# IEEE Cascading Failures Working Group (CFWG)

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

IEEE PES Computer and Analytical Methods Subcommittee (CAMS)

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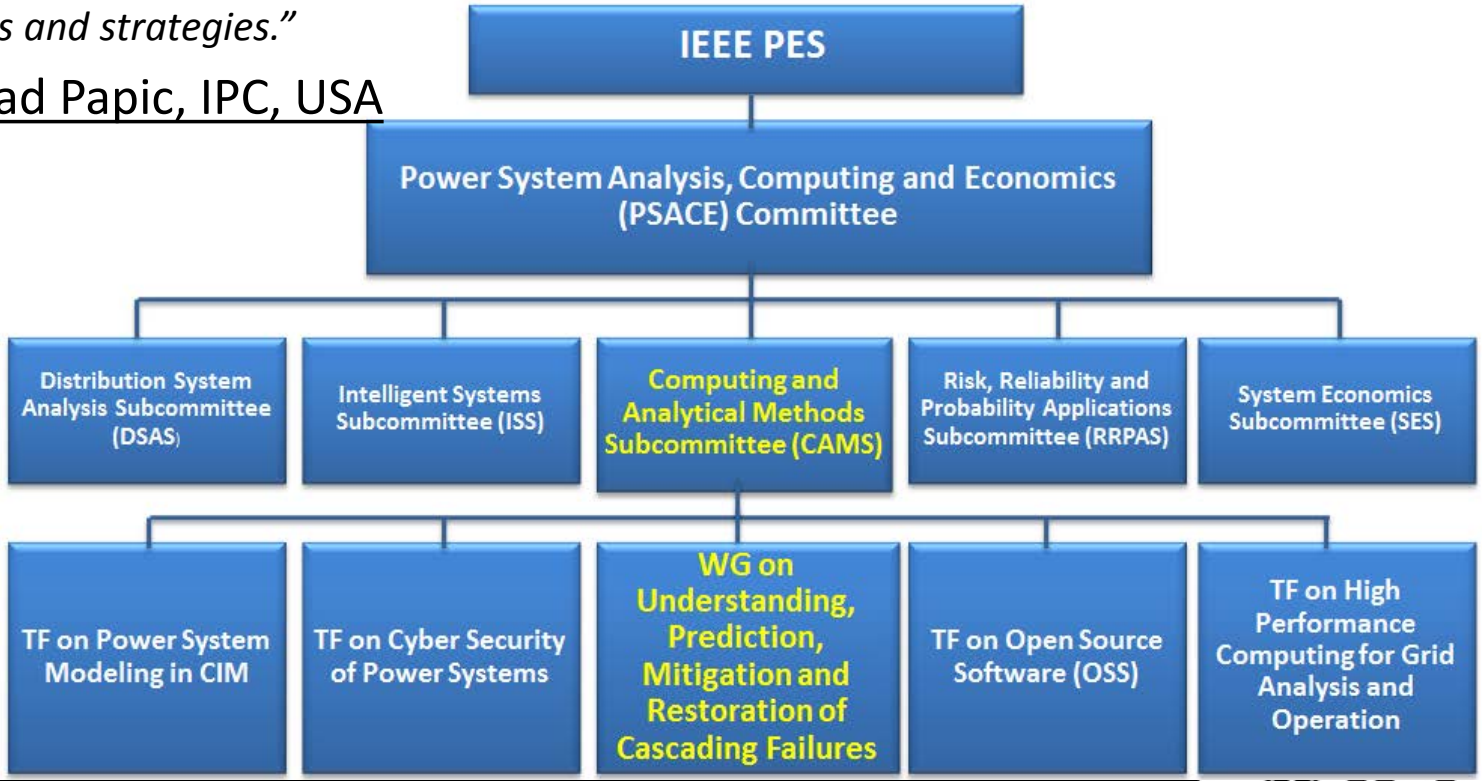
# IEEE CAMS WG on Cascading Failures

- 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

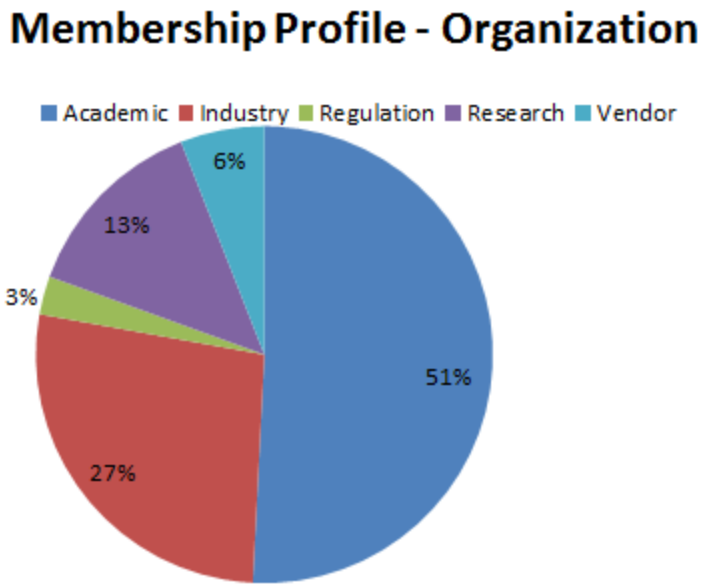


# IEEE CAMS WG on Cascading Failures – Drivers and Purpose

- 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 – Then (2013) and Now (2014)

