Application of Advanced Wide Area Early Warning Systems with Adaptive Protection

DOE Smart Grid Project DE-OE0000120

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ciee | California Institute for Energy and Environment

by:

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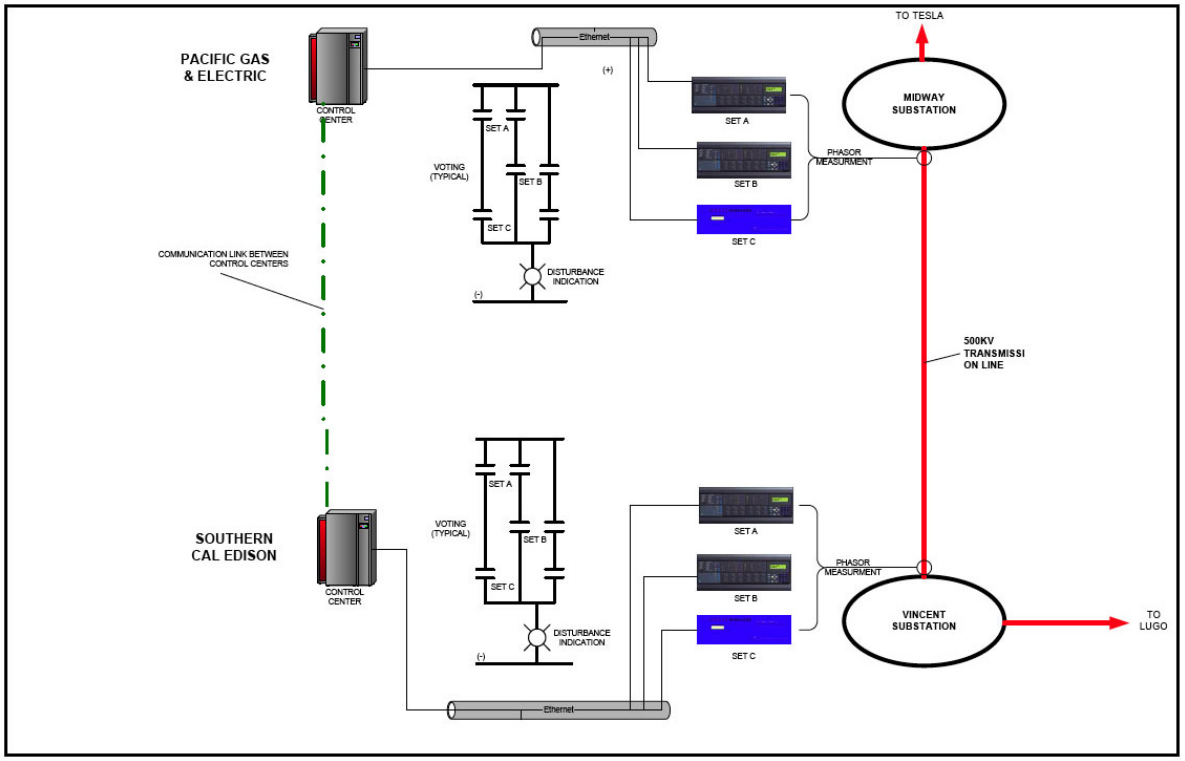
Electric Grid Research

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



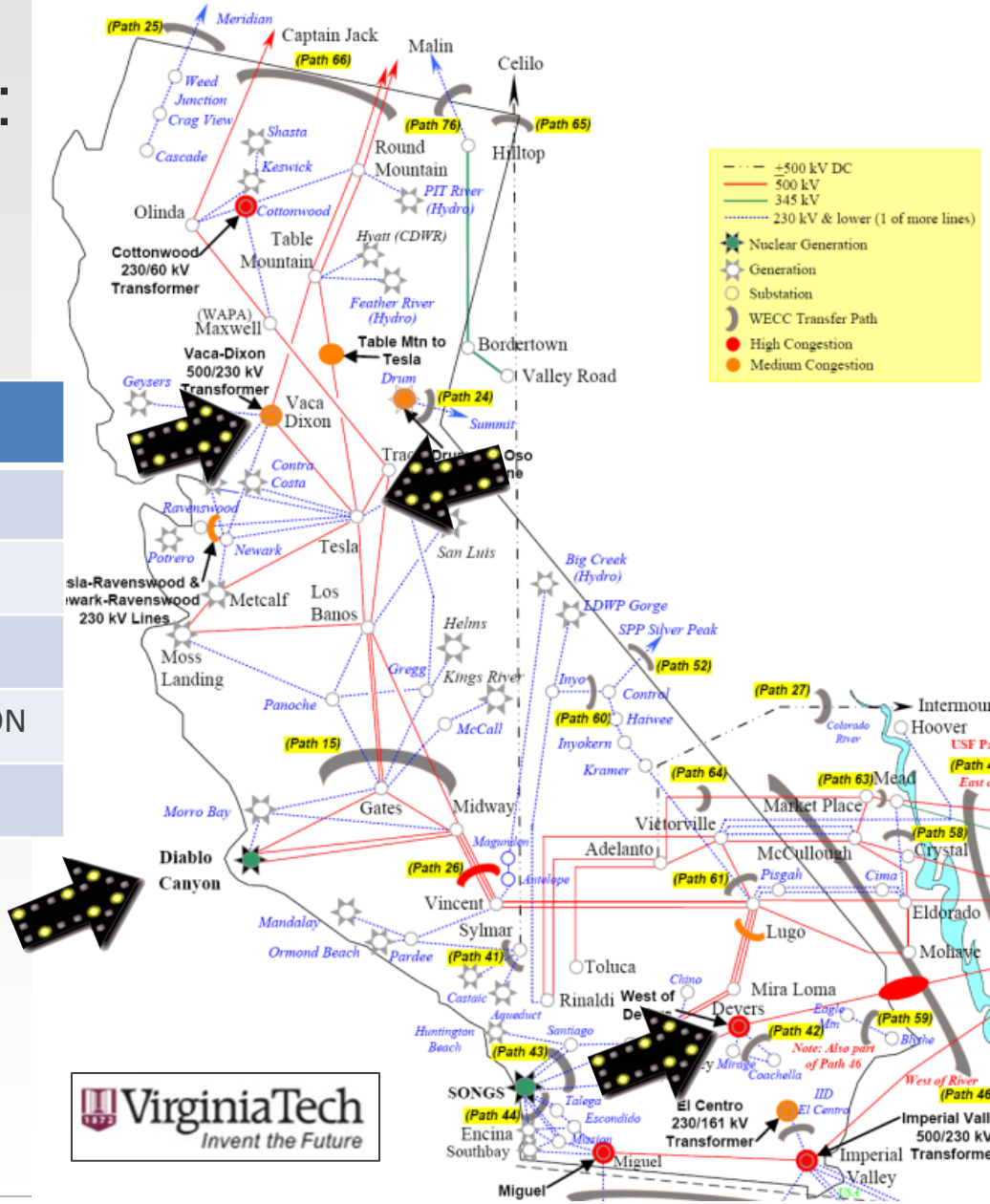
Dependability (Reliability): High probability that relays will operate for an actual fault.
Security: Low probability that relays will operate when there isn't an actual fault.

