Techniques to Support Next-Generation of Synchrophasor Technology Applications

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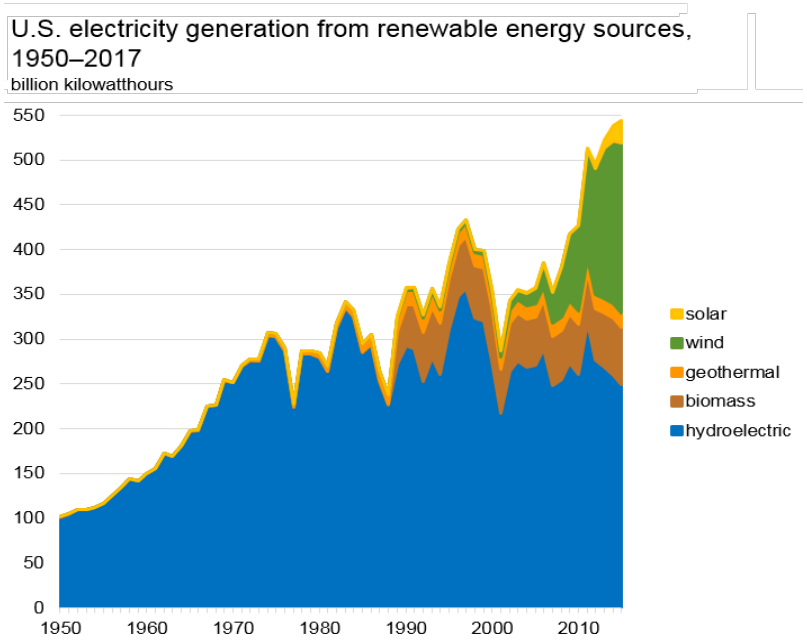
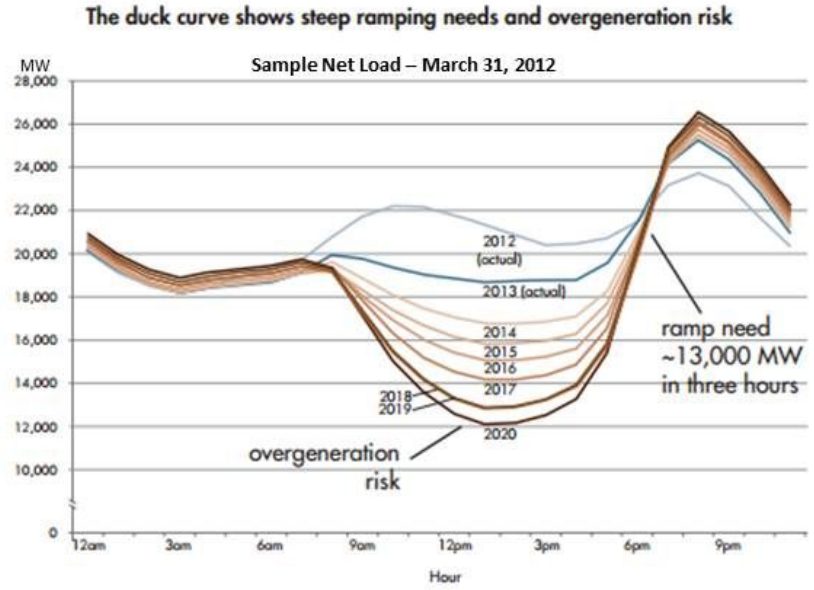
April 16, 2019

Evolving Grid – Evolving World





(from the California Independent System Operator)

