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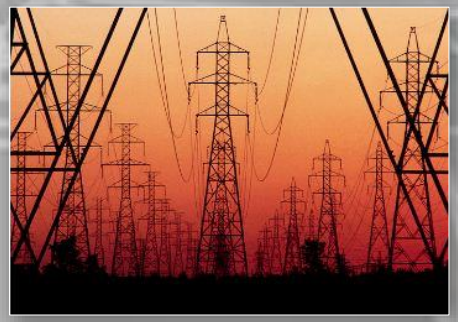

Cascading Outages : Monitoring & Detection

NASPI/ International Synchrophasor Symposium

March 22, 2016

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Background

- As a result of CIP-014 R1 requirement, set out to identify critical substations that could result in uncontrolled separation or Cascading outages for clients including PG and E.
- Several observations made that can be translated to real time operations
- Strong research being pursued in the direction of using offline planning tools (like PSLF- steady state / dynamics) to develop monitoring limits in real time.
- The accuracy of the planning model plays a very important role in this development.
- Sensitivities were studied to see the impact on development of thresholds. Sensitivities included
  - Detailed line protection as per utility protection recommendations, locti, Differential line and transformer protection, distance relays etc.
  - Generator protection using exciter models
  - All generators controls in place
  - WECC composite load models used
  - All UVLS, UFLS relays in place
  - Islands isolated and solved separately

Simulations Based Observations

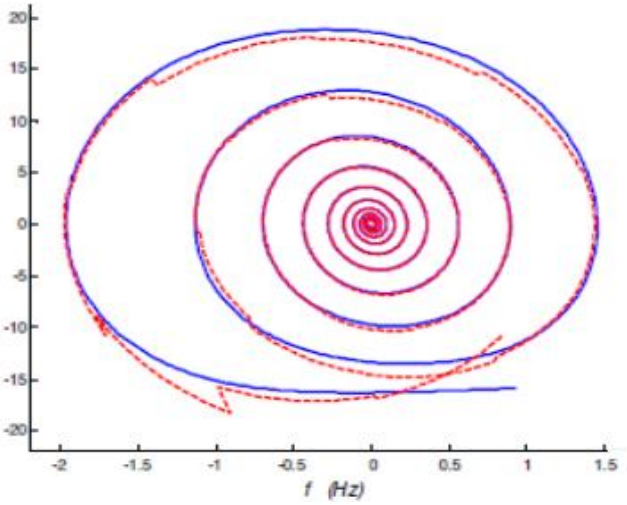
- Rotor angle separation between some of the largest generators in the area should be consistently monitored
- Voltage angle at several higher kV buses closest to interface show larger spread during cascading events
  - Angle Rate- of Change to detect disturbances
- The system loading on a case by case basis has an impact on what "defines" a triggering event .
  - Initiating events during peak loading conditions might not always hold during minimum loading conditions.
- Consequential load drop numbers contribute to the scale of cascading events.
- Area (aggregation of zones) margins provide a clear indication of system current operating point vs limits.
- Phase-plane (Frequency vs Angle difference) representation shows evolving pattern of cascading events.

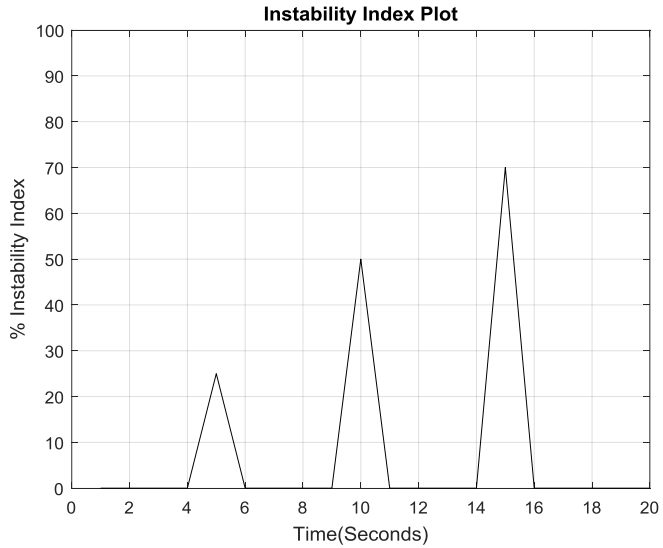
Monitoring Schemes Recommendations

- Need thresholds to be developed from offline transmission planning and operational tools.
- Thresholds are developed based on vulnerable transfer conditions across branches on the interface under “identified” critical limiting contingencies. Threshold takes into account elements with the largest contribution to cascading events.
- These thresholds are consistently monitored by phasor measurement units (PMUs) at control centers.
  - Thresholds are developed from angle and frequency differences at critical buses in the network: between monitored areas.
  - Angle separations between critical generators in the systems.

