SCE Fault Locating, Prediction and Protection Project

ADVANCED TECHNOLOGY
Transmission & Distribution Business Unit

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Southern California Edison
DOE Peer Review, Golden, CO
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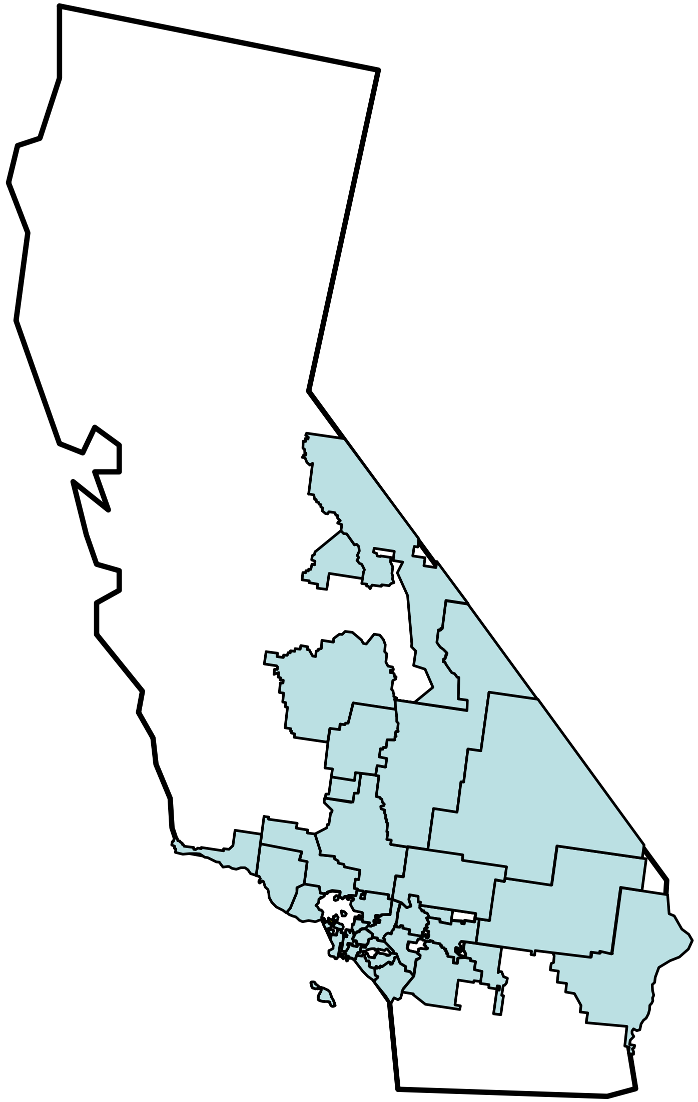

- 50,000 square miles
- ~23,000 MW peak demand
- 4.8 million customers
- 11 million people served
- 845 cities and communities

DOE Project - Completed

- Advanced Protection Methods on the Circuit of the Future
  - July 2006 to June 2010
- Three tasks:
  - Design and test new distribution protection scheme
  - Design and test distribution protection scheme with fault current limiter
  - Investigate, design and test advanced fault location, sensing and prediction methods
- Other Team Members:
  - KEMA – Dr. S. S. Venkata
  - Virginia Tech – Dr. Virgilio Centeno

Project Benefits

- Reduce number of customers seeing outage
- Reduce duration of outages for most customers
- Better locate faults and dispatch crews to problem quickly
- Reduce equipment cost
- More flexible protection to help with integration of DG/ renewables

Schedule

- Task 1 – New Protection Scheme
  - Initial operation – 8/2007
  - Dedication – 10/2007
  - Monitor the performance of the protection system
- Task 2 – Protection w/FCL
  - Model FCL – 2008 through early 2009
  - Put FCL in service – 3/2009
  - Monitor the performance of the protection system
- Task 3 – Advanced Protection
  - Evaluate measures – 2009
  - Design, model Irvine Smart Grid Demo protection system - 2010