PMUs – A Window to the Future

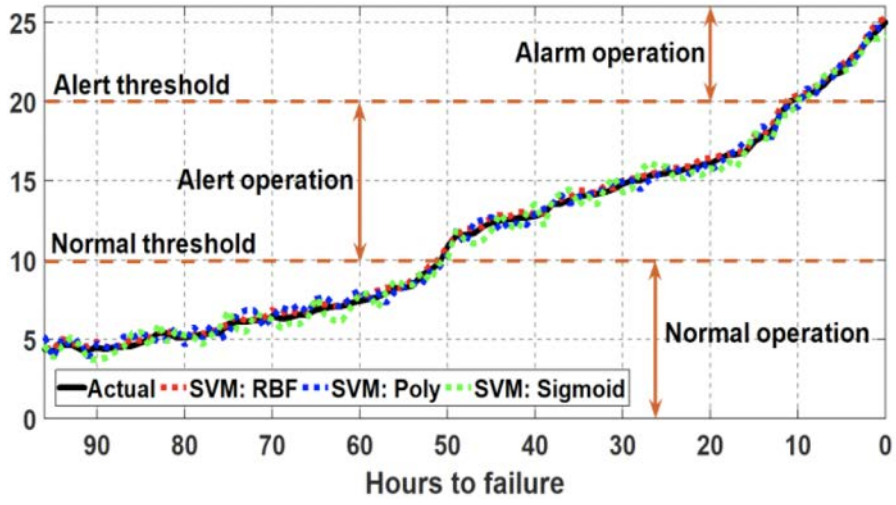
- PMUs provide insight into what is coming[1]:
  - Real-Time Capabilities
    - Situational awareness
    - Equipment problem detection
  - Study-Mode Capabilities
    - Model validation
    - Renewable resource integration

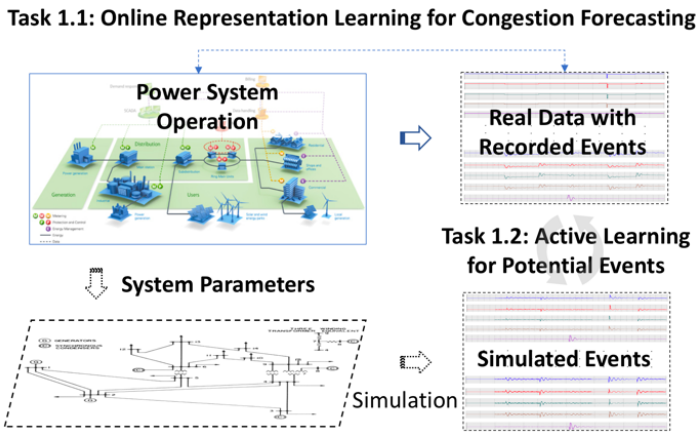
- Synchrophasor infrastructure must NOT be taken for granted:
  - Understand the information that is conveyed through the measurements
  - Perform periodic maintenance (calibration) of the associated equipment

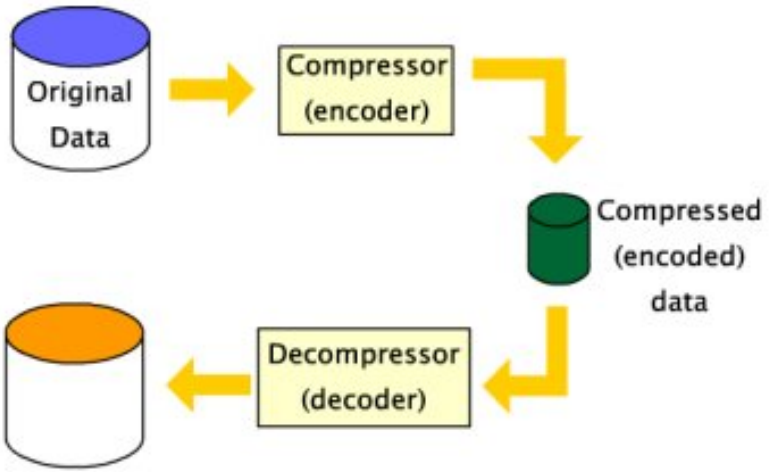
1. U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, "Advancement of Synchrophasor Technology", Mar. 2016. [Online]. Available: https://www.smartgrid.gov/files/20160320_Synchrophasor_Report.pdf

Machine Learning – Best Bang for Your Buck

- Translate raw data into actionable information:
  - Equipment Malfunction Identification through Signature Analysis and Transfer Learning (TL)
  - Intelligent Compression Techniques for Real-time Data Sharing as well as Data Storage
  - Contingency Forecasting using Online Dictionary Learning (ODL) and Active Learning (AL)

