DOE Project
Controlled System Separation Study

Schedule and Status

Schedule

- Enernex is working on a combination Task #2/Task #3 report due April 1
  - Task #2 is to develop criteria and control algorithms that are able to determine the need/trigger events for system separation and the interfaces where that should occur
  - Task #3 is to identify interfaces for system separation examining things such as coherent generation groups

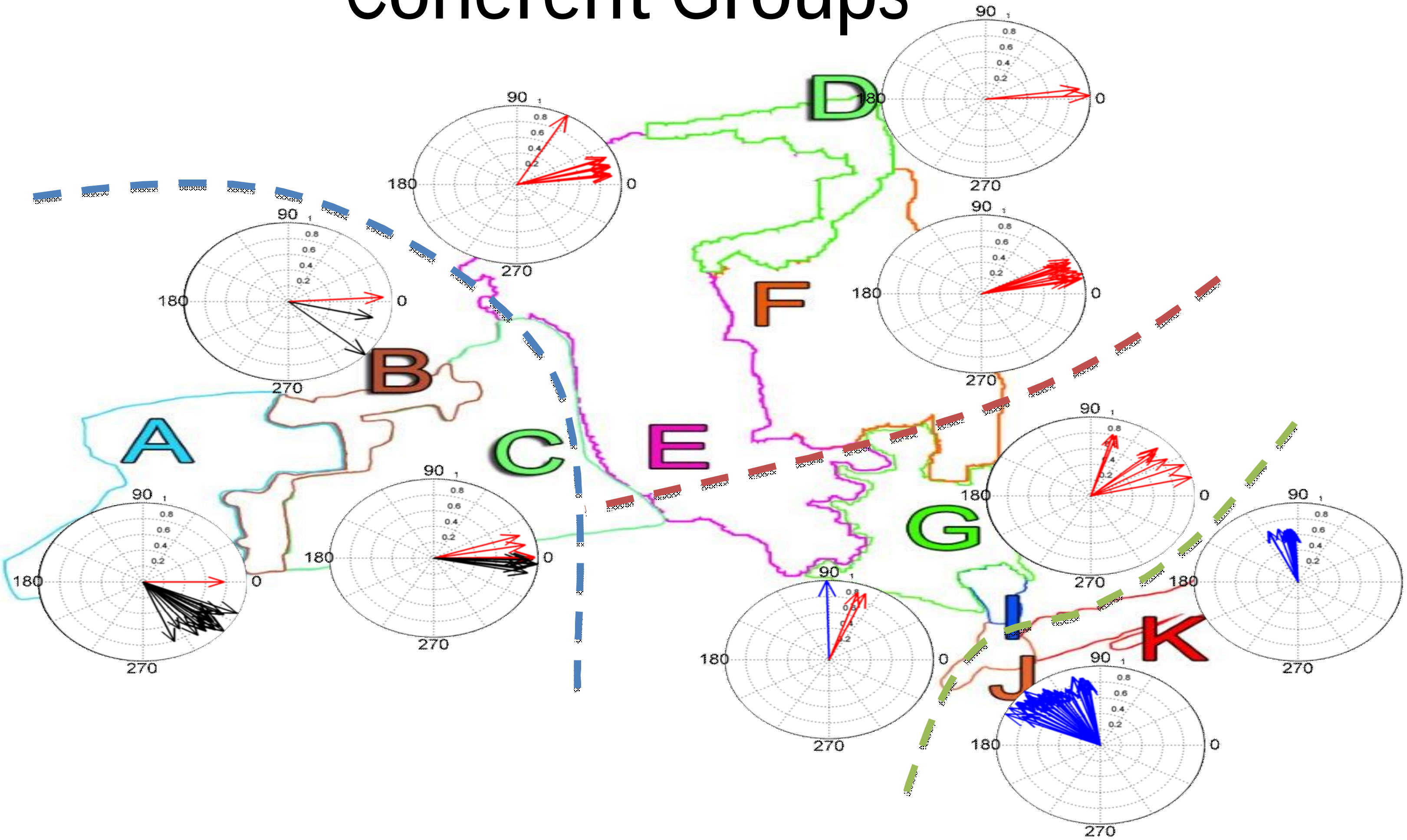
Schedule

- Next step after combination Task #2/Task #3 report is to complete a combination Task #4/Task #5 report due June 1
  - Task #4 is to determine appropriate locations for Dynamic Data Sources (PMU, DFR, etc.) to implement CSS
  - Task #5 is to identify the timing for when the CSS scheme would need to operate

