SOUTHERN CALIFORNIA EDISON®
An EDISON INTERNATIONAL® Company

Underground Remote Fault Indicator

EPIC Fall Symposium

Bryan Pham – Sr. Engineering Manager

October 18, 2017

Overview

- Project Description
- Project Benefits
- Project Status
- Procurement Summary
- Lessons Learned

Project Description – UG RFI

- Demonstrate field installations of Underground Remote Fault Indicators to meet the following SCE operating requirements:
  - Submersible;
  - Integrated radio;
  - No Shunt for CT, Fiber Optics output;
  - Power harvesting (15 amps min);
  - Bi-Directional current flow;
  - Lightweight/Small form factor;
  - Real Time current monitoring;
  - 12 CT sensors or 4 position switch; and
  - No planned outage.

Project Benefits

- Key component for Grid Modernization
- Improve Reliability - Reduce SAIDI index (System Average Interruption Duration Index)
  - Reduce Troubleman Response Time
  - Integrated with utility tools – Distribution Management System & Outage Management System
  - Support Fault Detection Isolation Restoration (FDIR) program
- Support DER (Distributed Energy Resource) Integration by providing real time circuit telemetry to improve Grid Situation Awareness
  - Provide engineering data to perform circuit analysis
  - Provide system operators fault location
  - Provide system operations with power flow & direction

Project Status Q3 2016 – Q4 2018

- Request for Proposals released to 11 Vendors
- Three vendors selected for demonstration: Power Delivery Product, Sentient Energy, & 3M
  - Power Delivery Product UG RFI
    - Complete field installations by December 2017
    - Complete field trial evaluation by Q3 2018
    - Complete standards by Q4 2018
  - 3M & Sentient Energy
    - Complete SCE lab evaluation by Q1 2018
    - Complete field demo evaluation by Q4 2018

Power Delivery Products UG RFI

Features:

- Integrated radio
- No Shunt for CT, Fiber Optics output
- Power harvesting (15 amps min)
- Bi-Directional current flow
- Lightweight/Small form factor
- Submersible* - currently being tested
- Real Time current monitoring
- 12 CT sensors or 4 positions switch
- No Planned outage

Procurement Summary

- Sentient Energy, one of the selected suppliers, is a California based company

Successfully demonstrated Sentient Energy Overhead Remote Fault Indicator in EPIC1. It is currently SCE standard for OH RFI.

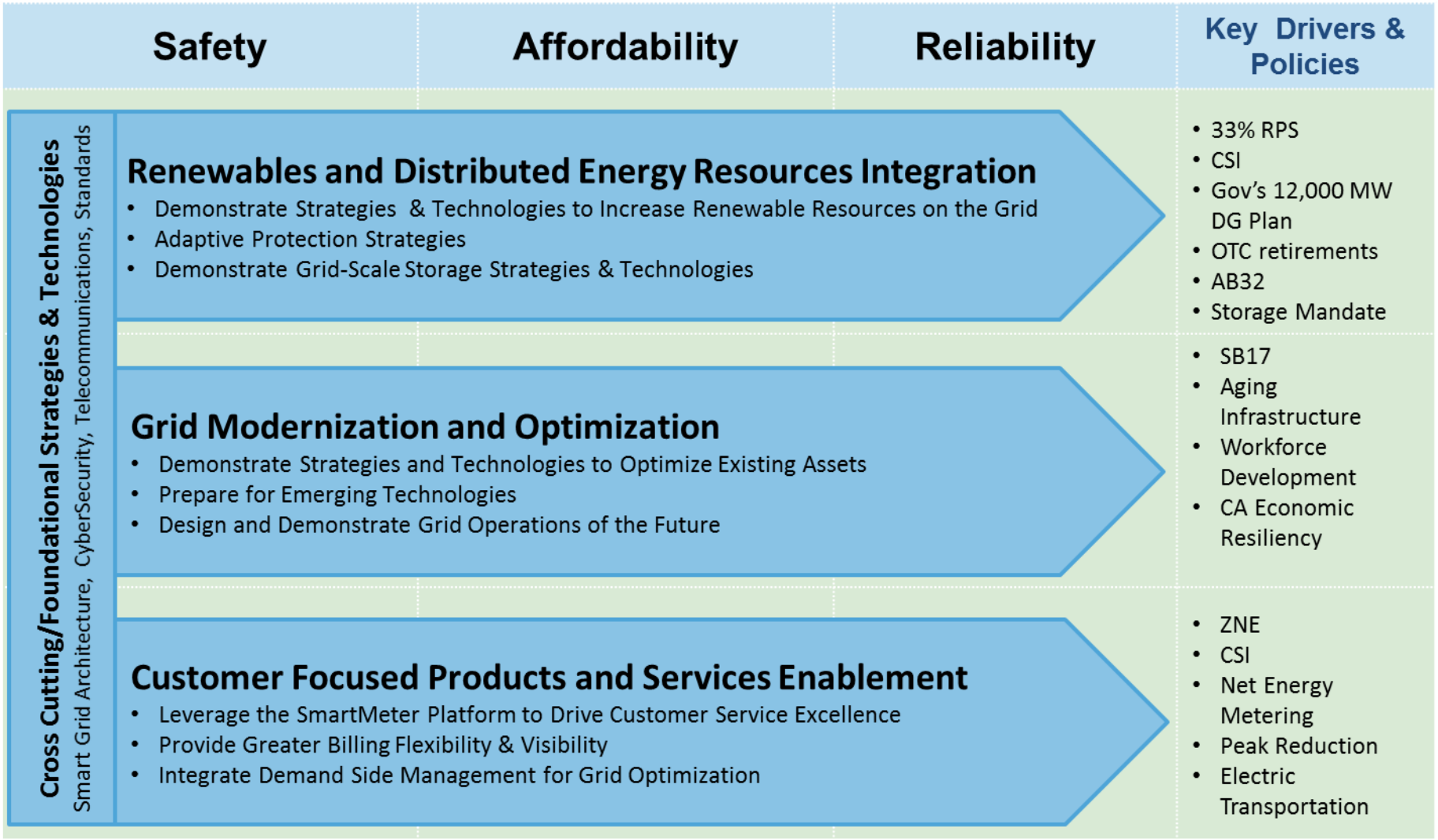
- Power Harvesting
- No battery
- Integrated Landis+Gry Radio & GPS
- Bi-Directional power flow*
- No Planned outage
- Real Time current monitoring
- 10-15 Year Life – Zero maintenance
- LED indication
- Plug & Play