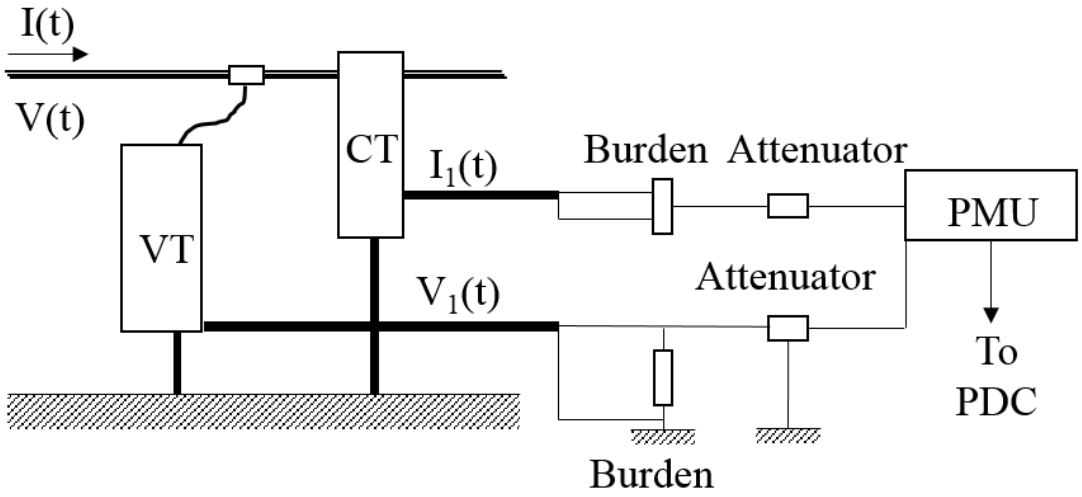


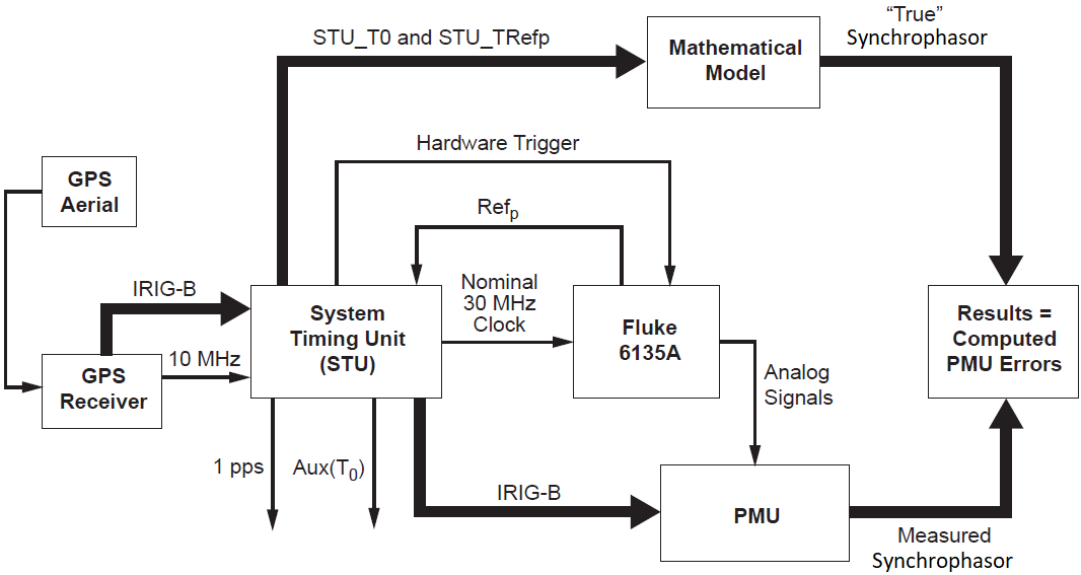




Periodic Calibration is Necessary

- **Goal:** Prevent degradation of PMU output with time and in presence of realistic errors
- Typical errors found in PMU Measurements:
  - Device error
  - Instrumentation error
- Existing PMU calibration systems can successfully calibrate PMU devices
- Instrumentation error is a function of age and system loading and is an active area of research[2]