- 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.

Adaptive Voting Scheme: PMU Placement

Line Current	
DEVERS	VALLEYSC
DEVERS	PALO VERDE
DIABLO	MIDWAY
TESLA	LOS BANOS
References	
Summer	VACA-DIXON
Winter	TESLA

PMU
DEVERS
TESLA
DIABLO
VACA-DIXON



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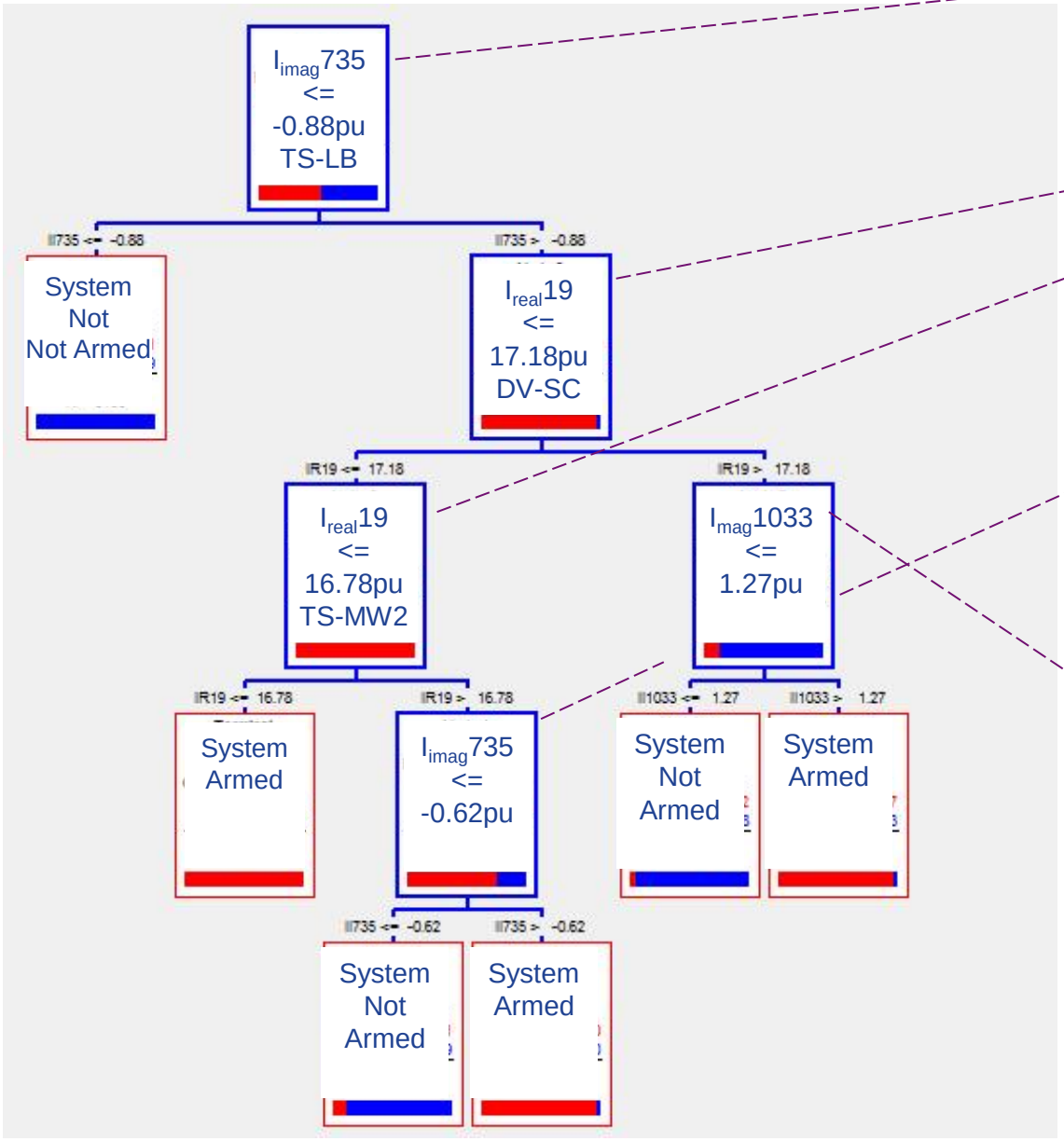
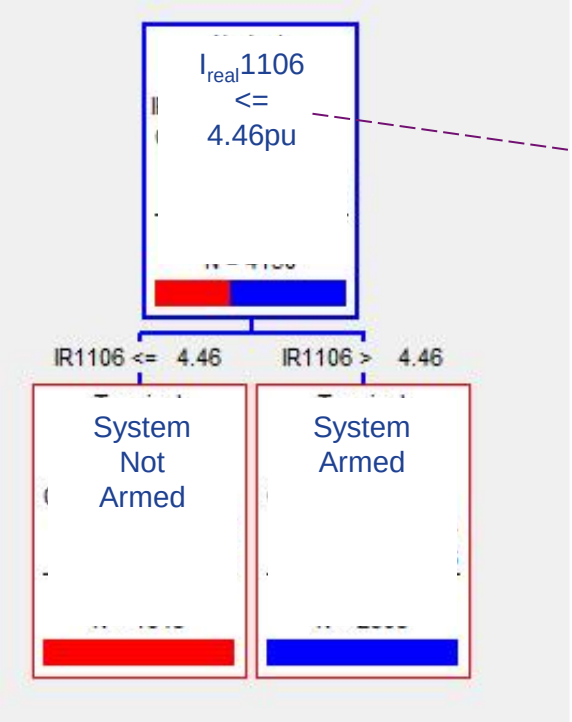
Heavy Summer Decision Tree



