IEEE Cascading Failures Working Group (CFWG)

Working Group: Understanding, Prediction, Mitigation and Restoration of Cascading Failures

IEEE PES Computer and Analytical Methods Subcommittee (CAMS)

Marianna Vaiman, V&R Energy

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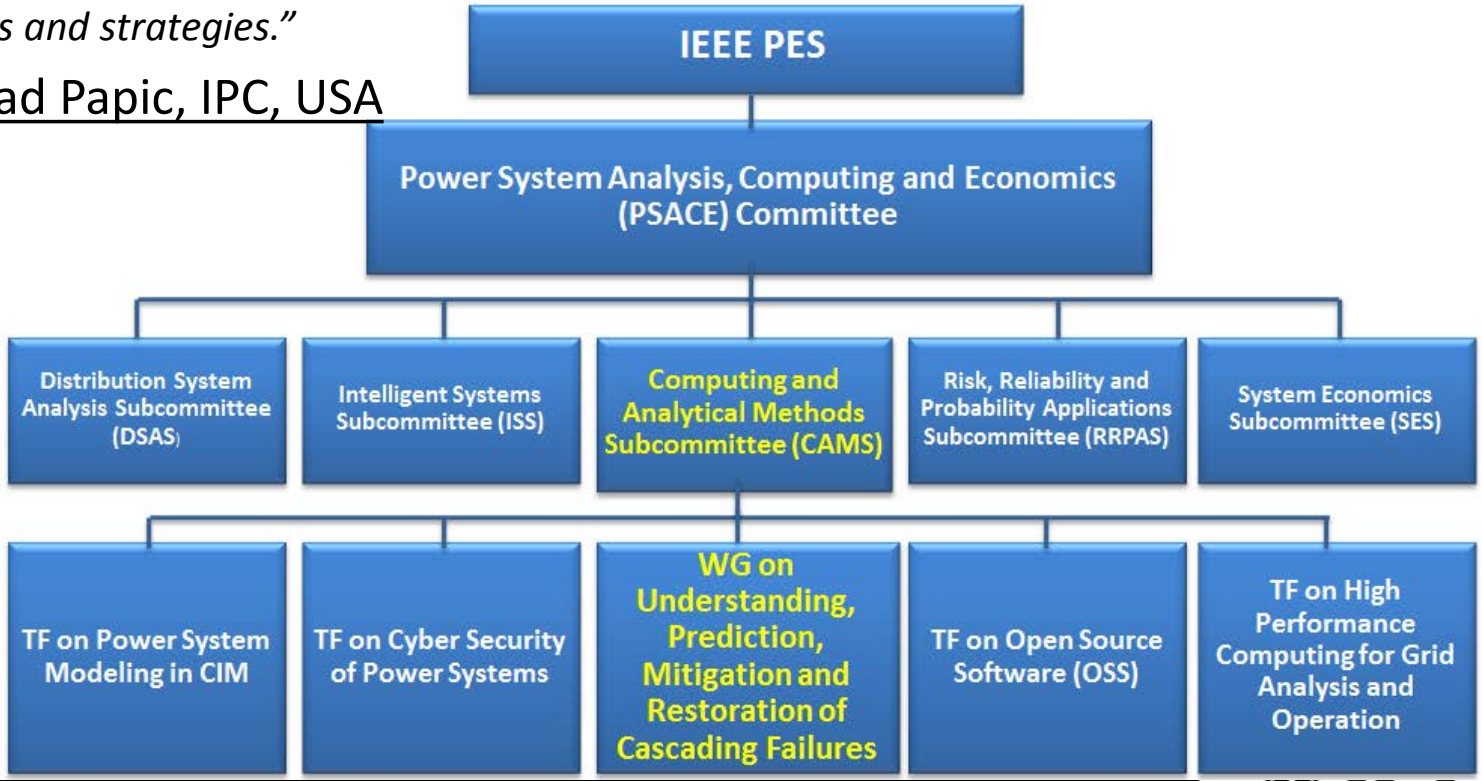
NASPI Meeting · October 23, 2014

Houston, TX

IEEE CAMS WG on Cascading Failures

- Initiated during 2007 IEEE PES GM:
  - *"To investigate new methods, technologies and tools in order to better understand, predict, mitigate and restore cascading failures. Sponsor technical sessions, tutorial courses, workshops, conferences for effective exchange of information on the state-of-the art, best practices, procedures and strategies."*
- Chair: Milorad Papic, IPC, USA