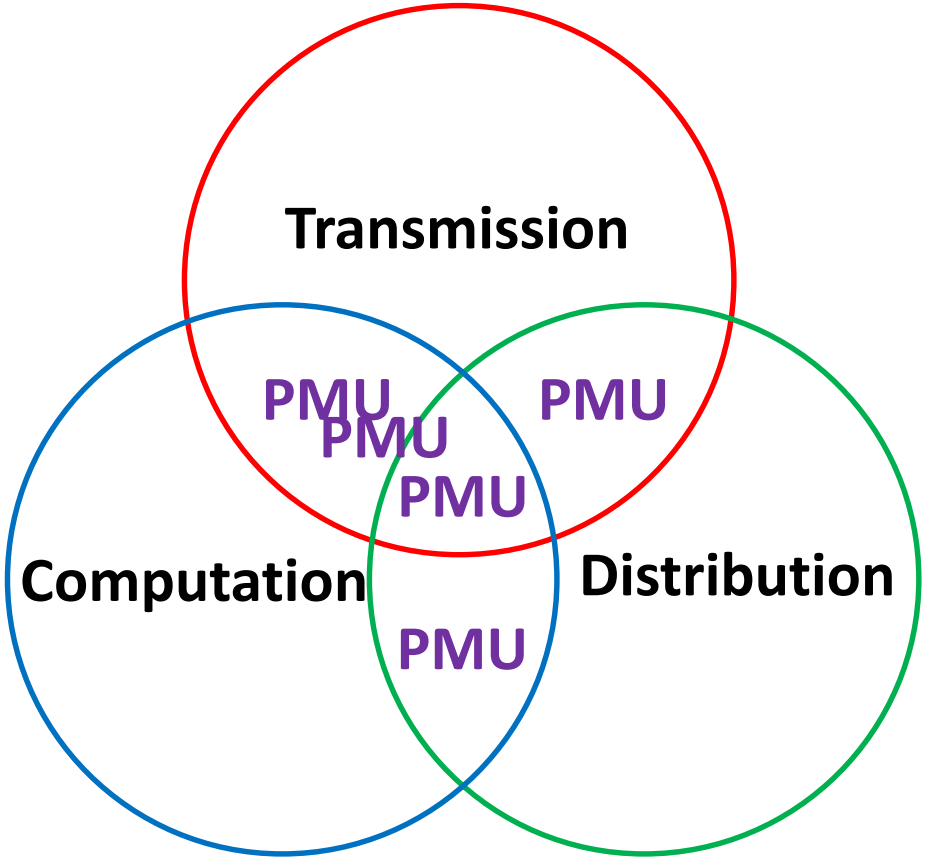




2. P. Chatterjee, A. Pal, J. S. Thorp, J. De La Ree, and V. A. Centeno, "Error reduction of phasor measurement unit (PMU) data considering practical constraints," *IET Gener., Transm. Distrib.*, vol. 12, no. 10, pp. 2332-2339, May 2018.

Evolution of Synchrophasor Analytics

- Transmission Related:
  - Three-phase linear state estimator (LSE) for 500kV network of Dominion Energy
  - Software developed by EPG (RTDMS, PGDA, …)
- Computation Related:
  - Synchrophasor solutions for the full transmission system
  - The PingThings Approach (High Performance Sandbox[3])
- Distribution Related:
  - Event localization
  - Anomaly detection
  - Distribution system LSE
  - Bad data detection/correction



3. K. D. Jones, and S. Murphy, "The role of a high performance sandbox in your synchrophasor analytics pipeline," NASPI, Albuquerque, NM, April 2018. URL: https://www.naspi.org/sites/default/files/2018-05/02_Jones_Murphy_TheRole_20180424.pdf

The Way Forward …

- Synchrophasor technology is here to stay and grow …
- There is NO "one size-fits all" solution with regards to data analytics for synchrophasor technology …
- Continued interest and support is CRITICAL!!!