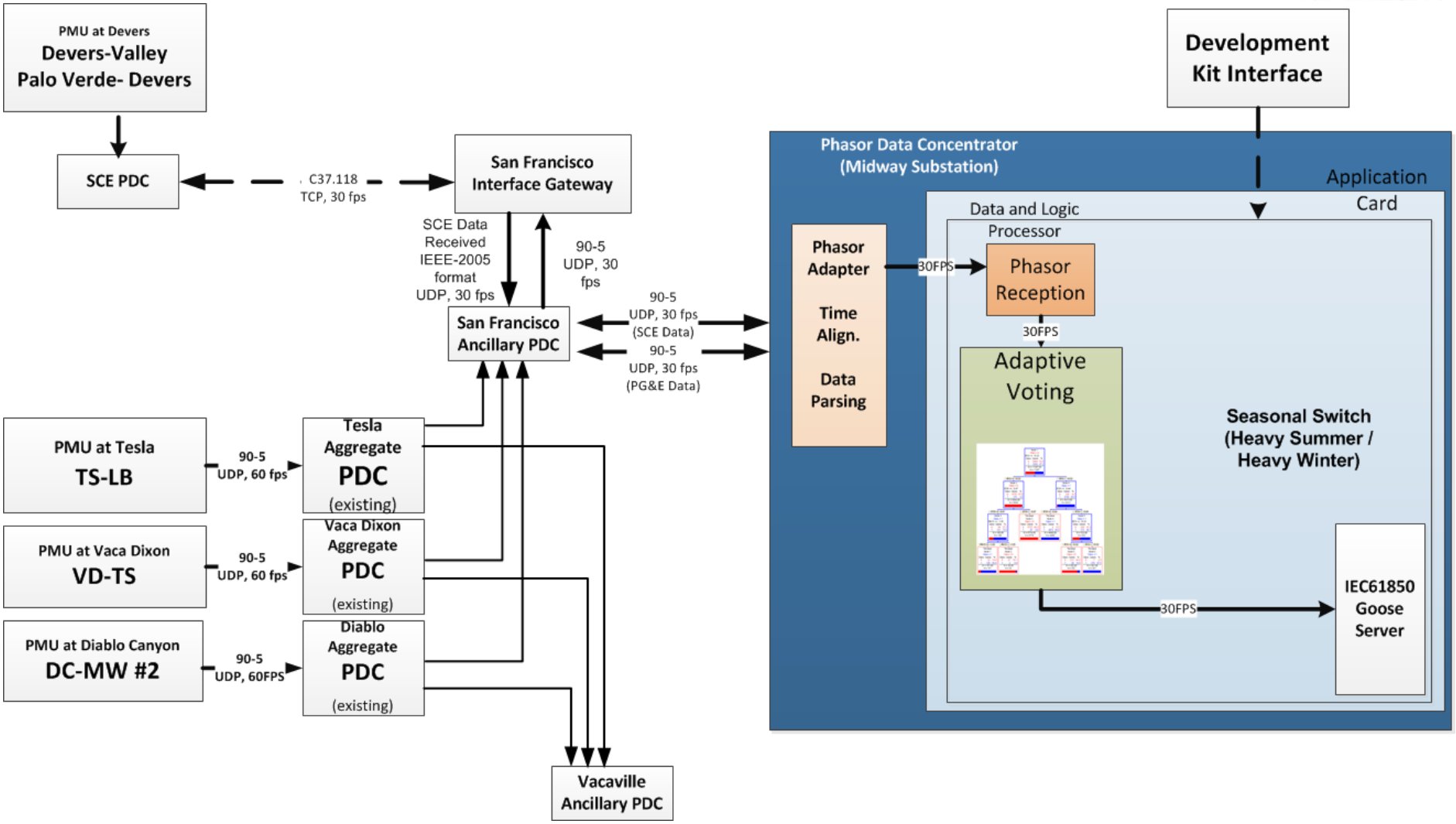

```
if (imag I735 <= -0.88)
    {
      state = 1;
    }
    else
    {
      if (real I19 <= 17.18)
      {
        if (real I19 <= 16.78)
        {
          state = 0;
        }
        else
        {
          if (imag I735 <= -0.62)
          {
            state = 1;
          }
          else
          {
            state = 0;
          }
        }
      }
      else
      {
        if (imag I1033 <= 1.27)
        {
          state = 1;
        }
        else
        {
          state = 0;
        }
      }
    }
```