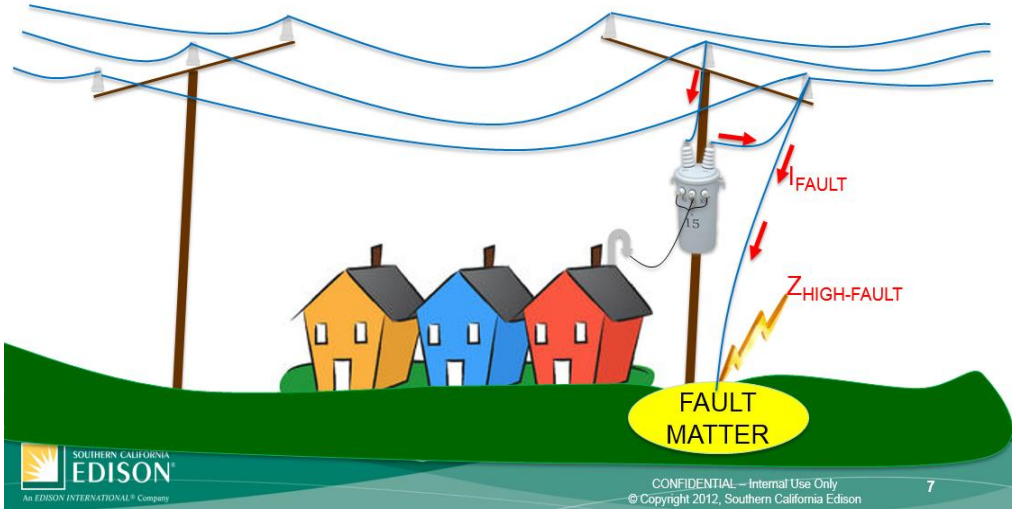
Summary - Lesson Learned

- Competition resulted in creativity & best efforts from vendors.
- Accurate technical specifications are crucial for prospective product vendors.
- Teamwork & collaboration are the keys to success. Vendors rely on SCE engineers to test product functionality and to integrate with SCE systems; e.g. Distribution Management System and Outage Management System.
- Accuracy degrades at higher currents.
- Integrated GPS expedited the deployment process.
- Over-The-Air firmware upgrade capability is required for future upgrade.