Task 1 – Protection on the CoF

- Performed literature review
- Distributed questionnaire about advanced protection practices and projects
- Prepared summary of both
- Installed advanced fault detection and isolation system on the SCE Circuit of the Future
- Monitored behavior of protection system

Literature Review/Survey Summary

- Drivers for fault location, detection and prediction
  - Improvement of system reliability
  - System automation
  - Increased customer focus
  - Distributed generation/ renewables
- Key technologies
  - Affordable IEDs
  - Better transducers/ sensors
  - Accessible communications channels
- Level of development and acceptance of each of these technologies determine the time frame for implementation

Circuit of the Future (CoF)

- New circuit
- Approximately 23,000 amps fault duty
- Serves approximately 2,000 customers
- Overhead / underground facilities
- New hardware and protection schemes
- High-speed communications with fiber

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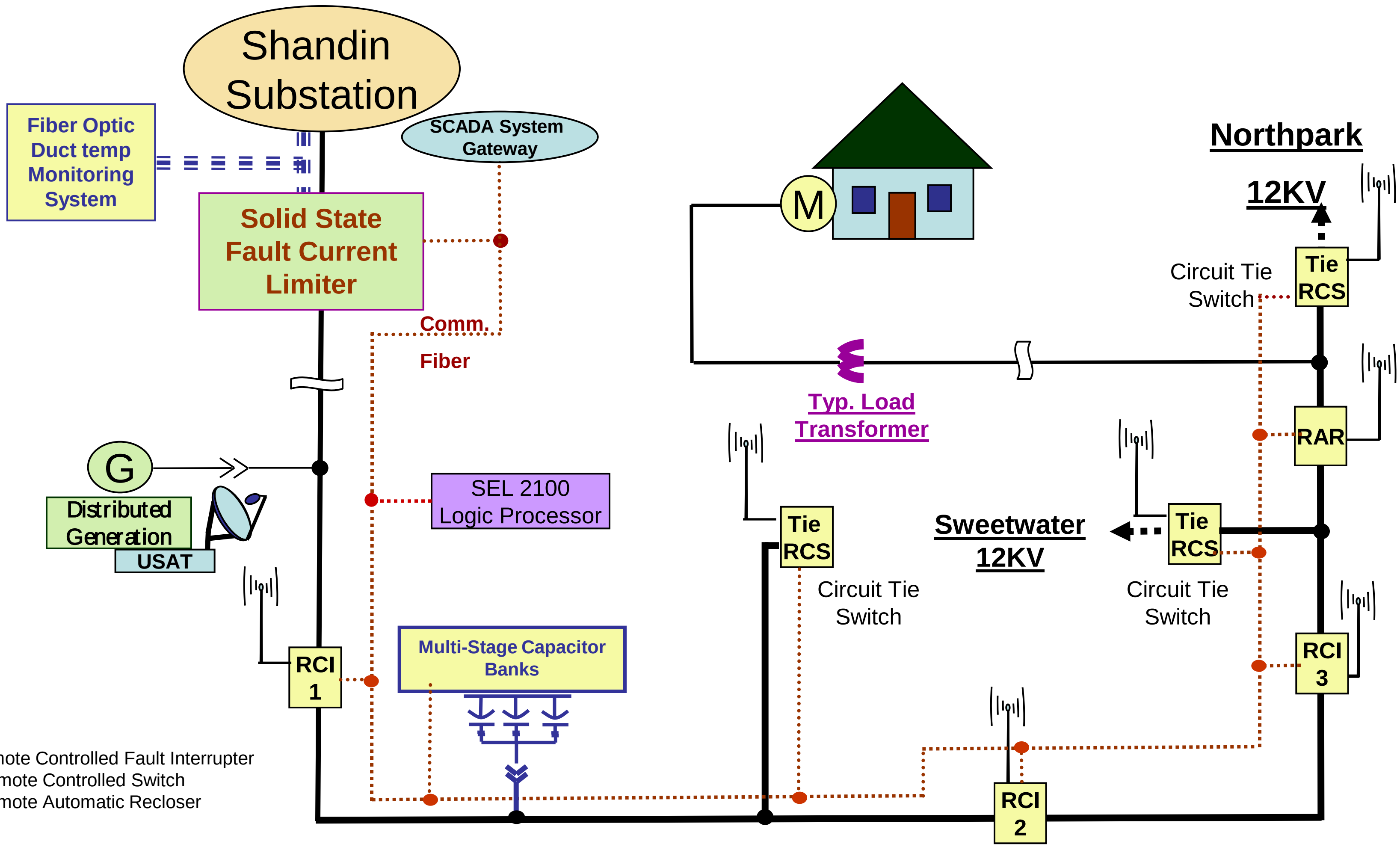
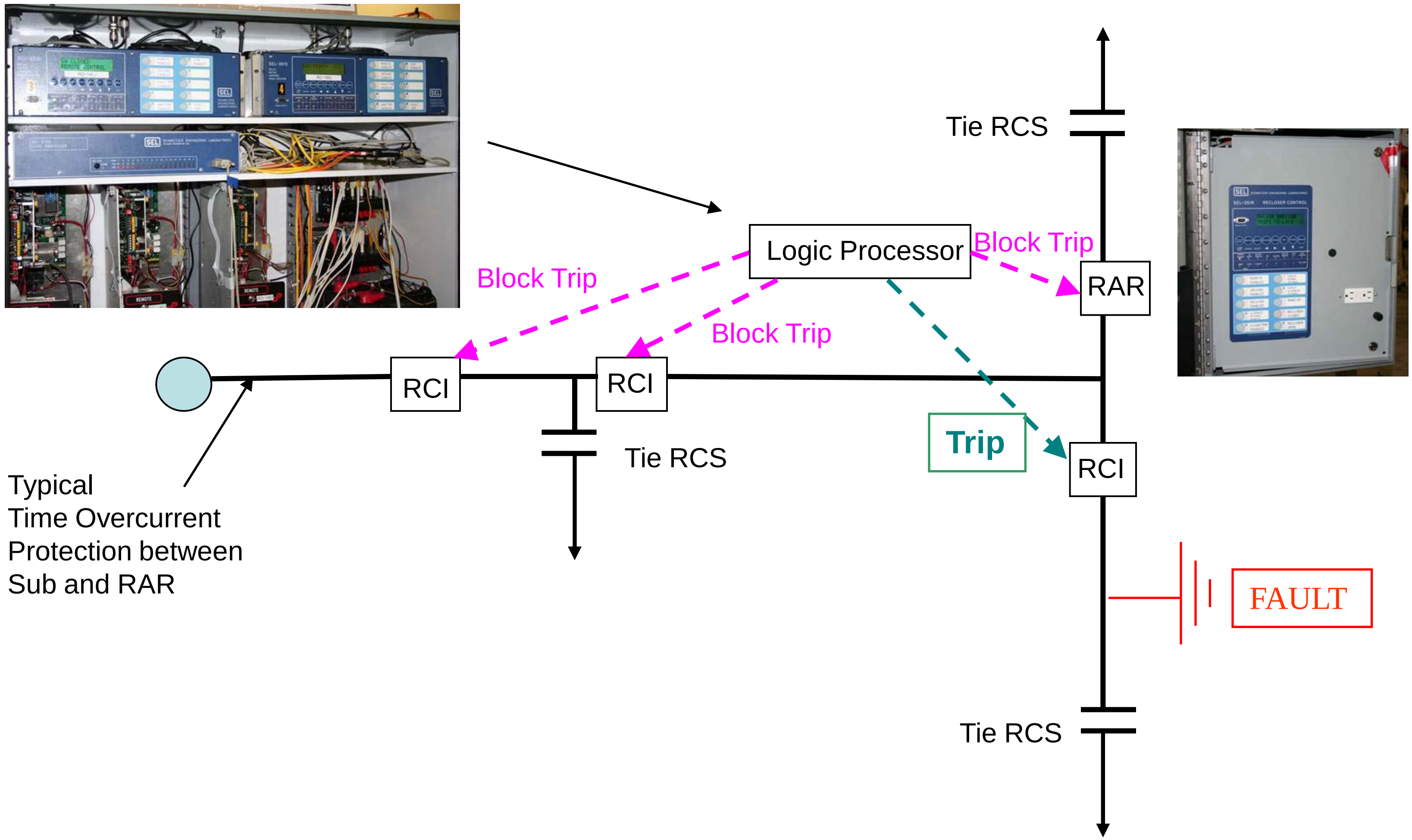
Circuit Features