Heavy Winter Decision Tree

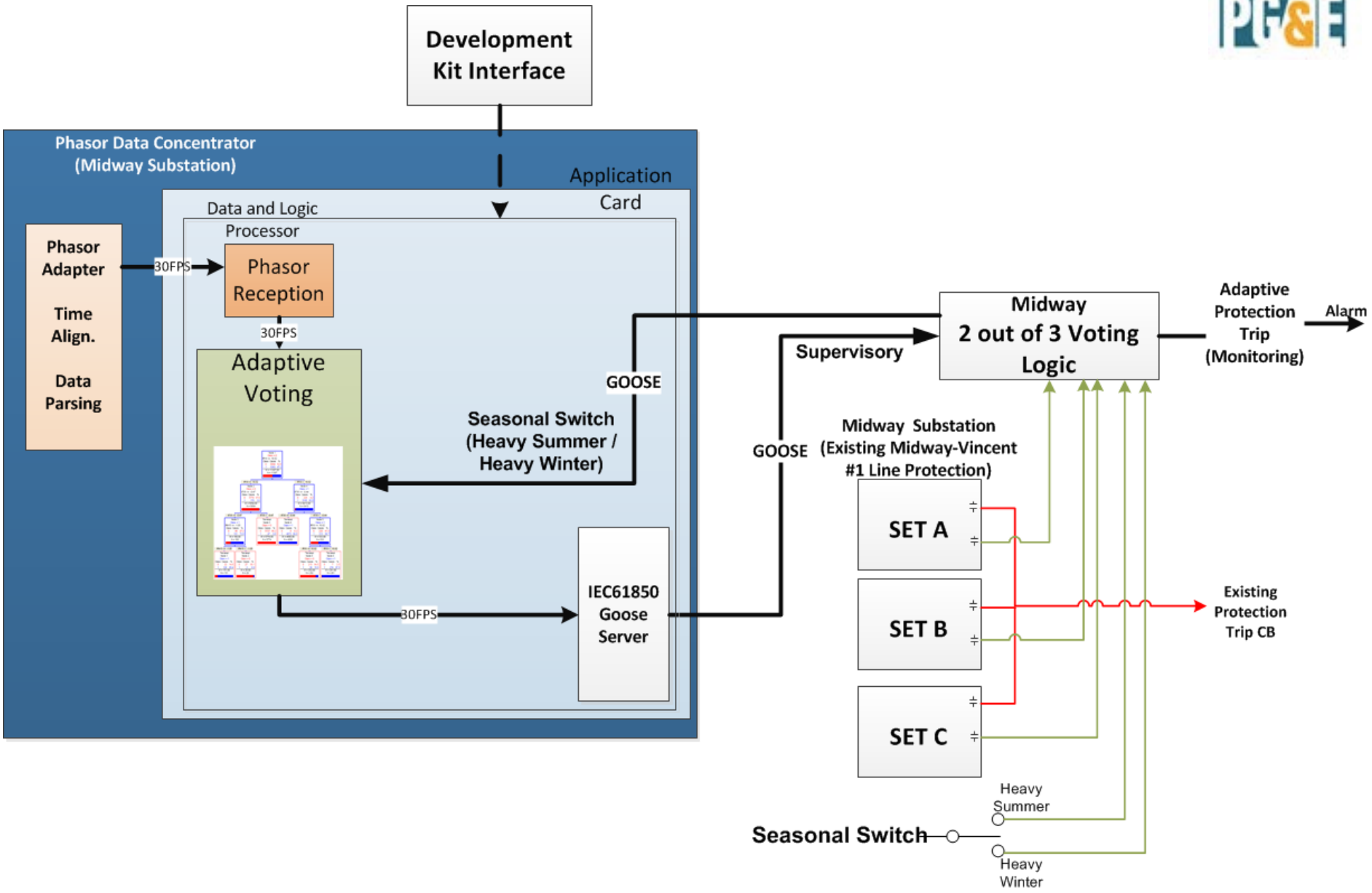



```
if (real I1106 <= 4.46)
        {
           state = 0;
        }
        else
        {
           state = 1;
        }
```