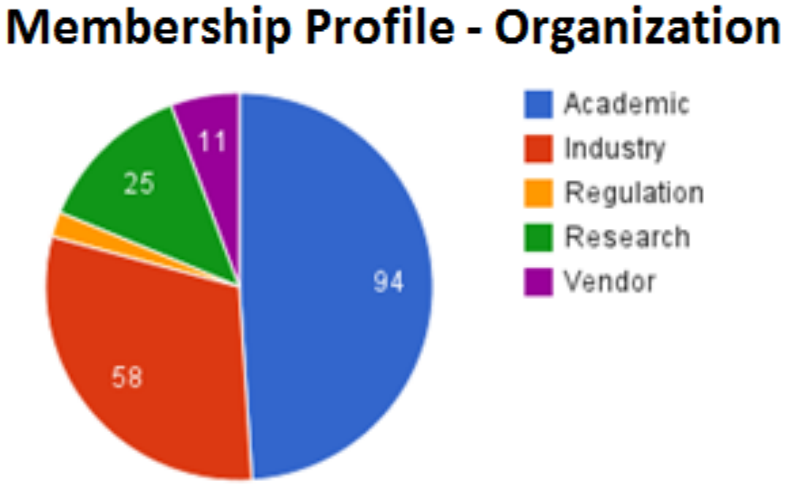


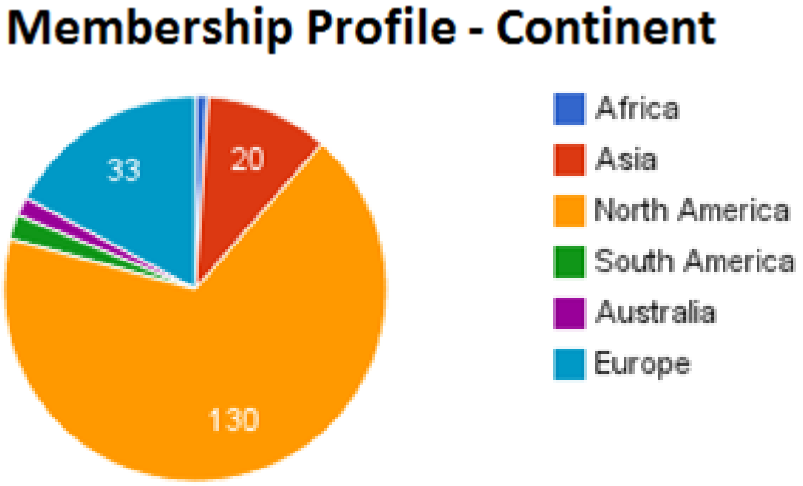
IEEE CAMS WG on Cascading Failures – Drivers and Purpose

- Drivers:
  - Blackouts
  - NERC Standards
  - Limited commercially available Tools
- The purpose of WG is to facilitate the following activities:
  - Understanding of Cascading Failures
  - Prediction of Cascading Failures
  - Mitigation of Cascading Failures
  - Restoration from Cascading Failures
  - Availability of Tools for Analysis of Cascading Failures
  - Availability of Data for Analysis of Cascading Failures

CFWG – 2014

- 192 members:
  - Industry 58 30%
  - Academic 94 49%
  - Regulation 4 2%
  - Research 25 13%
  - Vendors 11 6%





WG Current Activities

- Restoration from cascading failures
  - The objective is to review the state-of-the-art techniques and industry practice in power system restoration:
    - Analytical models and algorithms
    - Industry decision-support tools, strategy, practice
- Industry survey on practices for analysis of cascading outages

2014 Survey on Cascading Analysis

Multiple choice questionnaire:

1. How often is the analysis of cascading outages performed in your organization?
2. In which domain does your company study cascading events?
3. What are the main objectives in performing cascading outages analysis in your organization?
4. Is cascading outages analysis an automated process?
5. Do you analyze cascading outages using steady-state analysis tools?
6. Do you analyze cascading outages using dynamics?
7. Do you apply mitigation measures to alleviate consequences of cascading outages?
8. Is determining mitigation measures to alleviate consequences of cascading outages an automated process?
9. Do you use synchrophasor data for prediction and analysis of system blackouts/cascading outages?

WG Planned Activities

- Tutorial "**Understanding Cascading Phenomenon: Methodologies and Industry Practice for Analysis of Cascading Failures**"
  - Submitted for 2015 IEEE PES GM
- Panel Session "**Cascading Failures: Advanced Methodologies, Restoration and Industry Perspectives**"
  - Submitted for 2015 IEEE PES GM
- 2015 WG Annual meeting
  - At 2015 IEEE PES GM

