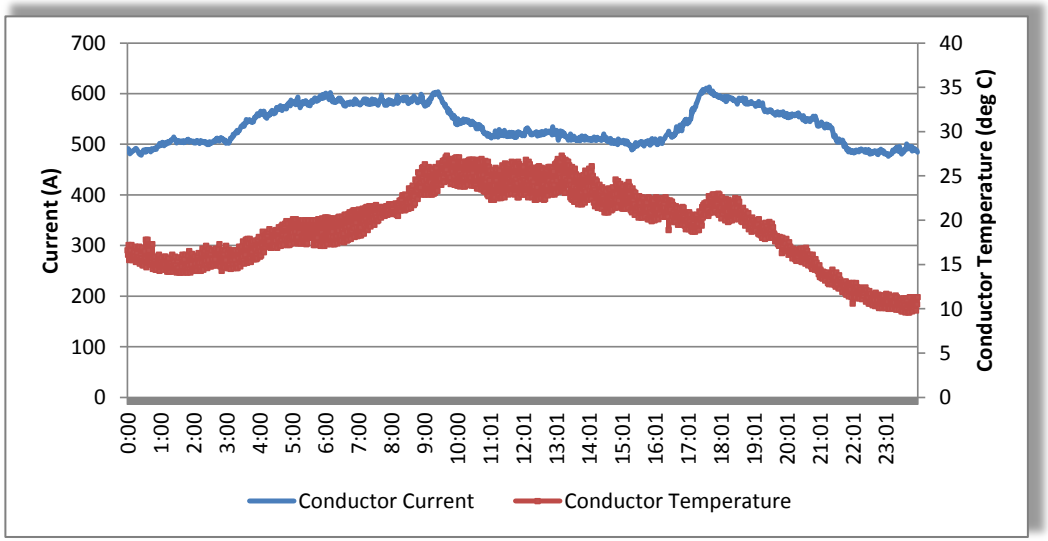


- **Life**: 20+ year life; zero maintenance
- **Fault current**: sense << 5 µs, then automatic transition from injection to monitoring mode in << 4 ms
- **No corona at operating voltage**
- **Environmental**: Resistant to salt fog, Aeolian vibration, ice buildup, thermal cycling
- **Conductor impact**: No mechanical or thermal conductor degradation
- **Lightning Strike**: tested to line BIL
- **Wind loading**: up to 250 km/hr
- **Communications**: as specified by owner