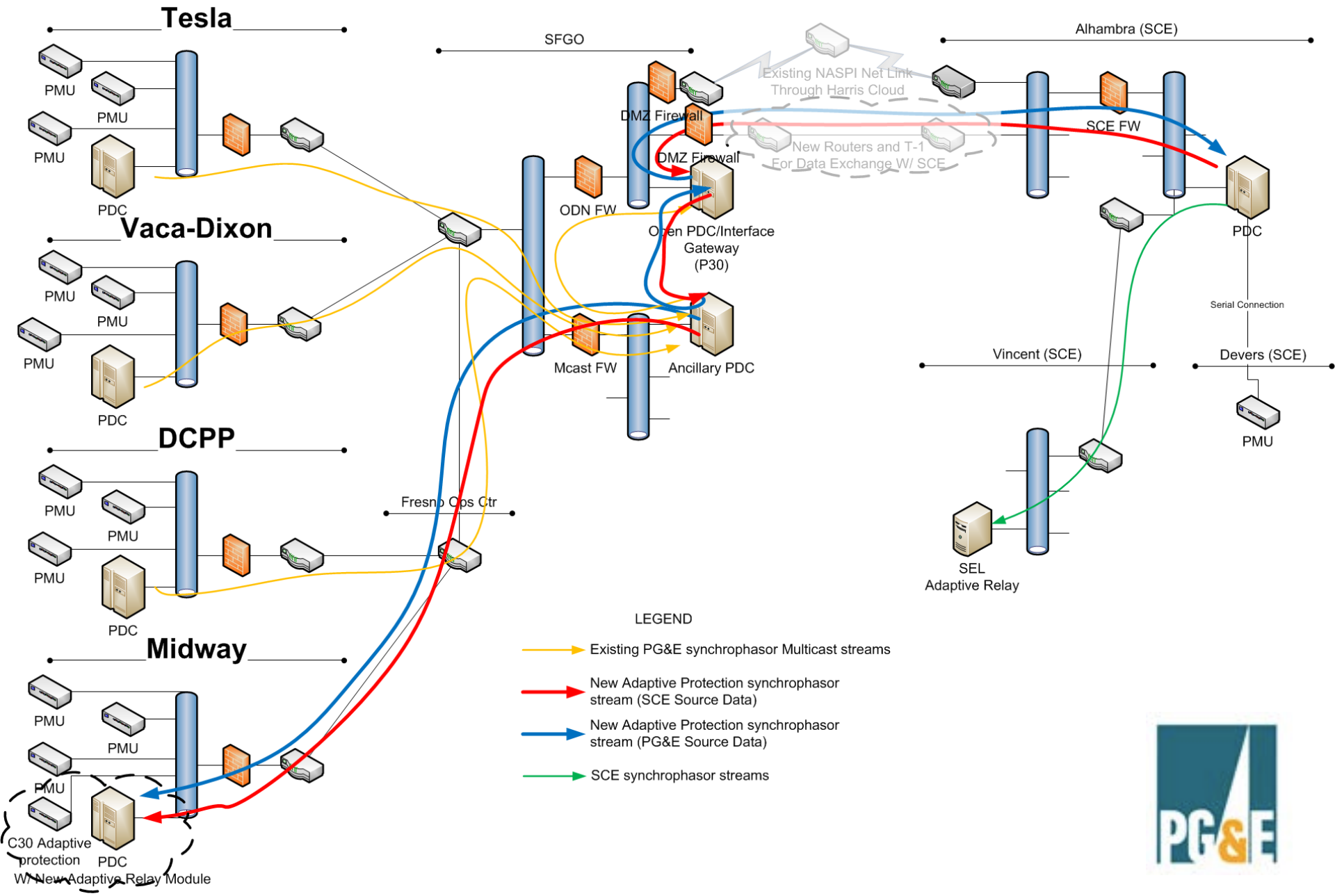
PMU Data Source & Processing



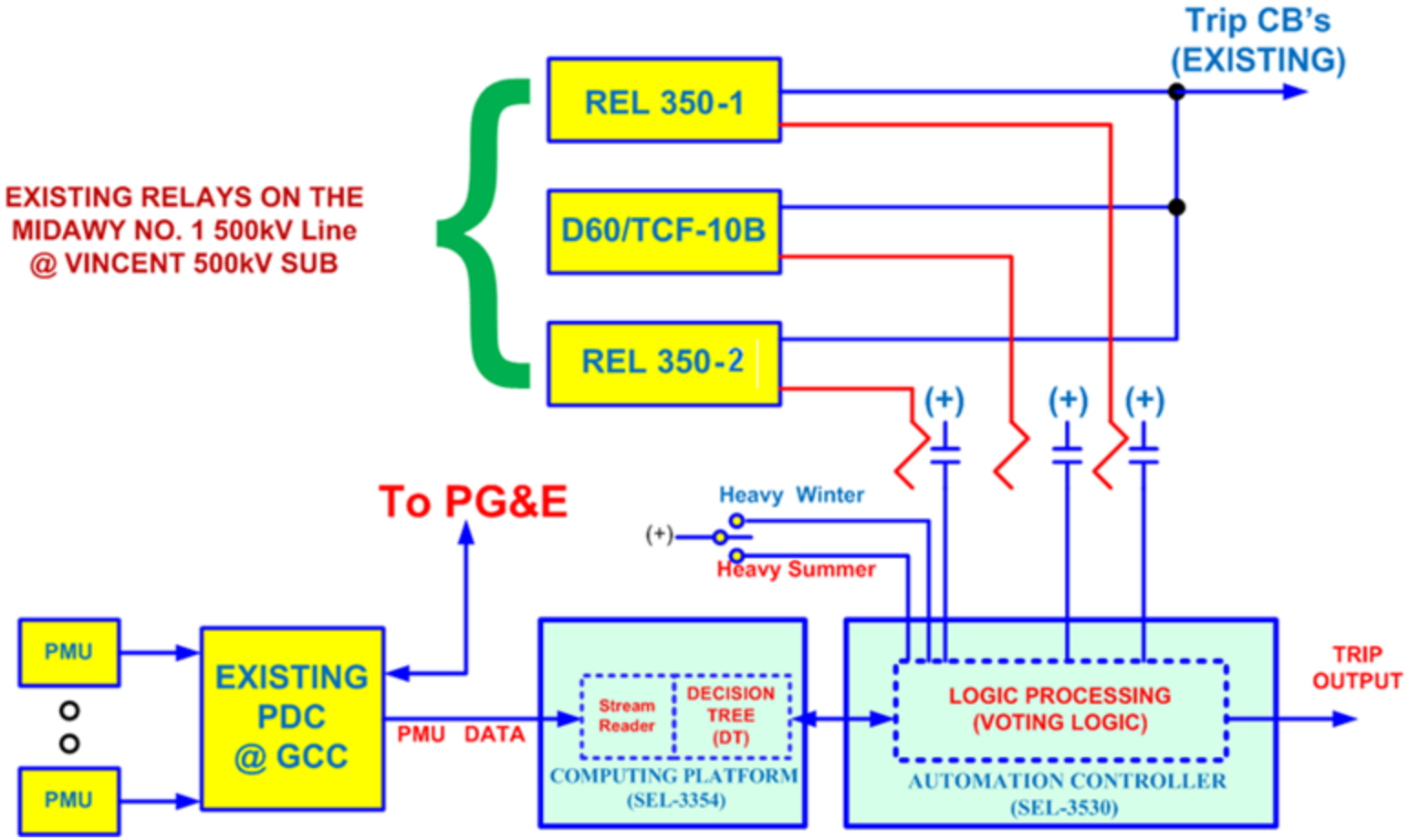
Data Processing and Trip Voting



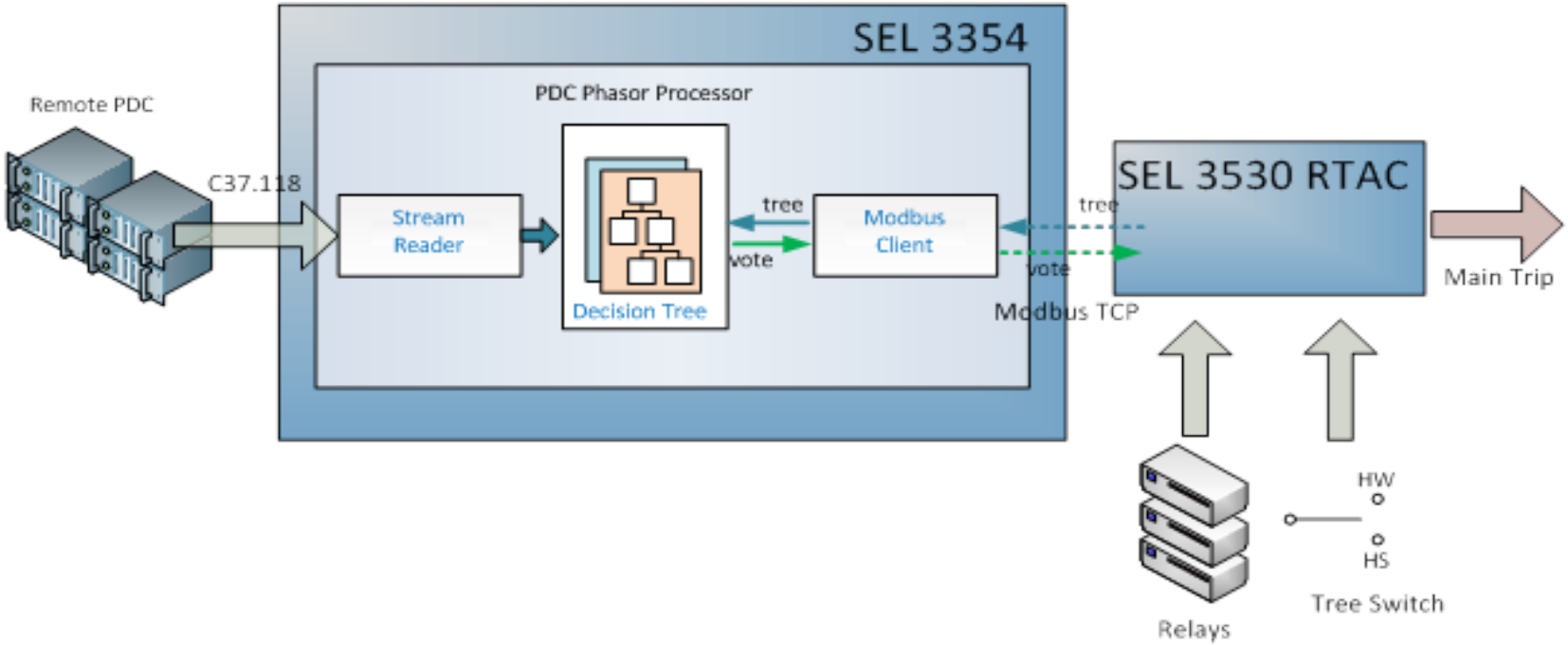