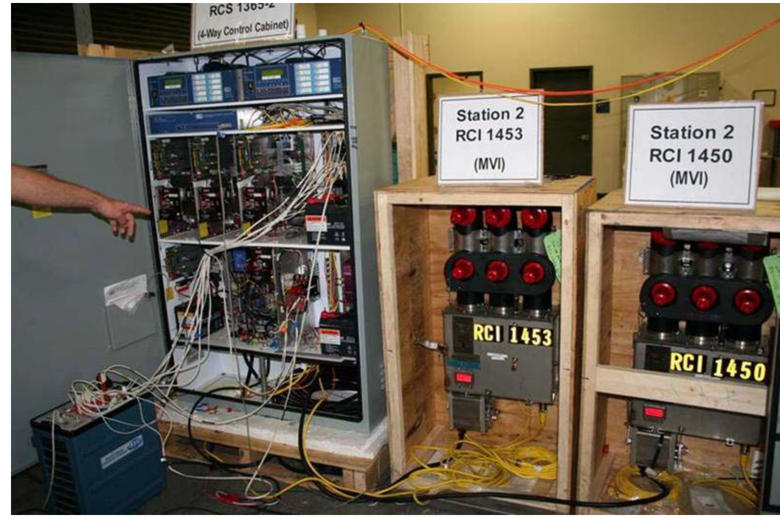


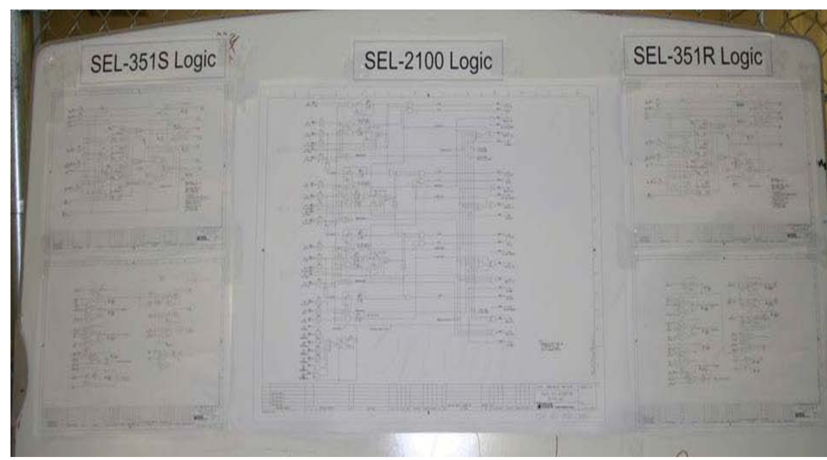
RCI = Remote Controlled Fault Interrupter
RCS = Remote Controlled Switch
RAR = Remote Automatic Recloser

Trip Blocking Scheme



Lab Testing and Training – Summer 2007





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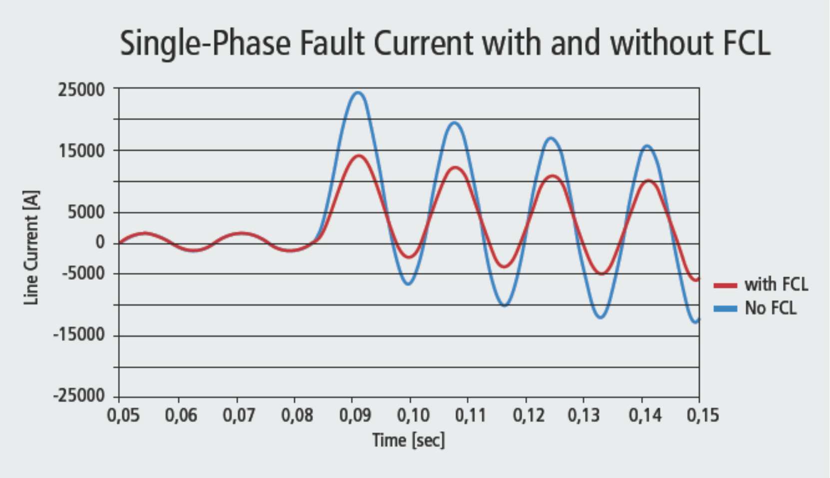
Circuit Fault Status – Four Faults Recorded