Status

- Enernex issued a draft Task #2 report on January 27th
  - They examined an approach to use Transient Energy Function (TEF) to explain the mechanism of generator separation
  - Spectral Analysis-Based Method Validation was tested using the Power Spectrum Density (PSD) and Cross Spectrum Density (CSD) to determine generator coherency

Impact of Disturbance Type/Location to Coherent Groups



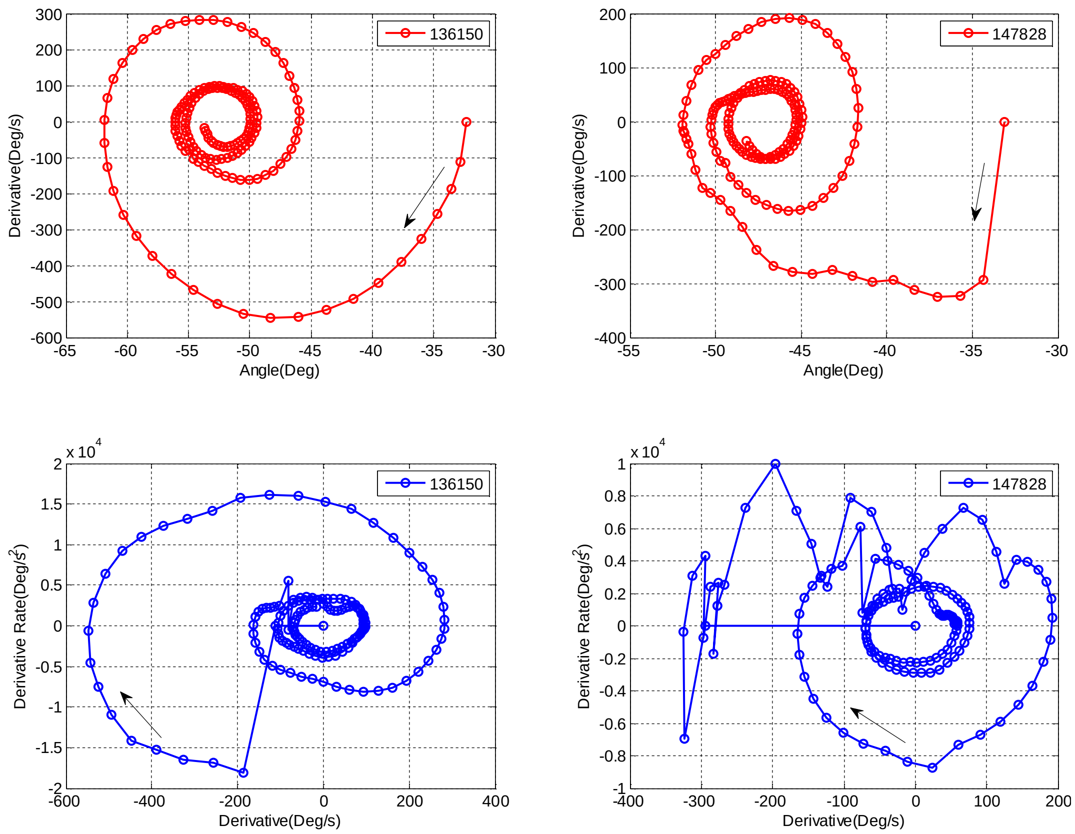
Enernex is now looking into Separation Indicators

- Look at angle, velocity of angle and acceleration of angle at a bus
- Look at angle, velocity of angle and acceleration of angle between buses

