System State Estimation

- Current practice
  - » SCADA – scans on the order of 1-5 seconds
    - – Somewhat variable rate
    - – |V|, P, Q,
    - – No angles
  - » To get angles and missing measurements need a non-linear state estimator
    - – Iterative solver
    - – Based on a model of the power system

Hybrid System State Estimation with Added PMU Data

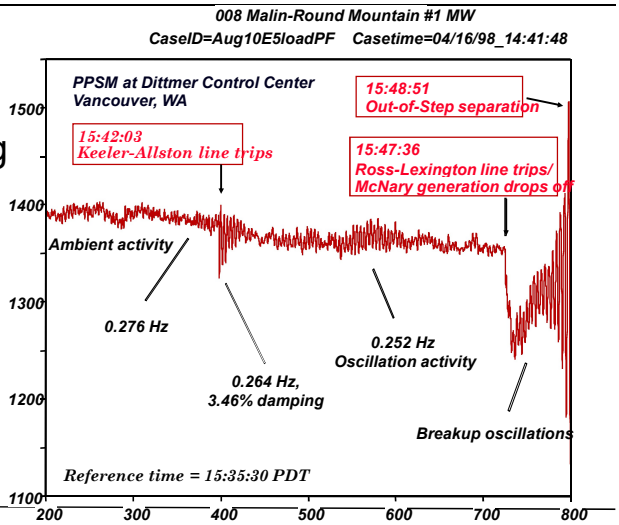
- The conventional SCADA isn't going away
  - » Infrastructure is in place
  - » Implementation of PMUs is limited in many utilities
- Supplement the state estimation with PMU data where |V| and angle are measured directly
  - » Still more of a future implementation
- Variant on this is using PMU data resolve anomalies in the conventional state estimator results (done now)

Dynamic System State Estimation with PMU data

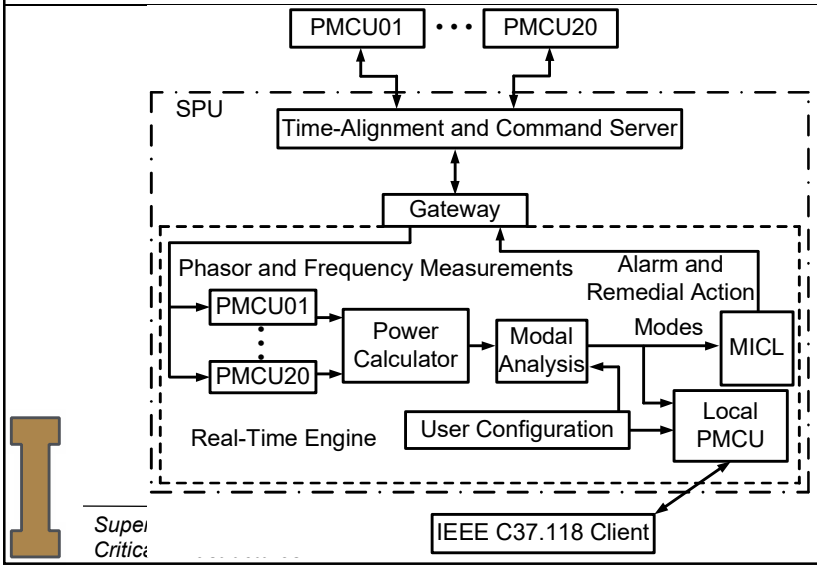
- Synchrophasor data only
  - » Have time aligned data with angle information
  - » Could possibly do a linear solution
    - – Could solve up to frame rate (even 60 samples/sec)
    - – Can catch power system dynamics
    - – Dynamic state estimator
  - » But may not have PMUs at every bus where need state
    - – Still need an observable system
  - » Measurement error
    - – So may end up over measuring.
- Hybrid

Modal Analysis

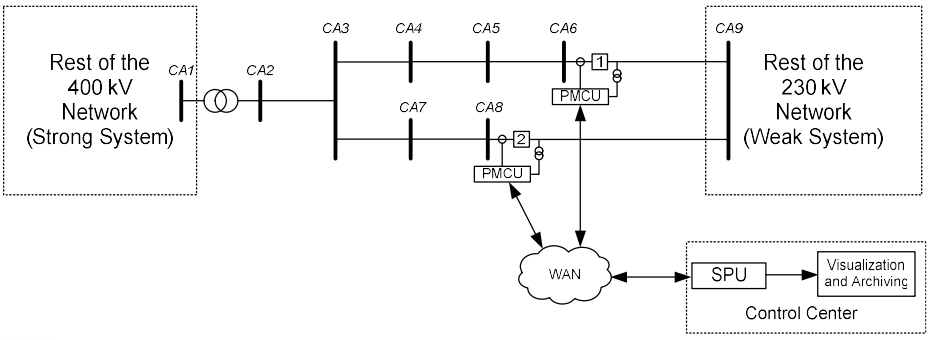
- Identify modal frequency
- Identify damping ratio
- Could take it further to implement remedial action