- 10/21/2007 (high winds)
  - Relay pick-ups, but no trip
- 12/25/2007 (high winds)
  - Protection operated correctly
  - Post-fault isolate function did not work due to problem with voltage sensor location
  - Problem corrected Summer 2008
- 11/14/2008 (high winds)
  - Protection and isolation operated correctly
  - Most customers restored in minutes
- 1/30/2009 (high winds)
  - Protection and isolation operated correctly
  - Most customers restored in minutes

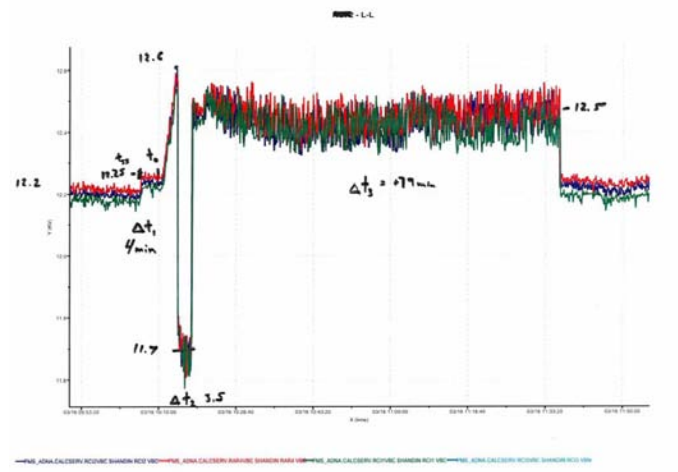
Task 2 - Protection with FCL

- Investigate and model protection changes necessary
  - Obtain/ construct model for Zenergy superconducting FCL and circuit
  - No changes needed due to reduced fault current
  - No changes needed due to distorted wave shapes
  - Bypass switch could be operated safely
- Commission fault current limiter (2/2009)



Magnet Disconnection Event (3/16/2009)

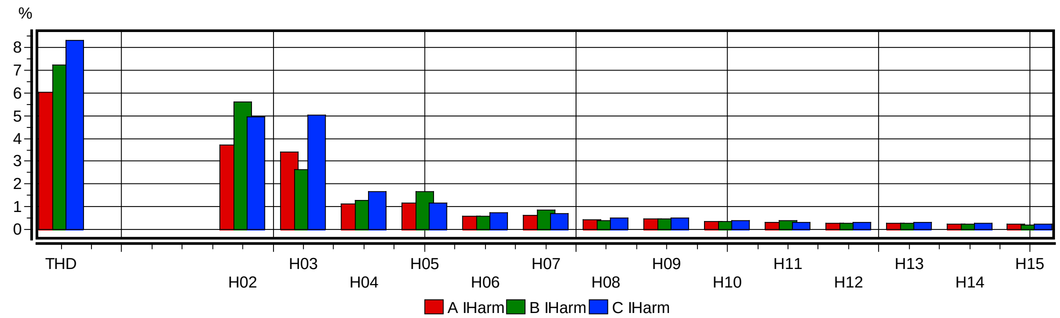
- De-energize superconducting magnet
  - Caused by processor reboot
  - Insert FCL impedance
  - Initially, 4% rise in voltage caused by resonance with capacitors
  - Capacitor trip cause 4% reduction
  - Another capacitor turn on causing 3% voltage rise
  - FCL bypassed
- Models upgraded to simulate the event accurately
- Repairs made and re-energized on 12/18/2009