2015 CFWG Tutorial

- First IEEE tutorial dedicated to cascading:
  - Full day (8-hour) tutorial

Summary of Topics	Panelists *(in the order of appearance)*
1. Overview of Cascading Outages Phenomenon	Ian Dobson, Iowa State University Vladimir Terzija, University of Manchester
2. Framework for Analysis of Cascading Outages	Mladen Kezunovic, Texas A&M University Paul Hines, University of Vermont
3. Current Tools and Emerging Technologies for Prediction and Detection of Cascading Outages	Frank Ashrafi, Southern California Edison Vahid Madani, Pacific Gas & Electric/ Damir Novosel, Quanta Technology
4. Current Tools and Emerging Technologies for Prevention and Mitigation of Cascading Outages	Marianna Vaiman, V&R Energy Vahid Madani, Pacific Gas & Electric/ Damir Novosel, Quanta Technology
5. Industry Experience in the Analysis of Cascading Outages	Milorad Papic, Idaho Power Company Ryan Quint, Dominion Virginia Power Dede Subakti, California ISO Eugene Litvinov, ISO New England
6. Restoration from Cascading Failures	Vijay Vittal, Arizona State University Michael Forte, Con Edison of New York
7. Analysis of Past Blackouts Caused by Cascading Outages: Lessons Learned	Bob Cummings, NERC Brett Wangen, Peak Reliability

2015 CFWG Panel Session

- The goal is to share latest methods in the areas of analysis, mitigation and prevention of cascades.
- Addresses the following aspects:
  - Industry perspectives and standards that deal with evaluation, mitigation and preventive actions for cascading failure events.
  - Power system restoration following an extreme cascading outage event
- Brings some main contributors from different countries together.

Definition of a Cascading Outage

- A cascading outage is a sequence of events in which an initial disturbance, or a set of disturbances, triggers a sequence of one or more dependent component outages:
  - In some cases they halt before the sequence results in the interruption of electricity service
  - In many case, cascading outages have resulted in massive disruptions to electricity service:
    - Northeast blackouts in 1965 and 2003, New York City blackout in 1977, two WECC blackouts in 1996, Brazil blackout in 2009, WECC blackout in 2011, etc.

Propagation of Cascading Outages

- Initiating events may include a wide variety of disturbances such as:
  - High winds
  - Lightning
  - Natural disasters
  - Contact between conductors and vegetation
  - Human error, etc.
- Many mechanisms cause subsequent outages can propagate beyond the initial outages
- Over 50% of blackouts involved many cascading elements and were “slow” in progression

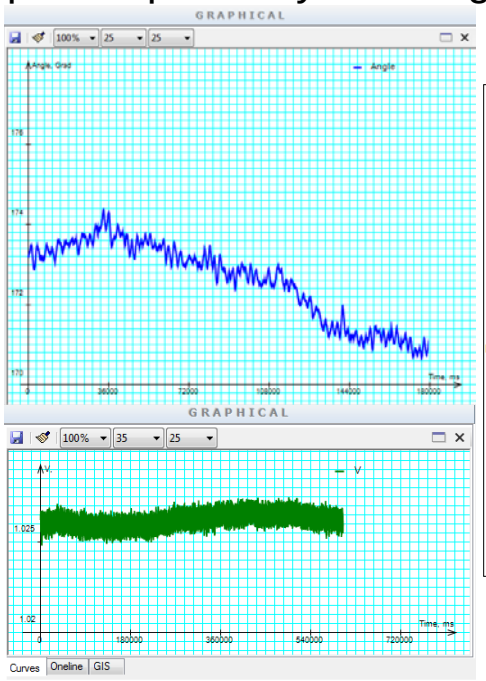
Why PMUs??

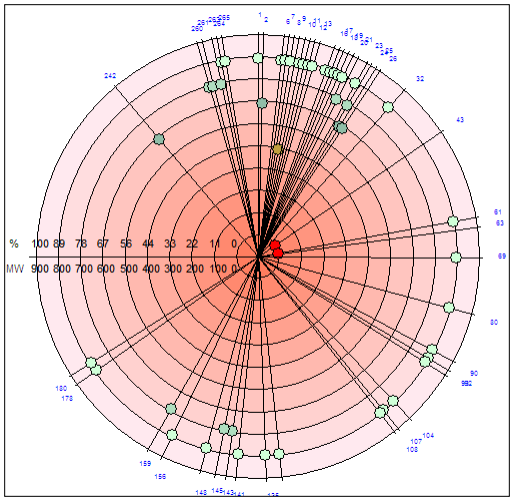
- PMUs are used for Wide Area Measurement Systems
- Functionalities to predict cascading outages include:
  - Early detection of events
    - Variations of reactive/active injections
    - Complements the information coming from breaker status signals
  - Voltage stability analysis on interfaces/corridors
    - Uses the V, I measurements at both ends of one line corridor and the maximum power transfer computation
    - Provides the voltage stability margin with respect to maximum transfer condition
  - Phase Angle Monitoring
    - Monitors high angle displacements, to detect highly loaded lines
  - Oscillatory analysis
    - Predicts unstable oscillations which may trigger line trippings