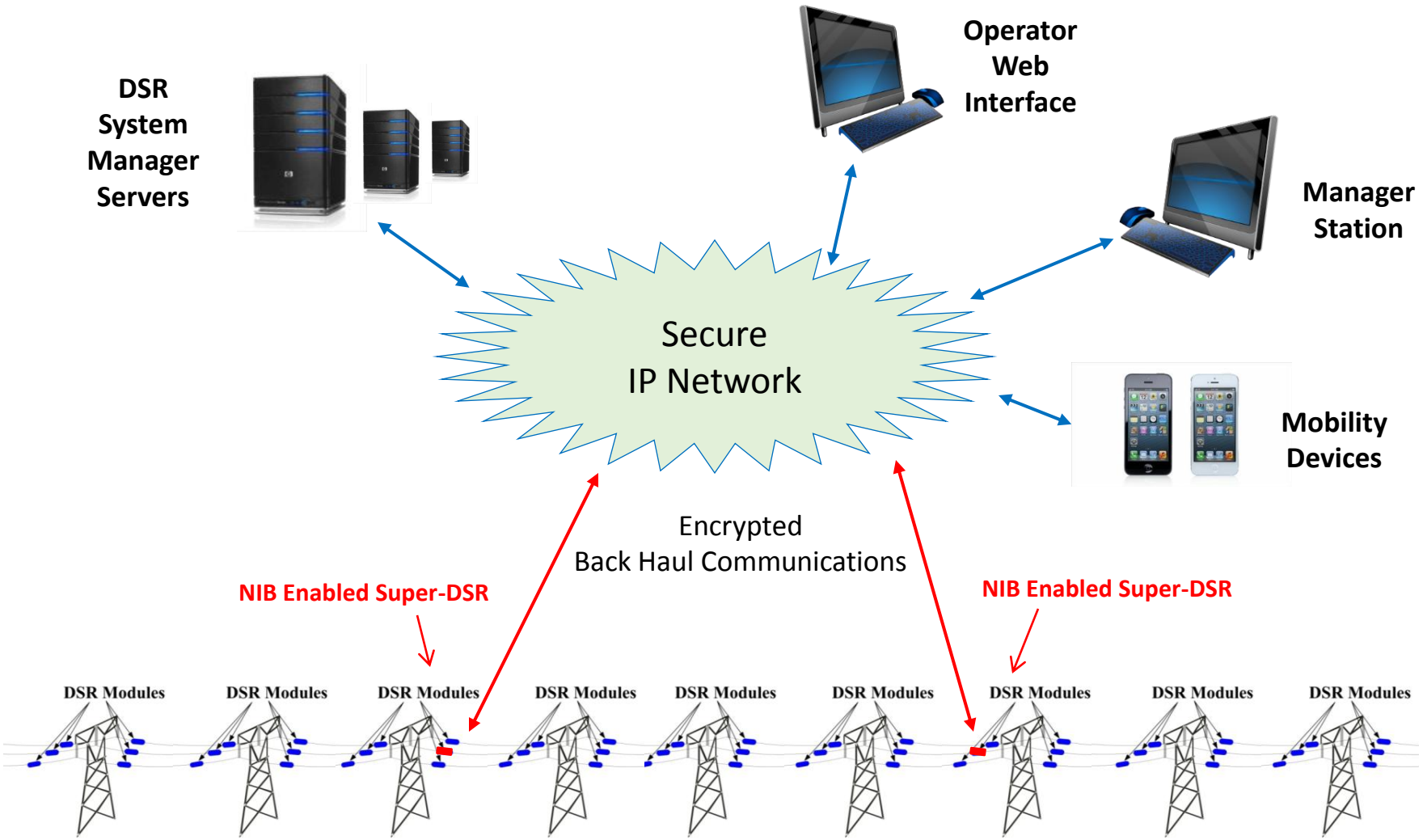
DSR Sensing & Monitoring Capabilities

- **Standard Capabilities**
  - Line Current
  - Conductor Temperature
  - System Frequency
  - Fault Indicator
    - Time
    - Fault Location
    - Through fault current
  - Span Sag Angle
  - Span Blowout Angle
  - Status (injection/monitoring)
  - DSR Set Point (injection)

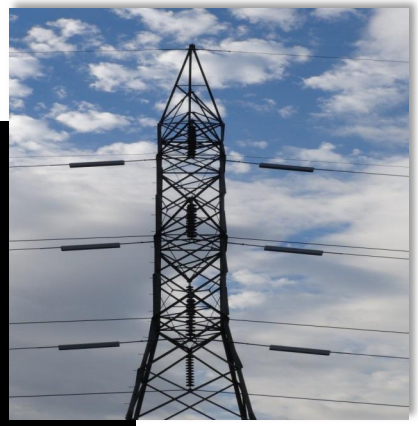
- **Available Capabilities**
  - Conductor Vibration
  - Real Time Fault Location
  - Geomagnetic Induced Current (GIC)

