C4 Power System Technica Performance

PS3 - Challenges and Advances in Power System Dynamics

Paper ID_11015

Identifying Regional Inertia Issues using Graph Theory and Spectral Clustering

P. DATTARAY, B. GRAHAM, V. SINGHVI, E. FARANTATOS, A. TUOHY

Electric Power Research Institute

Motivation

- Increasing penetrations of inverter-based generation are displacing synchronous generation - reducing the total system inertia.
- Large concentrations of these resources can also cause the remaining sources of inertia to become more sparsely distributed across the system
- Local regions emerge that have low inertia and low levels of dynamic coupling (synchronizing torque) to the other regions of the power system.
- Reduced coupling may potentially allow the local frequency in these regions to vary significantly from the frequency in the rest of the system. This may cause frequency security practices based on simplified 'system' models to fail to prevent localized frequency excursions outside of operational limits.

Method/Approach

The methodology proposed here is intended to process a multitude of operating conditions (topology and unit commitment) and entails three core phases:

- **Region Formation** : Generate a set of coherent synchronous generator groups for each unique combination of topology and unit commitment
- **Region Synthesis** : Shortlist the credible key regions that are most likely to emerge in the system.
- **R-SLI Ranking** : Rank the single largest infeed in each region (R-SLI) according to their potential to cause regional inertia issues. This will not be based on time domain simulations, but is based on region inertia, R-SLI size and the relative dynamic coupling of the region to the rest of the system

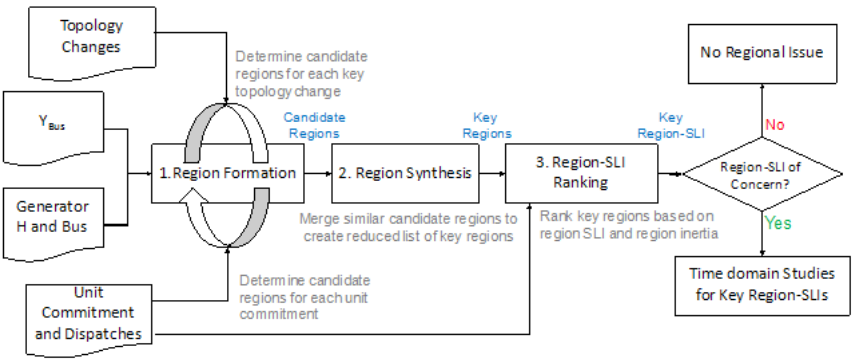

Figure 1:Overview of proposed regional inertia screening methodology

Spectral Clustering for Region Formation

- Low inertia regions are characterized by high levels of dynamic coupling between the synchronous generators in the region (intra region coupling) and relatively low levels of dynamic coupling between the region and other regions (inter region coupling).
- The clustering method is responsible for grouping the synchronous generators into *k* regions and has two key aspects:
    - Determine the optimal number k
    - Group the synchronous generators into k regions

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Test System

- The proposed methodology has been applied to the synthetic Texas system
- The synthetic Texas system studied here has over 400 generators and 2000 buses.
- The sum of the inertia constants of the online synchronous generation is 246 GVAs and the SLI is 1351 MW

Selecting the Cluster Number (*k*) and number of Eigen Vectors (*N*)

Figure 2: Metric calculated for the synthetic Texas system for candidate k values of 2 to 20

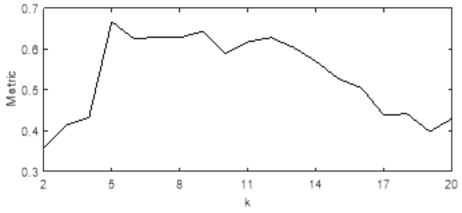
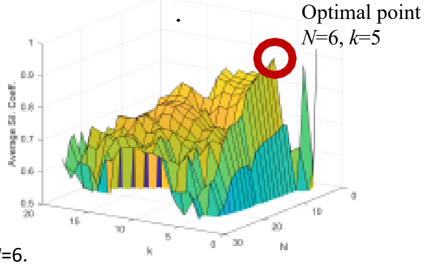


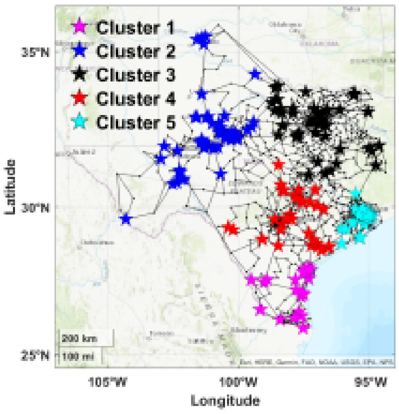
Figure 3: All average silhouette values for k = 2 to 20 and N = 2 to 20.



