Application of Advanced Wide Area Early Warning Systems with Adaptive Protection

DOE Smart Grid Project DE-OE0000120

presented to:

NASPI Working Group

Chicago, IL

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Project Objectives

• Demonstrations of advanced protection systems using synchrophasor data:
  – Adaptive Security/Dependability Balance
  – Impedance Relay Zone “Encroachment” Detection & Alarm

• Development of Protection Information Tool:
  – User-validated visualizations of protection information based on synchrophasor data
Adaptive Security/Dependability Balance

- The primary protection system consists of three redundant sets of relays, any one of which can trip the line if it detects a fault. This biases the protection system in favor of reliability for normal conditions.

- Objective of Adaptive S/D Balance is to minimize the possibility that any one set of relays will false-trip during stressed system conditions, which might contribute to a cascading outage.

- Technical Approach: Utilize an "Adaptive Voting Scheme." If stressed system conditions are detected using synchrophasor measurements, a relay supervisory signal based on a 2-out-of-3 voting scheme is generated.

Dependability (Reliability): High probability that relays will operate for an actual fault.
Security: Low probability that relays will operate when there isn’t an actual fault.
Adaptive Voting Scheme: PMU Placement

### Line Current
- DEVERS
- VALLEYS
- DEVERS
- PALO VERDE
- DIABLO
- MIDWAY
- TESLA
- LOS BANOS

### PMU
- DEVERS
- TESLA
- DIABLO
- VACA-DIXON

### References
- Summer: VACA-DIXON
- Winter: TESLA

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Virginia Tech
Invent the Future
if (imag l735 <= -0.88)
  {
    state = 1;
  }
else
  {
    if (real l19 <= 17.18)
    {
      if (real l19 <= 16.78)
        {
          state = 0;
        }
      else
        {
          if (imag l1033 <= 1.27)
            {
              state = 1;
            }
          else
            {
              state = 0;
            }
        }
    } else
    {
      if (imag l735 <= -0.62)
        {
          state = 1;
        }
      else
        {
          state = 0;
        }
    }
  }
if (real I1106 <= 4.46)
{
    state = 0;
}
else
{
    state = 1;
}
PMU Data Source & Processing

PMU at Devers
Devers-Valley
Palo Verde- Devers

SCE PDC

PMU at Tesla
TS-LB

PMU at Vaca Dixon
VD-TS

PMU at Diablo Canyon
DC-MW #2

San Francisco
Ancillary PDC

San Francisco Interface Gateway

Phasor Data Concentrator
(Midway Substation)

Phasor Adapter
Time Align.
Data Parsing

Adaptive Voting

Seasonal Switch
(Heavy Summer / Heavy Winter)

IEC61850
Goose Server

Development Kit Interface

Application Card

Data and Logic Processor

Phasor Reception

90-5 UDP, 30 fps
(SCE Data)

90-5 UDP, 30 fps
(PG&E Data)

90-5 UDP, 30 fps

90-5 UDP, 30 fps

90-5 UDP, 60 fps

90-5 UDP, 60 fps

Vacaville Ancillary PDC

Tesla Aggregate PDC
(existing)

Vaca Dixon Aggregate PDC
(existing)

Diablo Aggregate PDC
(existing)

SCE Data Received
IEEE-2005 format
TCP, 30 fps

C37.118
TCP, 30 fps
Data Processing and Trip Voting

Phasor Data Concentrator (Midway Substation)

Development Kit Interface

Phasor Adapter
Time Align.
Data Parsing

Phasor Reception

3CFFPS

Adaptive Voting

Seasonal Switch (Heavy Summer / Heavy Winter)

GOOSE

IEC61850 Goose Server

Midway
2 out of 3 Voting Logic

Adaptive Protection Trip (Monitoring)

Existing Protection Trip CB

Seasonal Switch

Existing Protection Trip CB

GOOSE

Supervisory

Midway Substation (Existing Midway-Vincent #1 Line Protection)

SET A

SET B

SET C

Heavy Summer

Heavy Winter
Application of Advanced Wide-Area Early Warning System with Adaptive Protection
Adaptive Relay System Architecture
Adaptive Relay Rack at Vincent Substation
Adaptive Relay Rack at Vincent Substation
Adaptive Relay Installation on RTDS at Protection System Laboratory
Alarms for Encroachment of Relay Trip Characteristics

• Looked at Following Relays:
  – Distance
  – Loss of Excitation
  – Out-of-Step

• Concentrated on Path 15 and Path 26

• Alarm system
  – Provides information and warning to engineers
  – Essentially a time-saving tool
Alarms for Encroachment of Relay Trip Characteristics

The supervisory boundary is 50% larger than the largest zone of the relay.

Alarm when system swings encroach on the supervisory zone.
Real-Time Alarm for Relay Characteristic Encroachment Events

• Define a help system for operators and/or system engineers
  – Alarms as system conditions approach relay characteristics

• Identify possible countermeasures
  – Warning System
    • Legacy Systems – Provide information and advance warning
    • Computer Relays – Supervisory Control Action - Alter Settings
Alarms for Relay Encroachment

Output to an alarm containing information on the event

Midway 500kV

PDC with processing to compute the apparent impedance and detect encroachment

Los Banos 500kV

Diablo 500kV

Vaca Dixon

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Project Status

• Phase I: R&D (Completed)
  – Development and adaptation of Adaptive Relaying and Relay Encroachment algorithms to real-time utility environment.
  – Prototype Protection Information Tool (PIT) visualizations developed.

• Phase II: Pilot Testing (Completed)
  – Testing and validation (POC) of relaying schemes in University, PG&E and SCE Protection System Laboratories.
  – Interviews and workshops with utility engineers to refine PIT visualizations.

• Phase III: Field Demonstration (In Progress)
  – Field installations of PMU architecture and software installations at SF Control Center (PG&E) and Power Systems Laboratory (SCE) completed September 2013.
  – Relay data collection and system performance evaluations to be completed by September 2013 September 2014.
Questions?

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