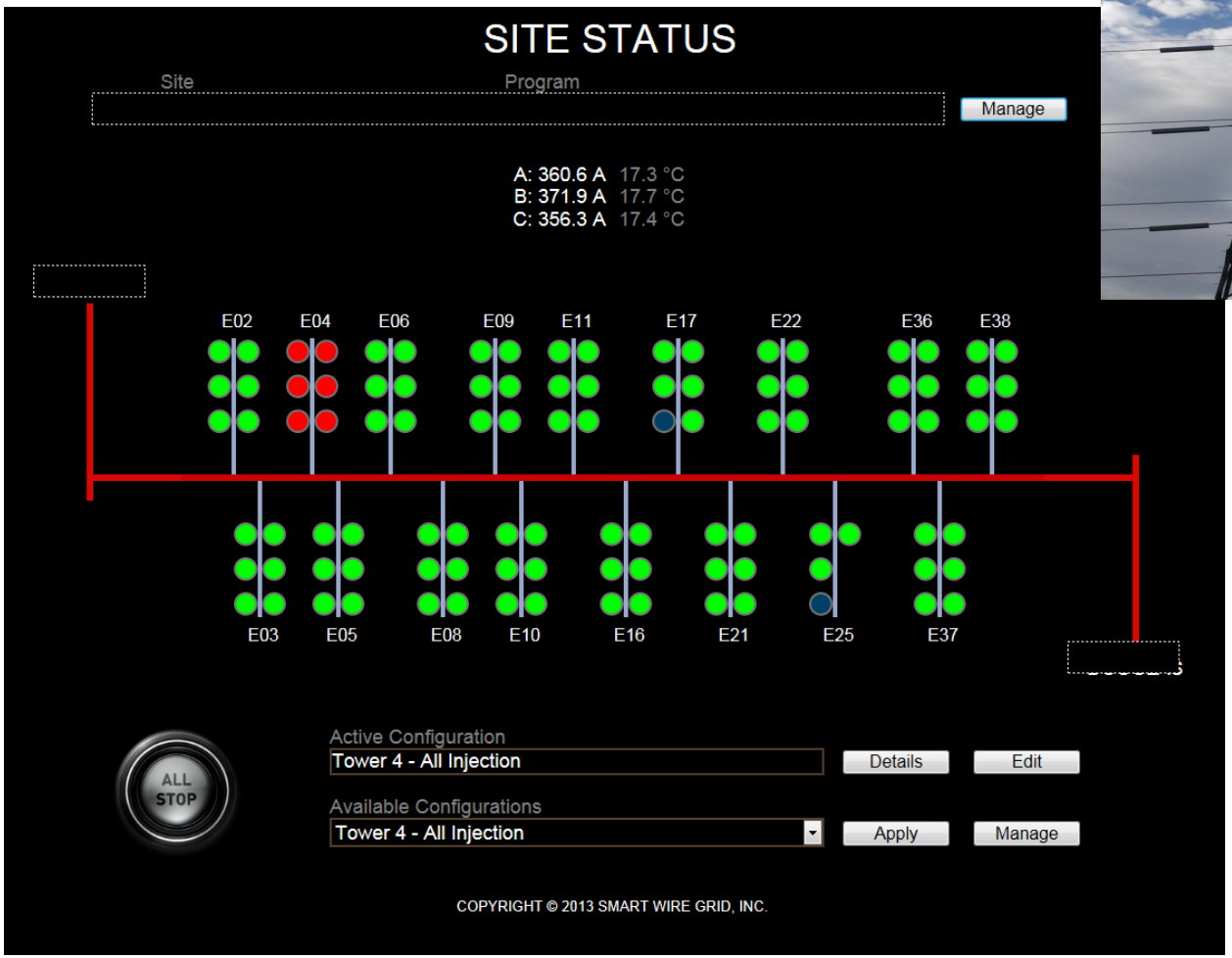


DSR Fleet Controls



DSR Fleet Status





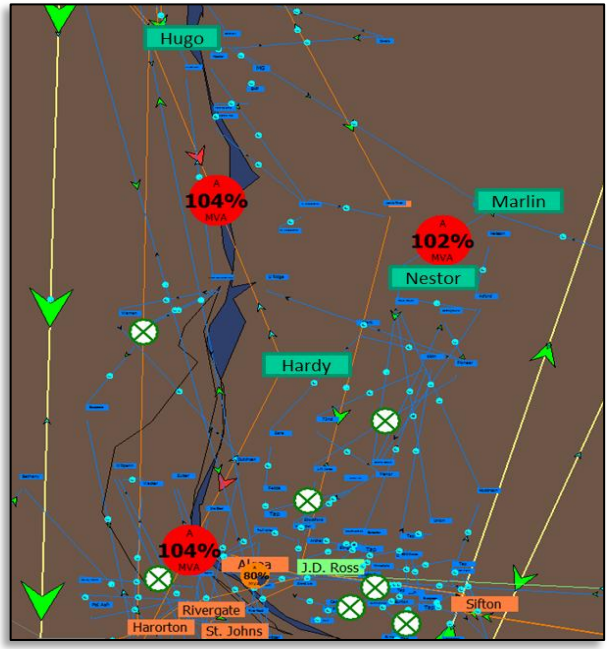
Applications

1. Reliability
2. Congestion/Uplift
3. RAS/SPS Simplification
4. Phase Balancing
5. Support for Construction and Line
6. Overvoltage Support
7. Grid Optimization