Q&A

EPIC Investment Framework for Utilities





High Impedance Fault Detection

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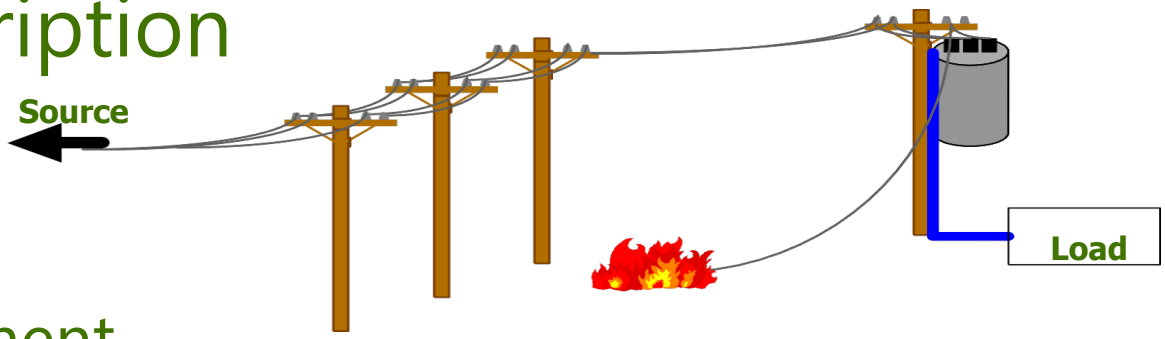
Project Description



Problem Statement

- Overhead distribution circuit conductors can break and fall to the ground due to car collisions, high winds, splice failures, etc.
- High impedance faults can occur when a conductor touches a high resistance surface (e.g., asphalt, concrete, sand, rocks, etc.). High impedance faults do not generate enough current to trip traditional protection devices (i.e., substation circuit breakers, automatic reclosers, and fuses).
- As a result, many distribution power lines are still energized when an SCE employee (e.g., a troubleman) arrives at the scene of a downed-wire.
- An energized wire laying on the ground poses serious public safety risk and can be fatal for any person touching the energized wire.

Objective

Demonstrate an innovative approach to improve public safety by detecting downed wires on high impedance surfaces; e.g. asphalt, concrete, sand, etc.

Develop an anomaly detection system using Spread-Spectrum Time-Domain Reflectometry (SSTDR) techniques that can identify anomaly (high) impedances on electrical distribution lines and determine where they are occurring.

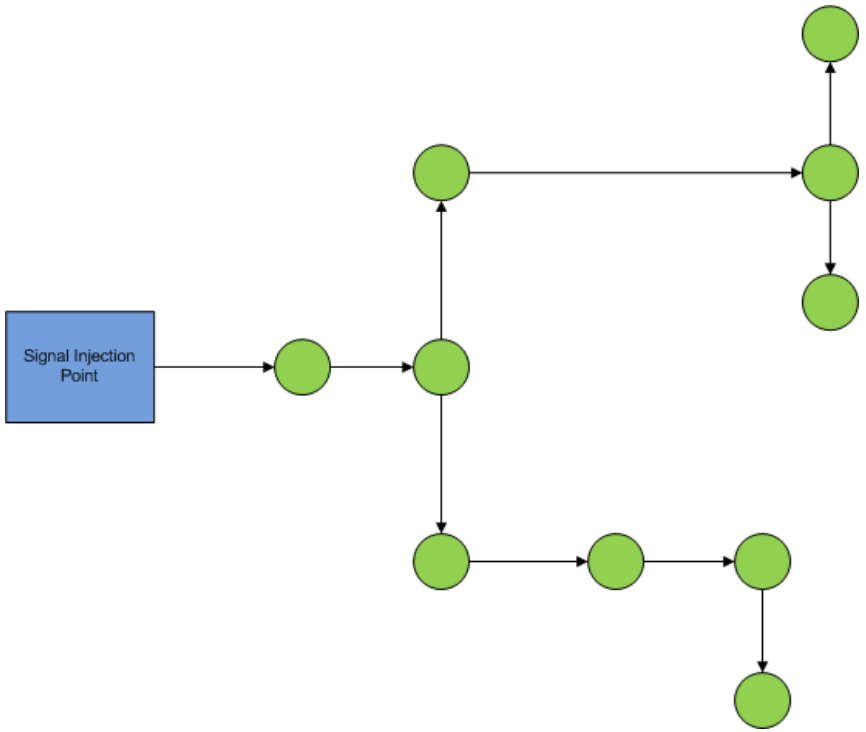
System Concept Overview

Spread Spectrum Time Domain Reflectometry (SSTDR) Concept:

- A radar signal, operating at frequencies between 2MHz – 40MHz is injected into the line at a known starting point.
- The signal will reflect back to the origin wherever it hits an impedance mismatch.
- Reflections are mapped to known objects to create a “good” map. The system can now look for reflections that don’t map to known objects.
- The system looks for impedance mismatches that aren’t a part of the normal line construction.