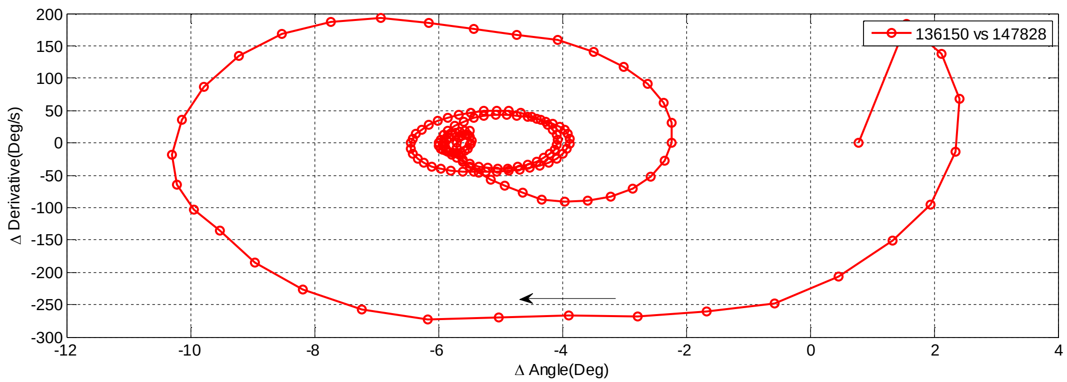
Trajectory Comparison

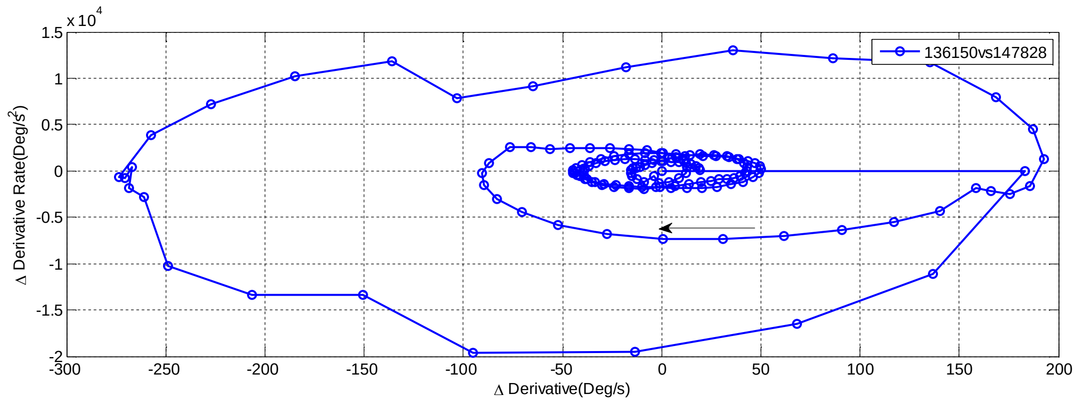
- Examine a trajectory comparison between these values
  - For example
    - Bus velocity versus Bus angle
    - Bus acceleration versus Bus velocity
    - Delta bus velocity versus delta bus angle
    - Delta bus acceleration versus delta bus angle