- 2013
  - 95 members:
    - Industry 29
    - Academic 44
    - National Labs 7
    - NERC 2
    - Vendors 7
    - EPRI 2
    - International industry members 4
- 2014
  - 185 members:
    - Industry 50
    - Academic 94
    - Regulation 5
    - Research 25
    - Vendors 11



# WG Success Stories

- Task Force was elevated to the status of the Working Group
- WG organized a Panel Session during 2013 PES GM
- Completed Tasks:
  - Task 1: Initial Review of methods for cascading analysis in electric power transmission systems, IEEE PES GM, Pittsburg, July 2008
  - Task 2: Vulnerability Assessment for Cascading Failures in Electric Power Systems, IEEE PSCE, Seattle, March 2009
  - Task 3: Risk Assessment Methodologies for Cascading Outages, IEEE PES GM, Detroit, July 2011
  - Task 4: Survey of Tools for Risk Assessment of Cascading Outages, IEEE PES GM, Detroit, July 2011
  - Task 5: Benchmarking of methodologies and tools for assessment of cascading outages, IEEE PES GM, San Diego, July 2012
  - Task 6: Mitigation and prevention of cascading outages; IEEE PES GM, Vancouver, July 2013

# Panel Session at PES GM 2013

- **Mitigation and Prevention of Cascading Outages: Methodologies and Practical Applications**
  - Milorad Papic (Idaho Power) and Robert Cummings (NERC) “Ex-post analysis of the blackout on 8 September 2011 in the US Southwest”
  - Anish Gaikwad (EPRI) and Sudhir Agarwal (General Reliability), “Ex-post analysis of the blackouts on 30 and 31 July 2012 in India”
  - Vladimir Terzija (The University of Manchester) “Ex-post analysis of the blackout on 4 November 2006 in Europe”
  - Jorge Jardim (HPPA, Brazil) “Ex-post analysis of the blackout on October 26 2012 in Brazil”
  - Dmitry Kosterev, Eric Heredia, Ryan Quint (BPA), “Wide-Area Measurements in Prevention of Cascading Outages”
  - Marianna Vaiman (V&R Energy) on behalf of the CFWG, “Mitigation and Prevention of Cascading Outages: Methodologies and Practical Applications”
  - Stephan Miller (CAI Inc.), “Benchmarking models and data for cascading failure analysis”
  - Janusz Bialek (Durham University, UK), “Preventing Cascading Outages by Islanding”
  - Ian Dobson (Iowa State University), “Emerging approaches for simulating and analyzing cascading outages”
  - Paul Hines (University of Vermont), “Using Random Chemistry and Influence Graphs to Estimate Cascading Blackout Risk”

# WG Current and Future Tasks

- Present tasks:
  - Benchmarking models and available data for cascading failure analysis
    - Writing a WG paper
  - 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
- Future task:
  - Standards development
  - Use of the new technologies (such as synchrophasors) for analysis of cascading outages

# 2014 Survey on Analysis of Cascading Outages: Draft

- 1. Does your Company regularly perform studies evaluating performance of your system under extreme contingency events of NERC category D or other cascading outages? If the answer is “yes”, how often?
- 2. What simulation/analysis tool do you use for the studies mentioned in 1?
- 3. How many and what types of extreme contingency events do you consider in your studies?
- 4. How do you create the list of extreme events for the studies (manually or automatically)?
- 5. What types of security violations do you monitor under extreme events? Which one does your company consider to be the most important violation?
- 6. In which domain does your company study cascading events (planning, operation, real-time)?
- 7. Do you apply some mitigation measures to alleviate problems resulted from extreme events/cascading? (If Yes, please list them).

# 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

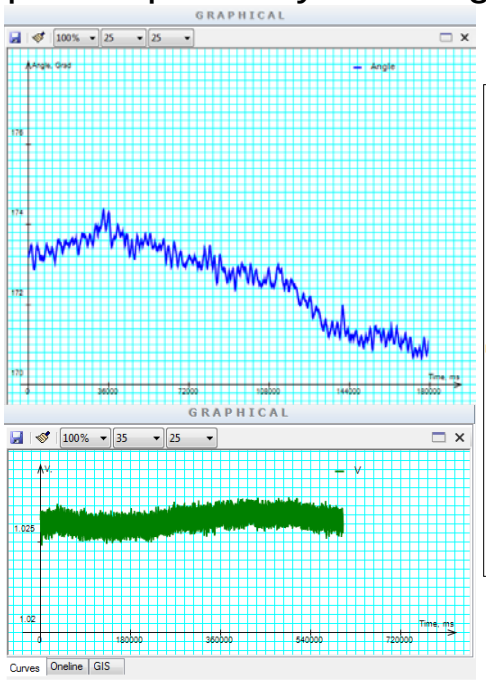
# Why PMUs??