Applications - Reliability

- **Based on 2013 Heavy Summer Case**
- **Outage of Sparta - Athens results in 3 thermal overloads:**

Facility	Voltage (kV)	Overload (%)
Hugo - Hardy	230 kV	104
St. Paul's Summer	230 kV	104
Nestor - Marlin	115 kV	102



- **Conventional Solution:**

Facility	Action	Est. Cost ($M)
Hugo - Hardy	Recon	18.8
St. Paul's Summer	Recon	2.0
Nestor - Marlin	Recon	2.1
	Total:	**22.9**

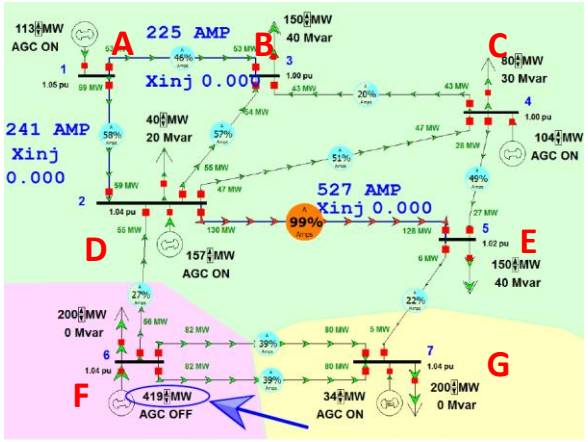
- **Alternative Solution:**
  - Combines reconductoring with DSRs and reduces all conductors to 99% or less of thermal limit during event.

Facility	Action	Est. Cost ($M)
Hugo - Hardy	DSRs	3.9
Nestor - Marlin	Recon	2.1
	Total:	**6.0**

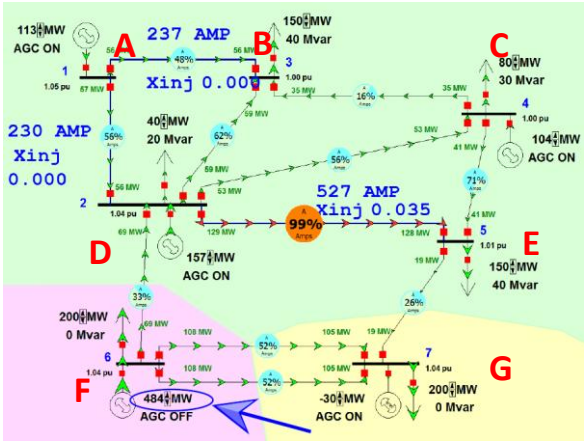
- **Result:**
  - Estimated $16.9 M in savings relative to conventional solution
  - 42 circuit-miles of avoided reconductoring
  - Capital freed up for strategic projects
  - Outage windows reduced

Applications – Improved Dispatch of Generation

Without Smart Wire Technology



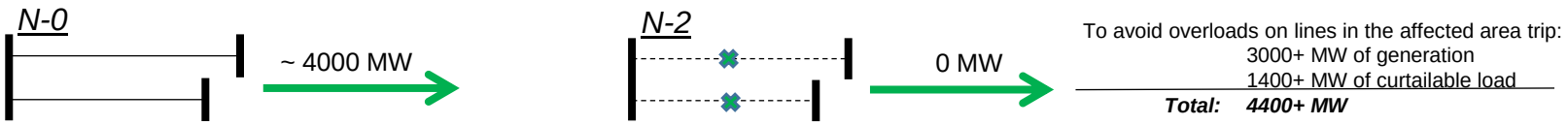
With Smart Wire Technology on line



		Without DSRs		With DSRs		Change	
Start	End	MW	%	MW	%	MW	%
A	B	53	46%	56	48%	3	2%
A	D	59	58%	56	56%	-3	-2%
C	B	43	20%	35	16%	-8	-4%
D	B	54	57%	59	62%	5	5%
D	C	47	51%	53	56%	6	5%
C	E	28	49%	41	71%	13	22%
D	***E***	***129***	***99%***	***129***	***99%***	***0***	***0%***
F	D	56	27%	69	33%	13	6%
F	G	81	39%	107	52%	26	13%
G	E	5	22%	19	26%	14	4%
Totals		555		624		69	12%

Applications – RAS/SPS Simplification

Existing RAS requires 4400 MW of tripping. DSRs can eliminate up to 1710 MW of tripping.