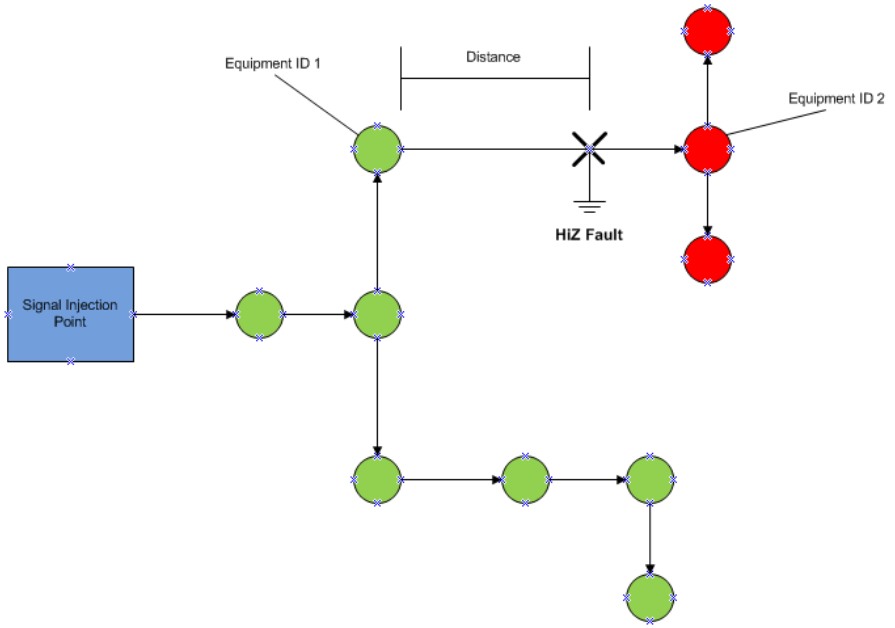
Concept continued

- Assume this represents a known “good” map of the circuit
- A series of signals is injected into the line and the reflections are captured
- All reflection points are mapped to the “good” map



Concept continued

- The signal is injected into the line regularly.
- Reflections are mapped to the “good” map.
- All known points that match the “good” map are eliminated from the reflection map.
- The anomaly is localized based on known good reflections received and reflections that were not received or that came back with different signatures.
- Note that an anomaly impedance will have an affect on the reflection signature downstream of it, which aids in finding distance to the anomaly and localization by branch.