New PG&E – SCE Connection



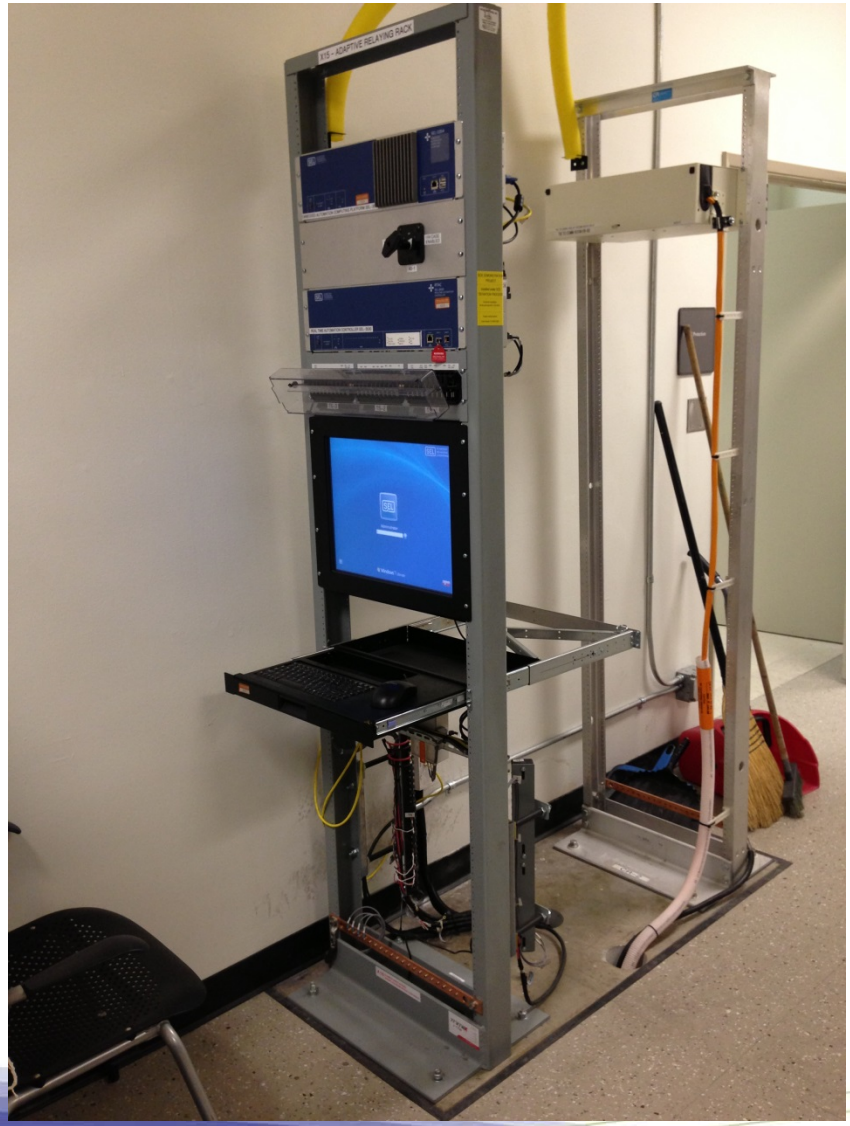
Application of Advanced Wide-Area Early Warning System with Adaptive Protection