Scenario (DSR and ckt count are cumulative)		Generation Not Tripped (MW)	Curtailable Load Not Tripped (MW)	Total Capacity Preserved (MW)	Non-interrelated Overloads (%)
1.)	111 DSRs 1 circuit	671	0	671	1.2 ***Total: 1.2***
2.)	651 DSRs 3 circuits	671	530	1,201	6.4 0.6 ***Total: 7.0***
3.)	1,341 DSRs 5 circuits	671	871	1,542	9.9 3.4 ***Total: 14.5***
4.)	2,013 DSRs 9 circuits	671	1,039	1,710	0.6 11.4 9.9 4.6 ***Total: 26.5***

Reference – Tennessee Valley Authority (TVA)

Installation Summary

- **Application:** Flow control to reduce need for redispatch during n-1
- **Installation Location:** 161 kV line
- **Circuit Length**: 30 km
- **Conductor Rated Temp:** 100° C
- **Installed:** October 2012
- **Use Case Testing:** December 2012
- **DSR Generation:** Generation 1
- **Model Installed:** 750 A
- **Units Installed:** 94 DSRs, 6 Super DSRs

TVA Installation

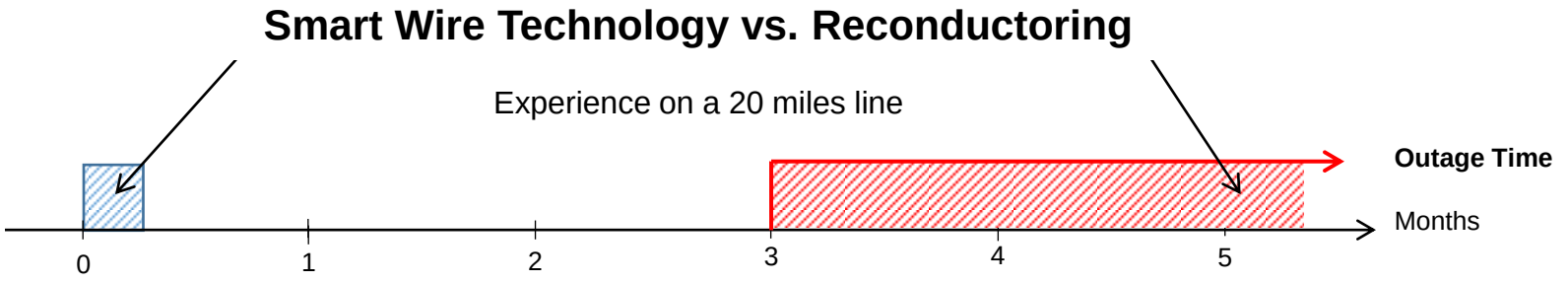
Reference – Southern Company

Installation Summary

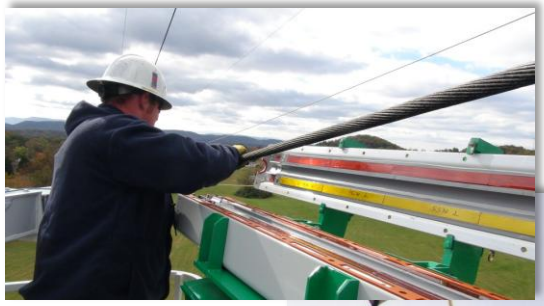
- **Application:** Mitigate overload during n-1 contingency without using prior solution, a permanently online air core reactor
- **Installation Location:** two 115 kV lines
- **Circuit Length**: 10+10 km
- **Conductor Rated Temps:** one at 100° C, one at 210° C
- **Installed:** March 2013
- **Use Case Testing:** June 2013
- **DSR Generation:** Generation 1
- **Model(s) Installed:** 1000 A, 1500 A
- **Units Installed:** 30 DSRs, 3 Super DSRs

Southern Company Installation

Easy to install with less outage time …



- **< 10 minutes per module – de-energized install**
- **Energized or de-energized installation**



TVA Lineman: "One of the easiest things I have installed…"

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