SCE Fault Locating, Prediction and Protection Project

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Southern California Edison

- 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
  – Monitor the performance of the protection system

• Task 2 – Protection w/FCL
  – Model FCL – 2008 through early 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
Circuit Features

- Shandin Substation
- Solid State Fault Current Limiter
- Fiber Optic Duct temp Monitoring System
- SCADA System Gateway
- Comm. Fiber
- SEL 2100 Logic Processor
- Multi-Stage Capacitor Banks
- Distributed Generation USAT
- RCI 1
- Typ. Load Transformer
- Northpark 12KV
- Circuit Tie Switch
- Tie RCS
- RAR
- RCI 3
- Sweetwater 12KV
- Circuit Tie Switch
- Tie RCS
- RCI 2
- RCI 1
- RCI 3

RCI = Remote Controlled Fault Interrupter
RCS = Remote Controlled Switch
RAR = Remote Automatic Recloser
Trip Blocking Scheme

Typical Time Overcurrent Protection between Sub and RAR

![Diagram showing trip blocking scheme with RCI, Logic Processor, and Trip components.](image-url)
Lab Testing and Training – Summer 2007
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
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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