Bus Value Trajectory

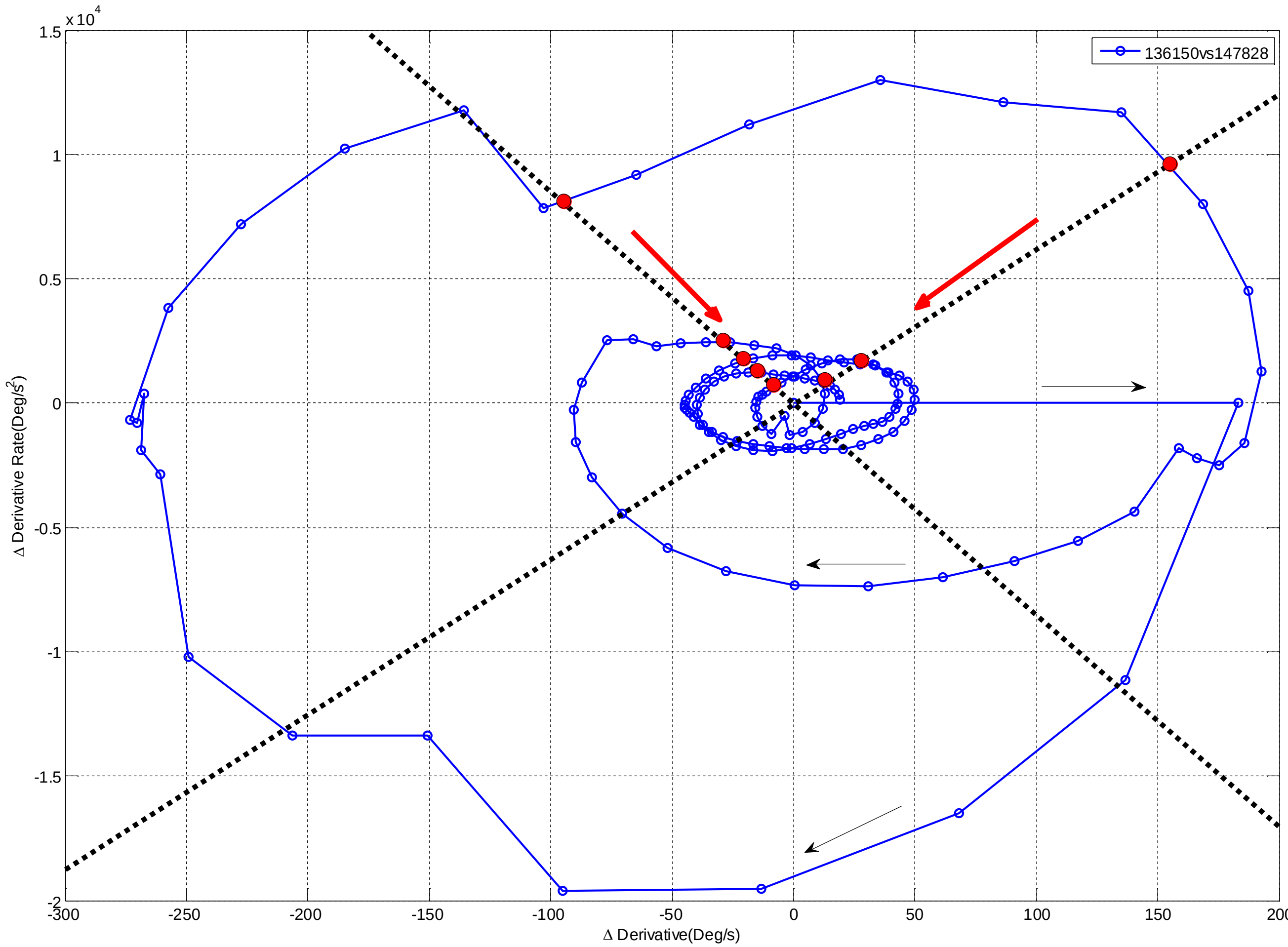


Delta Bus Value Trajectory





Convergent Attractor for Stable Case



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Observation

- For a stable case, the pre-fault equilibrium will reach a new equilibrium following a trajectory of eccentric periodic orbits. The moving direction of the trajectory is to minimize the distance between the point on the trajectory and the new equilibrium.
- An attractor can be observed in the trajectory.
- A correlation coefficient can be calculated between buses

Comprehensive Separation Indicators

- Assuming two monitoring locations and monitored signals are: δ_1, ω_1, α_1 and δ_2, ω_2, α_2
  - Step 1: α_1 and α_2 are constant -> normal
  - Step 2: Either α_1 or α_2 increases, or $\Delta\ \alpha_{12}$ increases -> warning 1
  - Step 3: Either ω_{1} or ω_{2} increases, or $\Delta\ \omega_{12}$ increases -> warning 2
  - Step 4: $\Delta\ \delta_{12} > 40°$ -> warning 3 and launch correlation analysis between δ_1 and δ_2 and trajectory analysis for $\Delta\ \omega_{12}$ vs. $\Delta\ \alpha_{12}$
  - Step 5: In a 0.5 second window, compute correlation coefficient and attractors in the trajectory
  - Step 6: Refer to the Look-up Table in the next slide

Look up table

Indicator	Event
Corrcoef > 0.5, convergent attractor	Coherent and stable
Corrcoef > 0.7, divergent attractor	Coherent but unstable
0 < Correcoef < 0.7, convergent attractor	Out-of-phase oscillation (0 - 90°) and stable
0 < Correcoef < 0.7, divergent attractor	Out-of-phase oscillation (0 - 90°) but unstable
Correcoef < 0, convergent attractor (?)	Transient OOS
Correcoef < 0, non-attractor	Separation