Adaptive Relay System Architecture



Adaptive Relay Rack at Vincent Substation

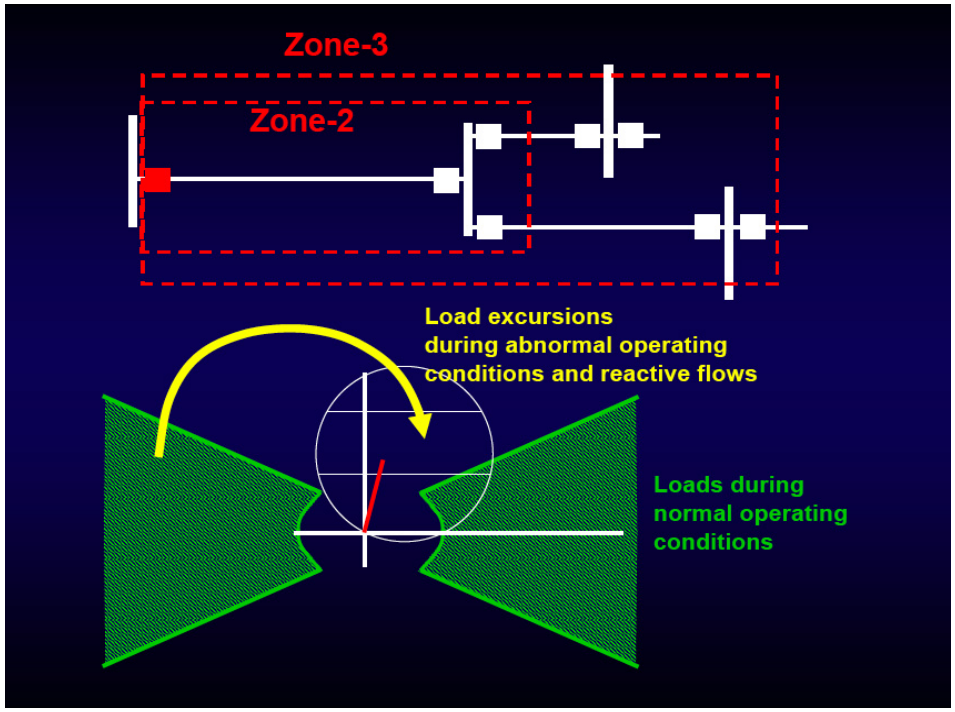


Adaptive Relay Rack at Vincent Substation

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



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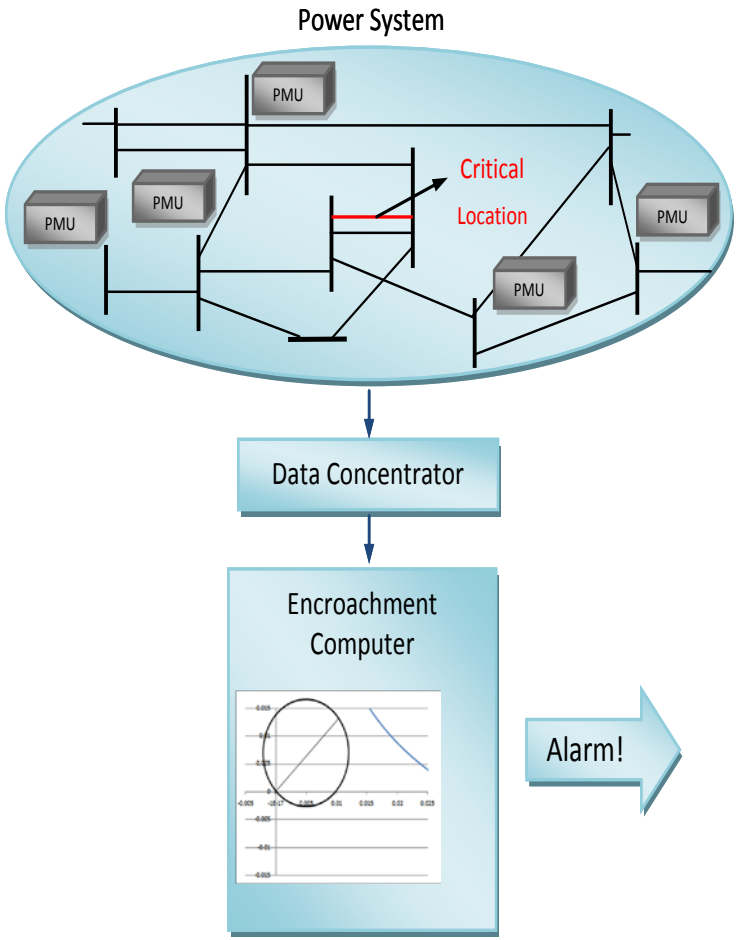
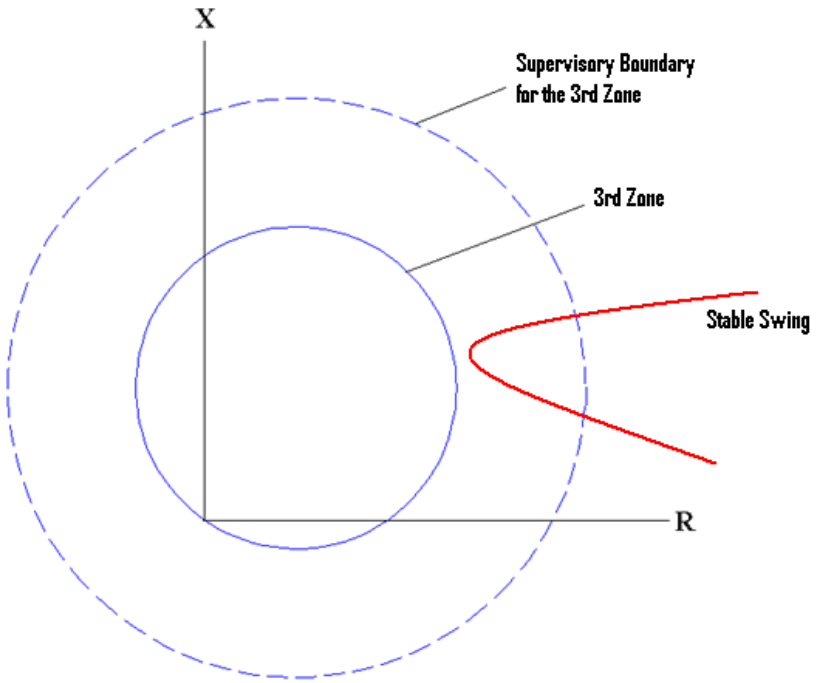
Alarms for Encroachment of Relay Trip Characteristics



