Formulating actionable information from synchrophasors to forestall cascading outages

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CHALLENGE

- Combine together synchrophasor measurements to get actionable information to forestall emerging cascading outages
- Need specific emergency actions based on the combined measurements

Synchrophasors are fast and can function even when the state estimator may not converge due to multiple outages

Looking at the measurements in an unstructured way may give monitoring but does not give actions

KEY ASPECTS OF APPROACH
Specific problem formulation and physics

- Pick a specific security problem: for example overloads or voltage collapse or oscillations
- Formulate indicator of a specific system stress according to physics/math principles

LINE OVERLOADS

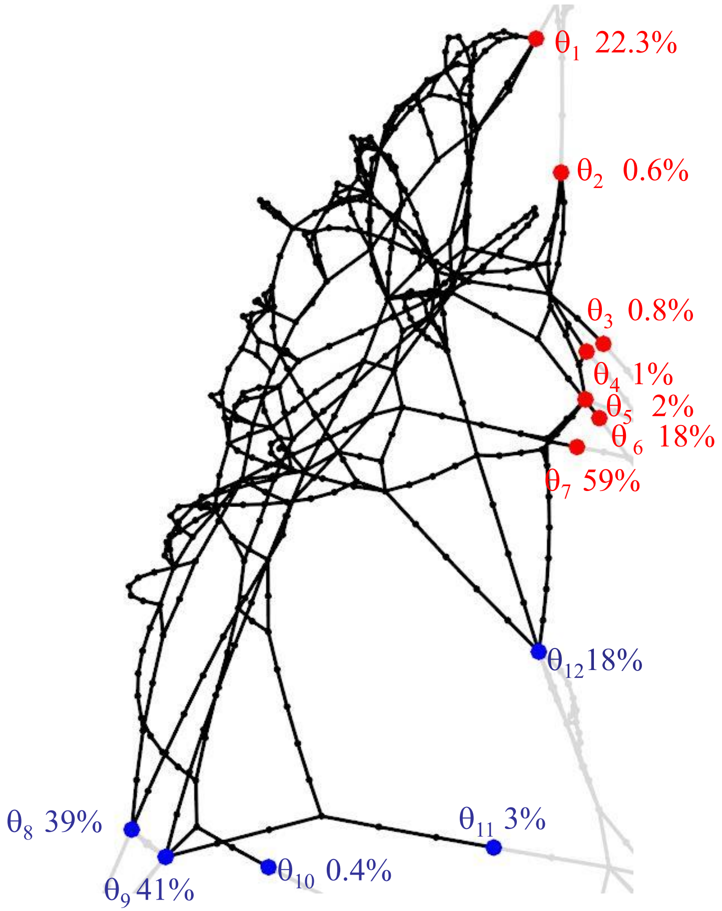
want emergency actions for overloads due to multiple outages

- Choose an area and power transfer stress direction … formulation naturally leads to mitigation action
- Measure angles all around the border of area
- Define scalar “area angle” by weighting angle according to circuit laws ….
  based on circuit theory so that it works like an angle across a single line
- Set thresholds for area angle related to N-1
- Test with multiple outages

OVERLOADS: MONITOR AREA BULK STRESS

- Area of WECC is WA/OR. Bulk power transfer stress is north to south
- Area angle is weighted combination of PMU angles at border
- Can set thresholds for reducing bulk transfer in emergency

Area angle across WECC area from red buses to blue



Area angle after triple outages

Triple outages in increasing order of severity

VOLTAGE COLLAPSE

want emergency actions for voltage collapse due to multiple outages

- Choose a power transmission corridor (area) between generation and load
- Measure PMU voltages, currents entering and leaving corridor; calculate powers
- Define scalar index based on approximate reduction of corridor to single line
- Set thresholds and test with multiple outages

See talk by Lina Ramirez, session 4, Wed AM

OSCILLATIONS

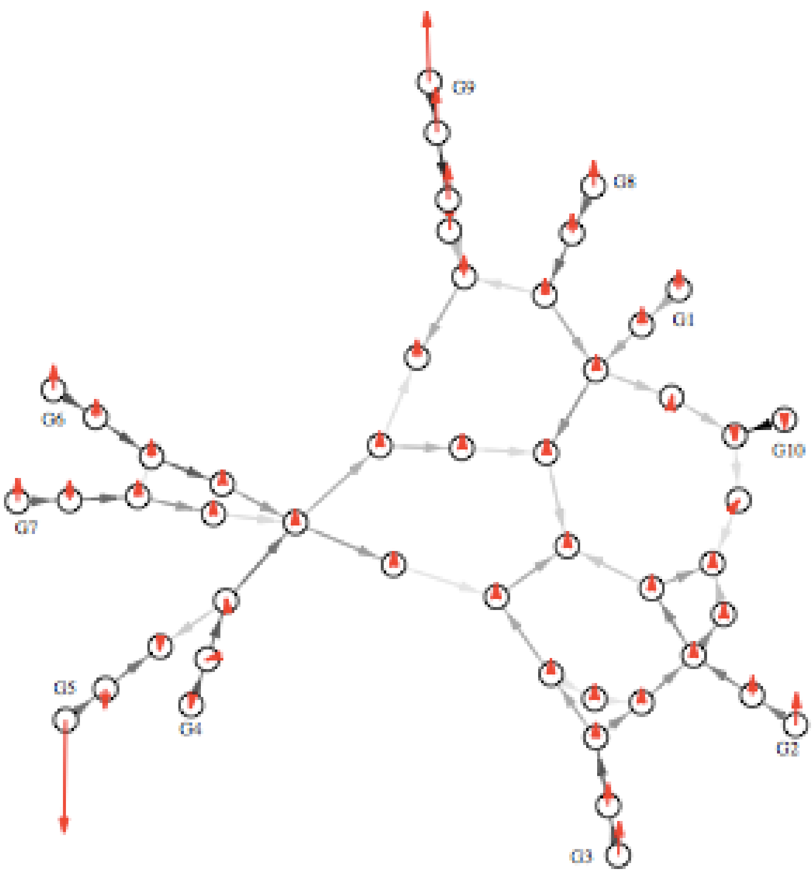
want an effective emergency generator redispatch to damp interarea electromechanical oscillations