Detection (1)

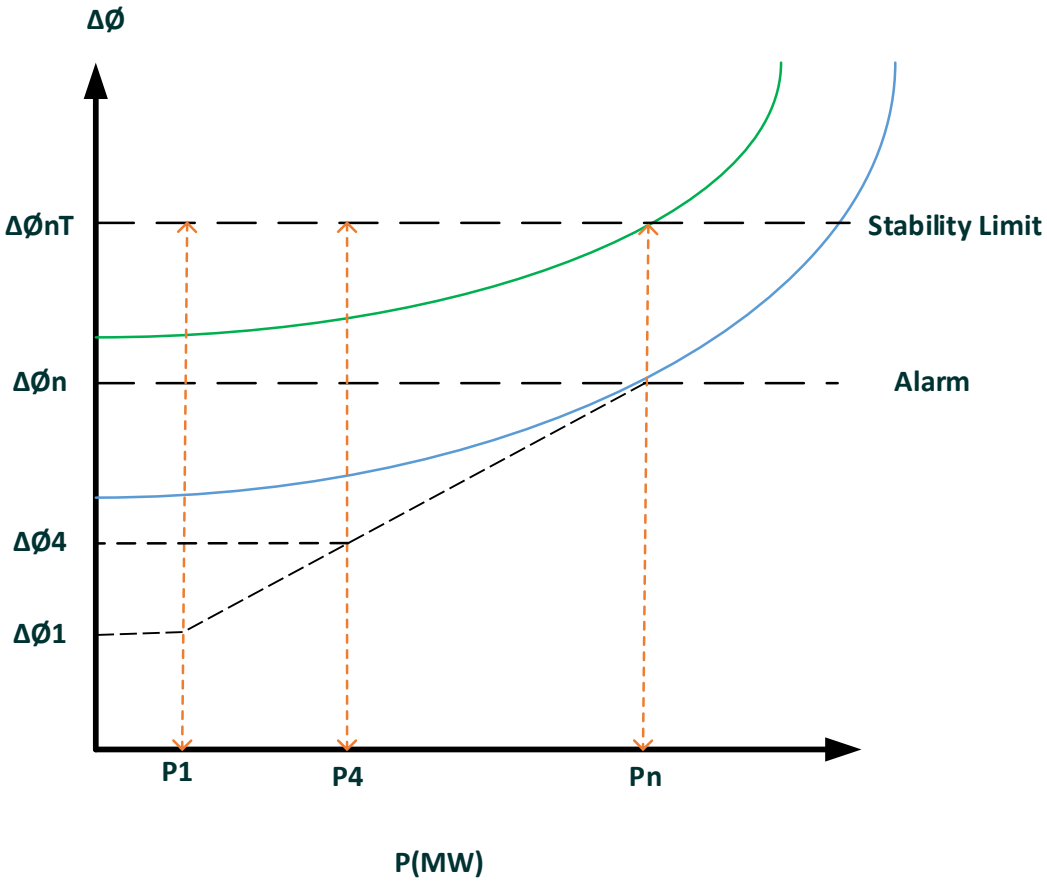
- DC power flow technique and pseudo inverse of admittance matrix is used to develop the cascading failure evolution
- Similar evolution pattern verified using AC solution techniques
  - These conditions are studied to establish angle/frequency differences between two areas during the batch run of dynamic simulations(offline) for critical contingencies at power transfer level.
  - BOCS methodology (proposed by EPRI) has been modified to calculate the Cascading event Instability Index.
  - The phase plane trajectory is plotted, surface function is estimated, and the stability margin is approximated.





Detection (2)

- Critical generator pairs are identified during the batch run of dynamic simulations(offline) for multiple power transfer levels.
  - The maximum and minimum phase angle differences under different power transfer levels can be computed.
  - This is further translated onto a P vs Phase angle plane to define the stability region.



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Thank You!

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