The maximum average silhouette score for *k*=5 was found for *N*=6.

Clustering Result for Base System

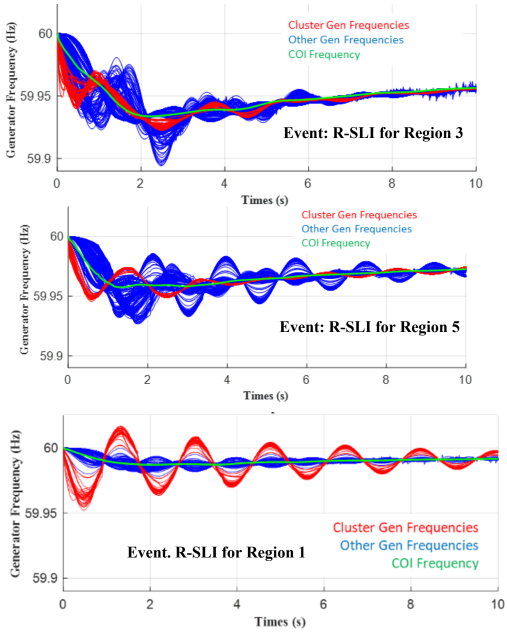
Figure 4. Cluster solution for intact system



Summary of Regional metrics

Region	1	2	3	4
Region Inertia (GWs)	24.4	11.8	58.5	59.1
R-SLI (MW)	1144	209	1212	552
Regional -RoCoF (Hz/s)	1.4	0.5	0.6	0.3

Figure 5. Generator frequencies in the event of the R-SLI



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Region Solutions under Topology Changes (On-going work)

- Clustering process is repeated under the outage of the ten most heavily loaded transmission lines.
- 6 of the line outages resulted in the same clustering solution as for the intact system (3,4,5,8,9,10)
- For four lines a new, 9 cluster solution was found (1, 2, 6, 7)
- Further work is required to define an appropriate projection that allows consistent region formation and broader review to generate region synthesis methods

Figure 6. Original 5 cluster solution , solution with 9 cluster and location of line outages

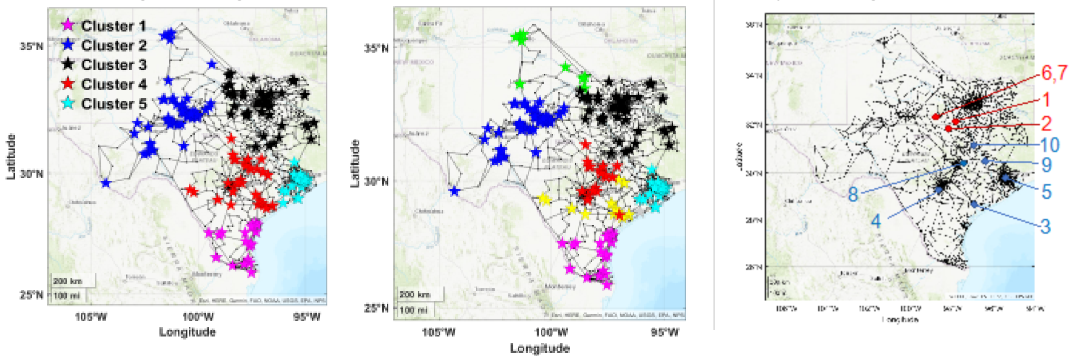
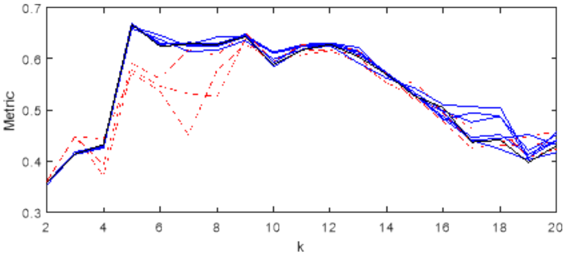


Figure 7. Results of the k metric calculation (blue lines denote 5 cluster solutions and red dashed lines 9 cluster solutions)



Conclusions

- Paper outlines a methodology for screening for regional inertia issues without requiring time domain simulations.
- Results for a 2000 bus synthetic Texas which demonstrate the ability of this method to reliably generate coherent generator groups that could exhibit regional inertia issues.
- A basic metric for determining relative vulnerability is described and time domain simulations are used to illustrate its effectiveness.
- This approach is based on existing work but is refined to facilitate its application to large, complex systems for non-bisection results
- Further work is required to develop an effective projection of the system state matrix for large power systems and development of effective, efficient region synthesis methodologies