Fault with FCL in Service (1/14/2010)

- FCL properly limited fault current
  - 8% fault current reduction
  - Matched what expected from fault current tests and models
- Harmonics
  - FCL insertion increases current harmonics < 0.5% THD
  - Voltage – increase from 1-1.5% steady-state to 2-5% during fault
  - Current – increase from 4-5% steady-state to 6-16% during fault

FCL Current Harmonics



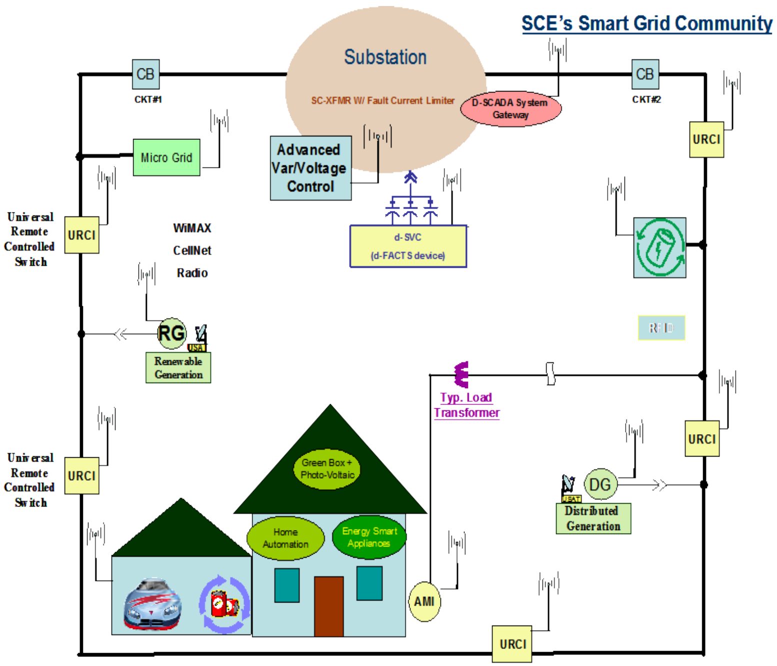
	AI	BI	CI
RMS	1713.26	1247.71	1214.08
FND	100.00	100.00	100.00
DC	0.79	-7.04	1.07
THD	6.02	7.21	8.32

Task 3 - Advanced Protection Schemes

- Evaluate measures and select most promising ones for modeling/implementation (focus on standards)
- Measures implemented:
  - Measure power quality upstream and downstream of the FCL
  - De-centralized sensing, control, protection, and automation
  - Design and model the System of the Future relay protection system
- System of the Future protection improvements over CoF
  - Loop two circuits to eliminate loss of power to customers beyond the faulted section
  - Implement low-latency radio in place of costly fiber communications for fault interrupting switches
  - Distribute protection logic in each relay

Advanced Protection on the System of the Future

- Use fault-interrupting switches with relays supporting IEC 61850
- Use Ethernet-based radio communications
- Communicate using GOOSE messaging (IEC 61850)
- GOOSE message latency allowed to be 100 ms
- Use substation breaker as backup
- Intelligence located in each relay
- This project designed logic and built model of the circuits
- Construct and implement under DOE ARRA Irvine Smart Grid Demo project



Technology Transfer and Collaborations

- Presentations at conferences and meetings
  - IEEE T&D
  - Several EPRI PQA/ADA (now PQA/SD) meetings
    - Share information with EPRI fault anticipation project
  - Northwest Energy Symposium
  - IEEE PES meetings
- Updated regulatory agencies
  - California PUC
  - California Energy Commission
- Public dedication of Circuit of the Future

Recommendations

- De-centralize sensing, control, protection, and automation
  - New sensors
  - Distributed intelligence
  - Distribution system communications
  - Real-time analysis and control
- Advanced and adaptive protection
  - Integration of renewable generation (distribution-based)
  - Microgrid protection
- Advanced DMS system with supervisory control over:
  - protection settings
  - Volt/VAR settings
  - Demand response operations
  - Distributed generation and storage use

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