Location = Equipment ID 1 + distance towards Equipment ID 2

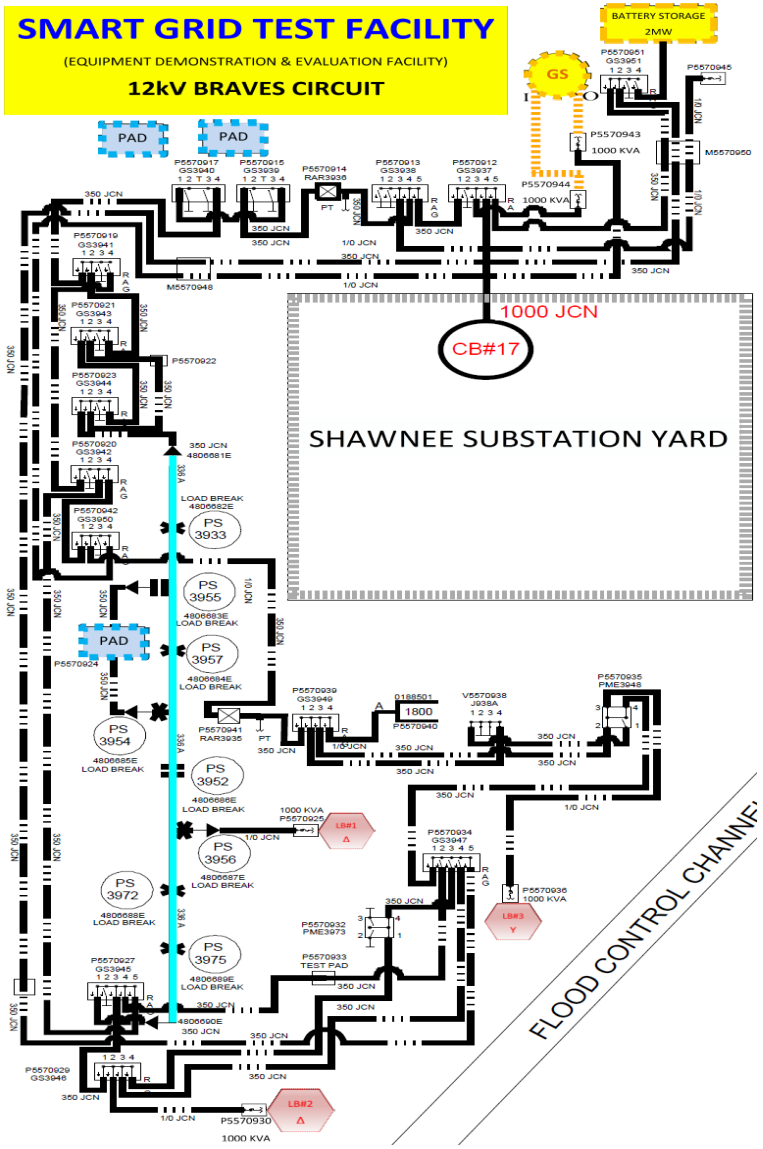
Project Benefits

Potentially:

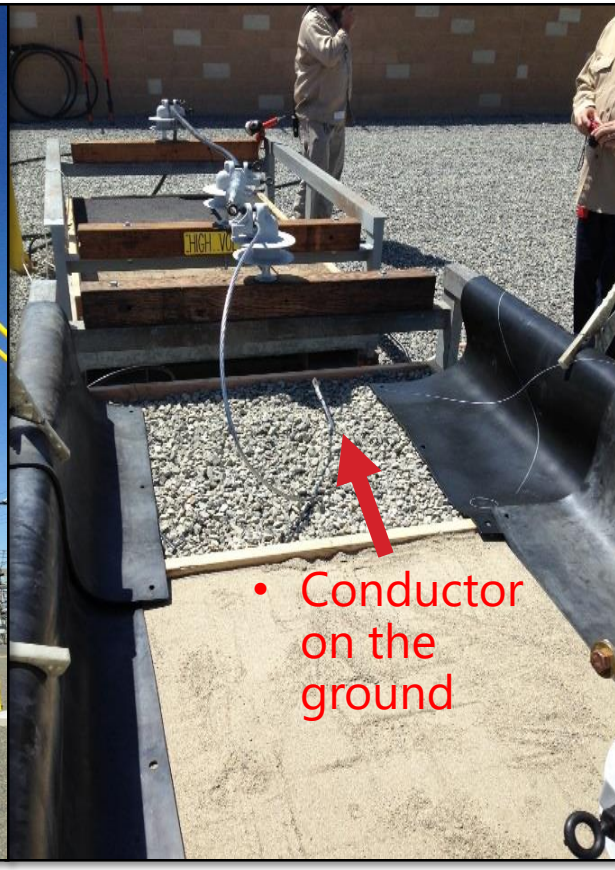
- Improve Public Safety
- Improve situational awareness for system operators

Equipment Demonstration & Evaluation Facility

- Located in Shawnee sub
  - 66/12kV
- Test circuit: BRAVES
- Dedicated circuit breaker for test circuit
  - In addition various circuit protection
- Two circuit sections
- Overhead and underground line
- Equipment:
  - Automatic Reclosers (ARs)
  - RAG Switches
  - Load Banks
  - Capacitor Banks
  - Grid simulators
  - 2MW Battery



EDEF's First Test on 4/25/2016: High Impedance Fault Detection



Project Status

- Phase 1: (2014)
  - Demonstrate the feasibility of technology to solve the project objective.
- Phase 2A & 2B: (2015-Q2 2017)
  - Develop solution, including software algorithms, detection hardware, and integrated systems. Conduct prototype field testing and demonstration at Chino Test Circuit. Conduct energized circuit testing at Shawnee Substation's Equipment Demonstration & Evaluation Facility (EDEF).
- Phase 2C: (Q4 2017-Q2 2018)
  - Improve distance & localization accuracy and branching limits.
  - Evaluate effects of various distribution equipment on line.
  - Demonstrate system's ability to self-learn new circuit to an event and accurately detect new anomalies.
  - Develop mapping strategy to Distribution Management System/Outage Management System.
  - Refine Prototype to be ready for pilot on actual distribution circuit.
- Phase 3: (Q3 2018- Q2 2020)
  - Pilot on several distribution circuits.
  - Provide solution for system wide deployment.

Summary - Lesson Learned

- Spread Spectrum Time Domain Reflectometry technology has the potential to solve high impedance fault (wire down) detection.
- The SCE 12 kV Equipment Demonstration and Evaluation Facility was instrumental in conducting energized wire down tests without affecting customers.
- Actual field trial will be needed to refine this solution for deployment.

Q&A

EPIC Investment Framework for Utilities