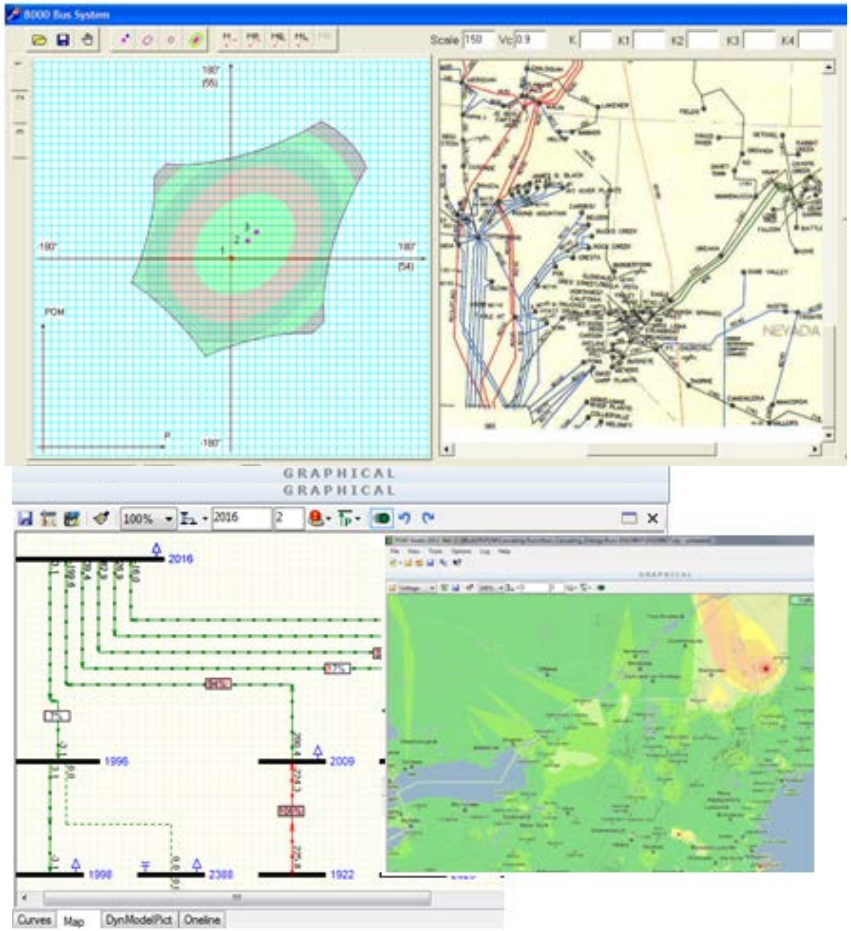
PMU Applications for Cascading Prediction: the US Experience

Phase angle and voltage monitoring

Using PMU measurements to compute system steady-state stability limits and predict proximity to voltage collapse







Source: M.Ya. Vaiman, M.M. Vaiman, S. Maslennikov, E. Litvinov, X. Luo, "Calculation and Visualization of a Power System Stability Margin Based on the PMU Measurements", 2010 IEEE SmartGridComm:31 - 36

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Use of PMUs for Analysis of Cascading Outages

- Prediction of “slow” cascading outages:
  - These cascades may be analyzed from steady-state stability perspective
- The most sensitive phase angles are identified in real-time for each scenario/interface/corridor:
  - These quantities are monitored, reported and visualized
  - May change over time as the system conditions change
- The accuracy of the limit values computed off-line may be improved by using real-time PMU measurements
  - These values are adjusted dynamically

Use of PMUs for Fast Identification/Prevention of Cascades

- PMU measurements allow for faster and more accurate relay operation and enabling ***RAS***
- Wide area oscillation ***damping control***
- Advanced defense functions, like ***coordinated*** wide area ***load shedding*** actions, ***controlled islanding***, etc
- No consolidated solutions so far

IEEE Papers Published by the WG

- Conference papers:
  - Mitigation and Prevention of Cascading Outages: Methodologies and Practical Applications, 10.1109/PESMG.2013.6672795, PES GM 2013 GM
  - 2011GM0847 Risk Assessment of Cascading Outages: Part I - Overview of Methodologies, PES GM 2011.
  - 2011GM0803 Risk Assessment of Cascading Outages: Part II - Survey of Tools, PES GM 2011.
  - Vulnerability Assessment for Predicting Cascading Failures in Electric Power Transmission Systems, PES PSCE 2009.
  - Initial review of methods for cascading failure analysis in electric power transmission systems, PES GM 2008.
- IEEE Transactions on Power Systems:
  - Risk Assessment of Cascading Outages: Methodologies and Challenges, May 2012, Vol. 27, No. 2 pp. 631-641

Conclusion

- If you receive an email from the Working Group with survey questions, please do NOT DELETE it!
  - Just respond to our questions
- Next WG meeting is during 2015 PES GM:
  - Please come and join us for a discussion on the phenomenon of cascading failures and use of PMUs to predict, prevent and analyze cascades.

Thank you!