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



Alarm when system swings encroach on the supervisory zone.

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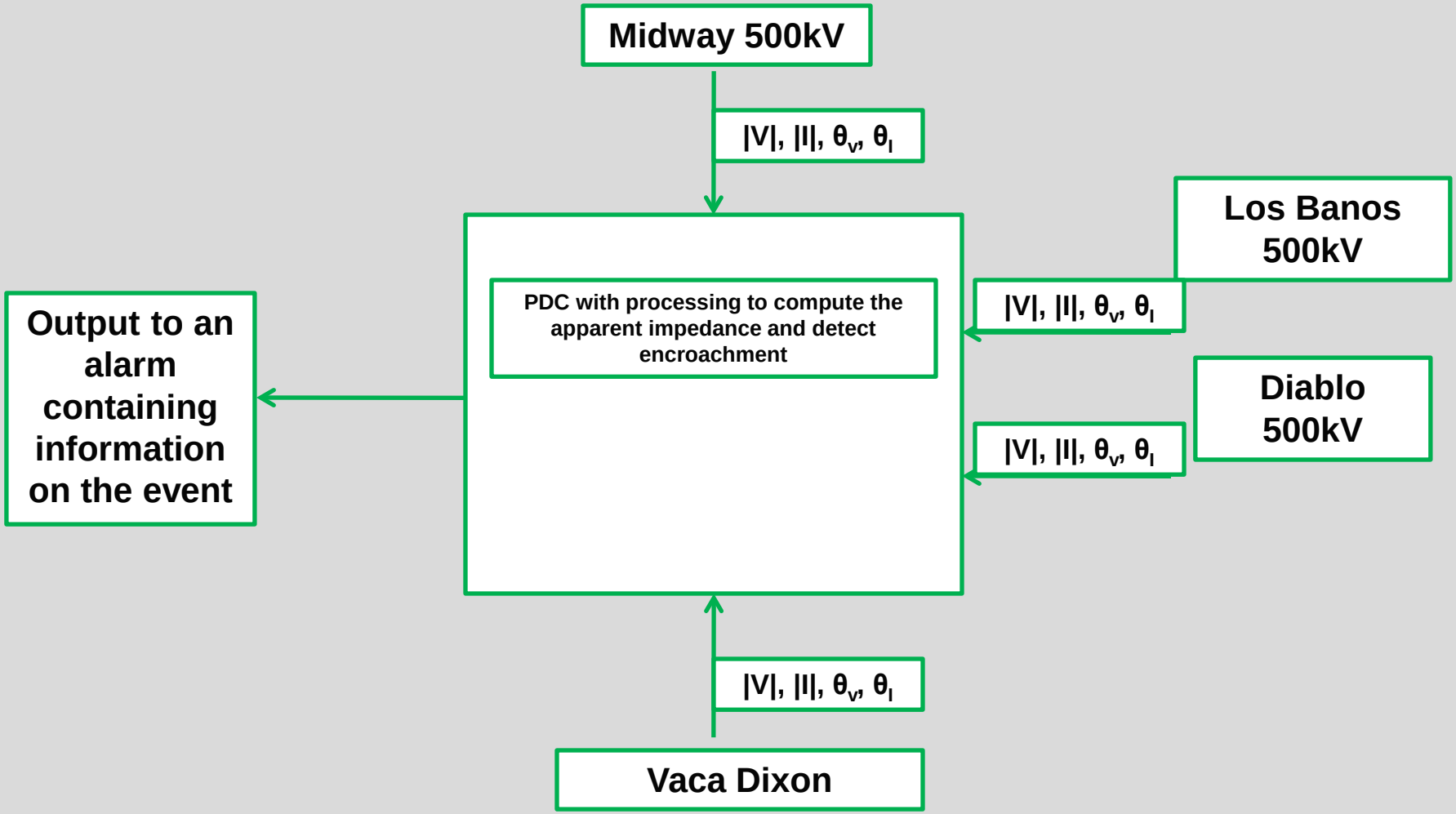
Real-Time Alarm for Relay Characteristic Encroachment Events

- 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



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.**
  - Demonstration of PIT visualization methods using actual utility data by ~~December 2013~~ **September 2014.**

Questions?

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