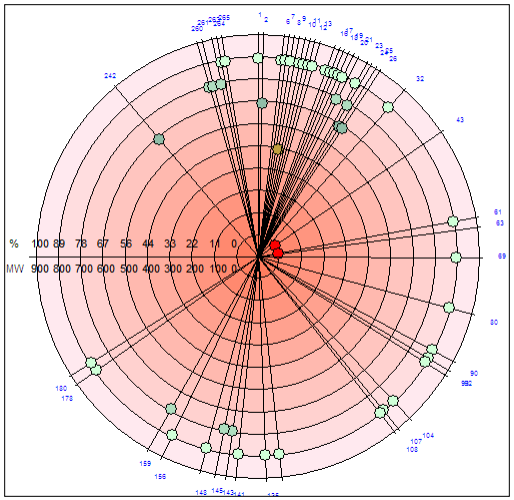
- PMUs are used for Wide Area Measurement Systems
- Functionalities to predict cascading outages include:
  - Early detection of events
    - Variations of reactive/active injections
    - Complements the information coming from breaker status signals
  - Voltage stability analysis on interfaces/corridors
    - 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

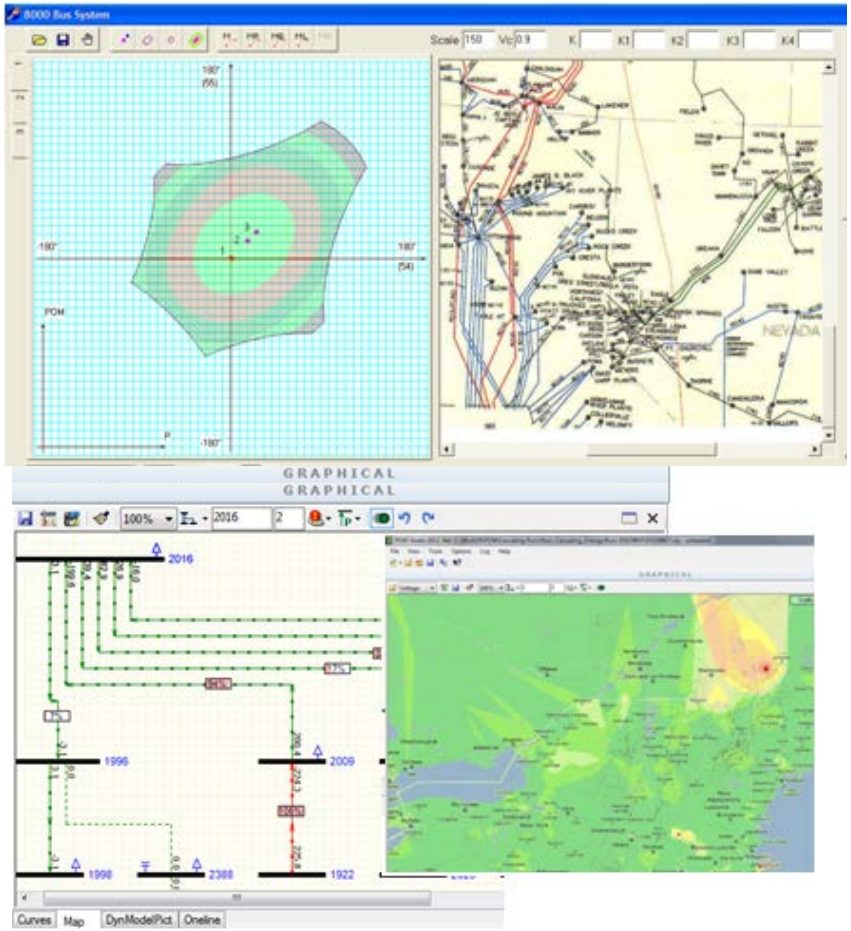
# PMU Applications for Cascading Prediction: the US Experience

***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:
  - Initial review of methods for cascading failure analysis in electric power transmission systems, PES GM 2008.
  - Vulnerability Assessment for Predicting Cascading Failures in Electric Power Transmission Systems, PES GM 2009.
  - 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.
  - Mitigation and Prevention of Cascading Outages: Methodologies and Practical Applications, 10.1109/PESMG.2013.6672795, PES GM 2013 GM
- 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 2014 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!