- Derive formula based on physics for sensitivity of eigenvalue to redispatch
- Measure dynamics with synchrophasors; get load flow from state estimator; put into formula
- Formula gives ranking of generator redispatches

$$d\lambda = -\frac{1}{\alpha}\left\{\sum_{k=1}^{\ell}\left\{[(x'_{\nu_k})^2 - (x'_{\theta_k})^2]p_k - 2x'_{\theta_k}x'_{\nu_k}q_k\right\}d\theta_k + \sum_{i=m+1}^{n}\left[\sum_{k=1}^{\ell}|A_{ik}|(C_{q_k}q_k + C_{p_k}p_k) + C_{Q_i}Q_i\right]dV_i^{\ln}\right\};$$

0.76 Hz mode of 39 bus New England; arrows show mode pattern

OSCILLATIONS: formula ranks generator redispatches according to sensitivity of eigenvalue. Redispatch generators 5 and 9 is best



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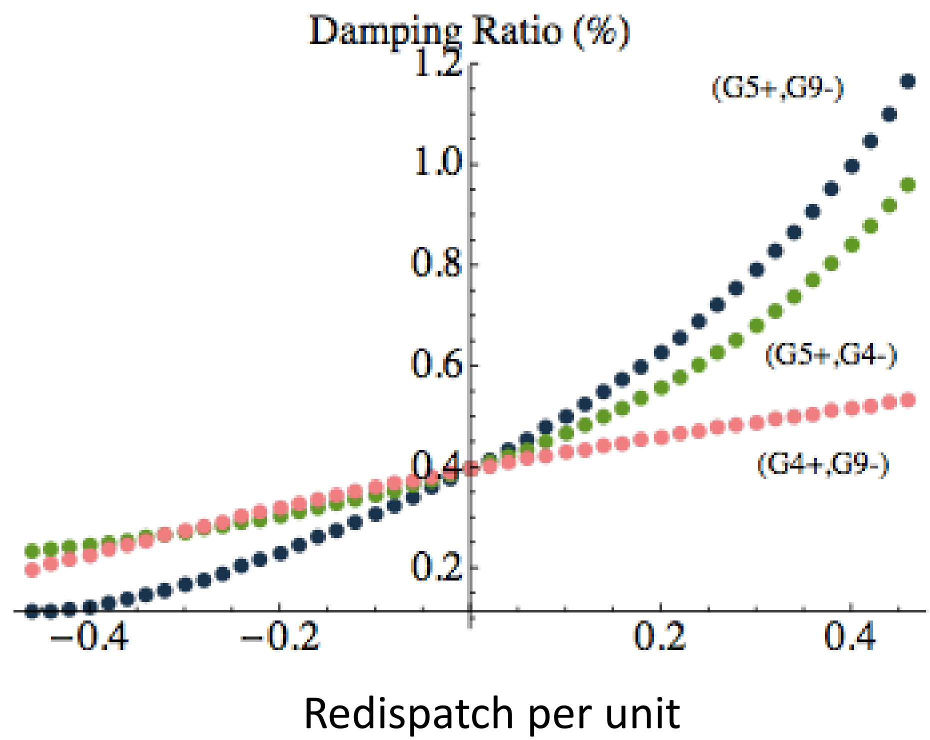

CONCLUSION

Formulating the cascading problem in **specific** ways and using **physics** yields **actionable indices** combining synchrophasor measurements

REFERENCES

at www.iandobson.ece.iastate.edu or IEEE Xplore

OVERLOADS: A. Darvishi, I. Dobson, Threshold-based monitoring of multiple outages with PMU measurements of area angle, to appear in IEEE Transactions Power Systems 2016

VOLTAGE COLLAPSE: L. Ramirez, I. Dobson, Monitoring voltage collapse margin with synchrophasors across transmission corridors with multiple lines and multiple contingencies, IEEE PES General Meeting Denver 2015

OSCILLATIONS: S. Mendoza-Armenta, I. Dobson, Applying a formula for generator redispatch to damp interarea oscillations using synchrophasors, to appear in IEEE Transactions Power Systems 2016.