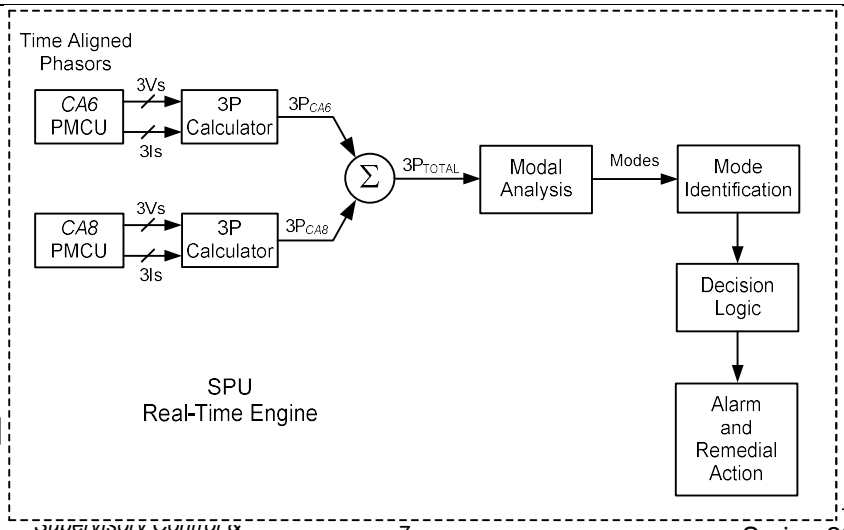
Real-Time Modal Analysis for Detecting Inter-Area Oscillations



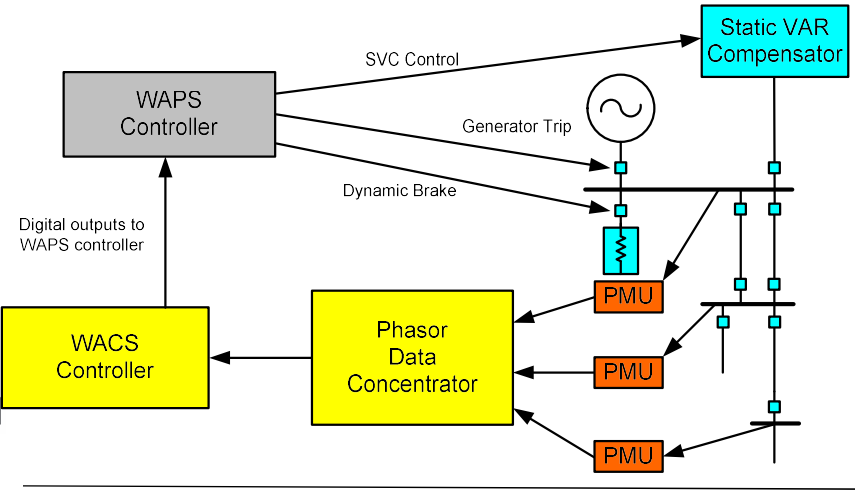
Field Installation to Detect Inter-Area Oscillation



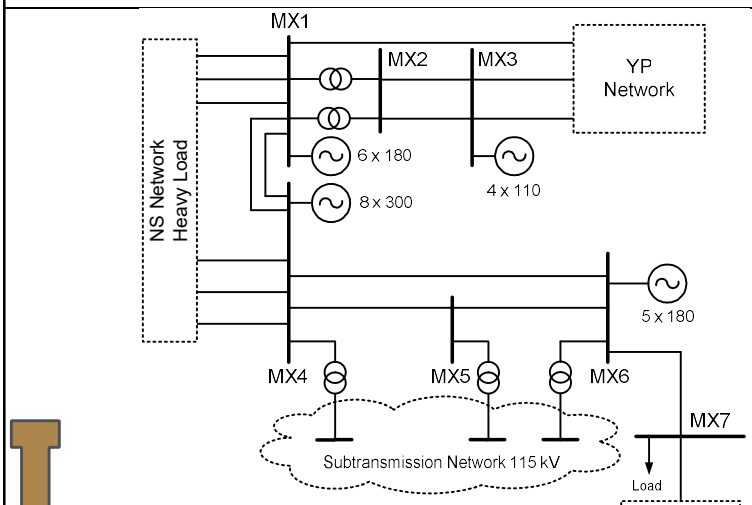
Algorithm to Detect Unstable Power Oscillations and Take Remedial Action



Complex Multi-Task System Integrity Protection Scheme



Automatic Generator Shedding Scheme Using Synchrophasors



Angle Dif. Between MX4 and MX6 for Single Contingencies – Less than 100 ms