NASPI White Paper: Integrating Synchrophasor Technology into Power System Protection Applications Update Report

Task Force on Synchrophasor Protection Applications
NASPI Engineering Analysis Task Team

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Task Force Purpose

- Formulate a NASPI position on the future of synchrophasors in Power System Protection
  - Comprehensive look at protection applications and utilization of synchrophasors for each
  - Perspective and framework for the utilization of synchrophasors for protection
- Develop a venue to showcase utility uses and expectations for synchrophasors in power systems.

Task Force Efforts

- Task Force on Synchrophasor Protection Applications formed at the March 2015 WG meeting.
- Volunteers from utility, vendor and research communities have provided invaluable contributions to this effort.
- Position Paper
  - Research applications of synchrophasors for protection systems
  - Identify obstacles for the proliferation of synchrophasor technology
- Industry Survey
  - Utility – Current applications and future expectations
  - Vendor – What services are offered now and in the future
  - R&D – Current research into new applications

Position Paper Status

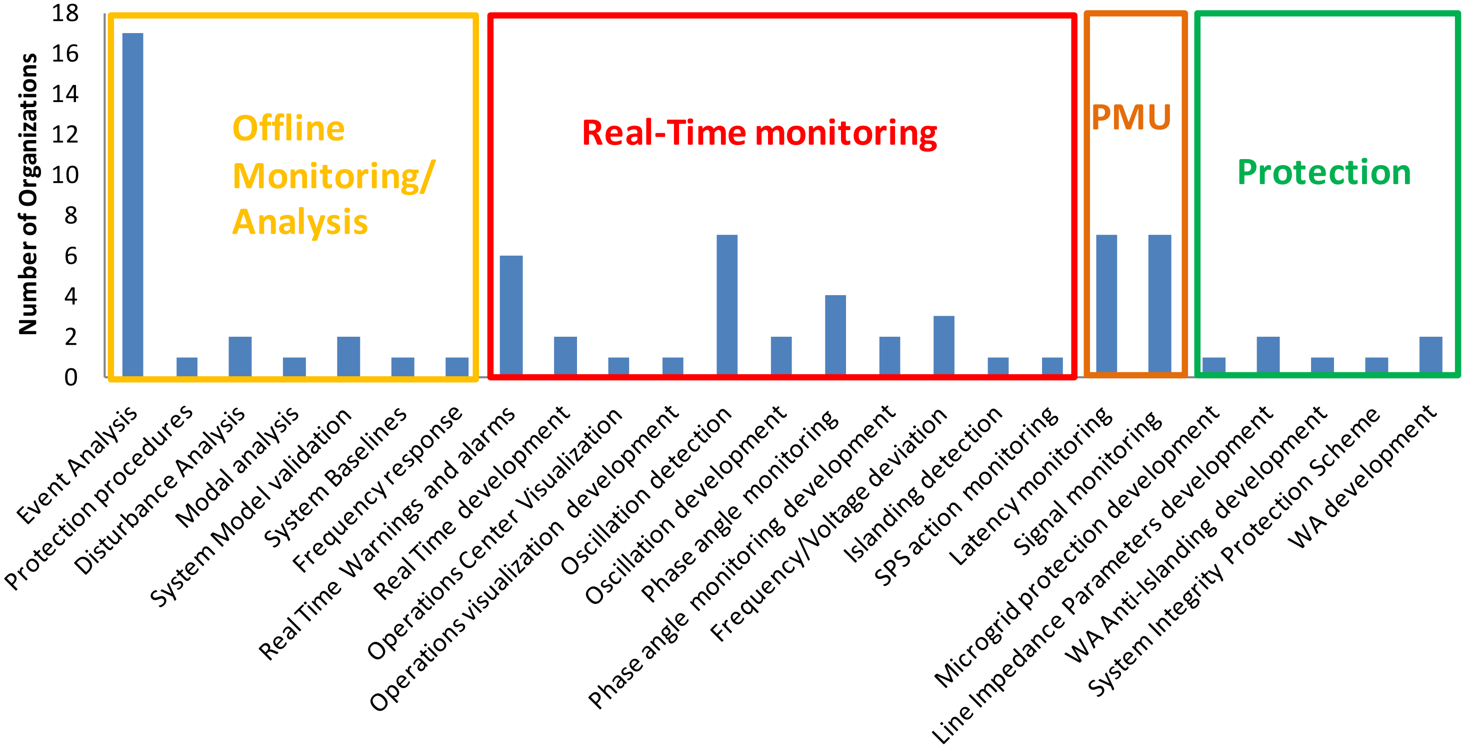
- Finalizing and consolidating NASPI protection synchrophasor positions into an overall mission statement.
- Preparing paper for internal NASPI review and comments.
- Final paper expected by October 2016 WG meeting

Survey

- Purpose: Pulse the industry on current utilization, obstacles, and expectations for synchrophasors applied to protection systems
- Utility survey scope
  - Those surveyed were asked to categorize their uses of Synchrophasor and their expectations for Synchrophasor protection applications
- R&D survey scope
  - Those surveyed were asked to categorize their synchrophasor application projects with the associated TRL level and their plans for the future
- Vendor survey scope
  - Those surveyed were asked to describe their synchrophasor product integration, addressing of latency and cyber security, and present and future synchrophasor applications.

Utility Survey Results

- Utility Current Synchrophasor Practices



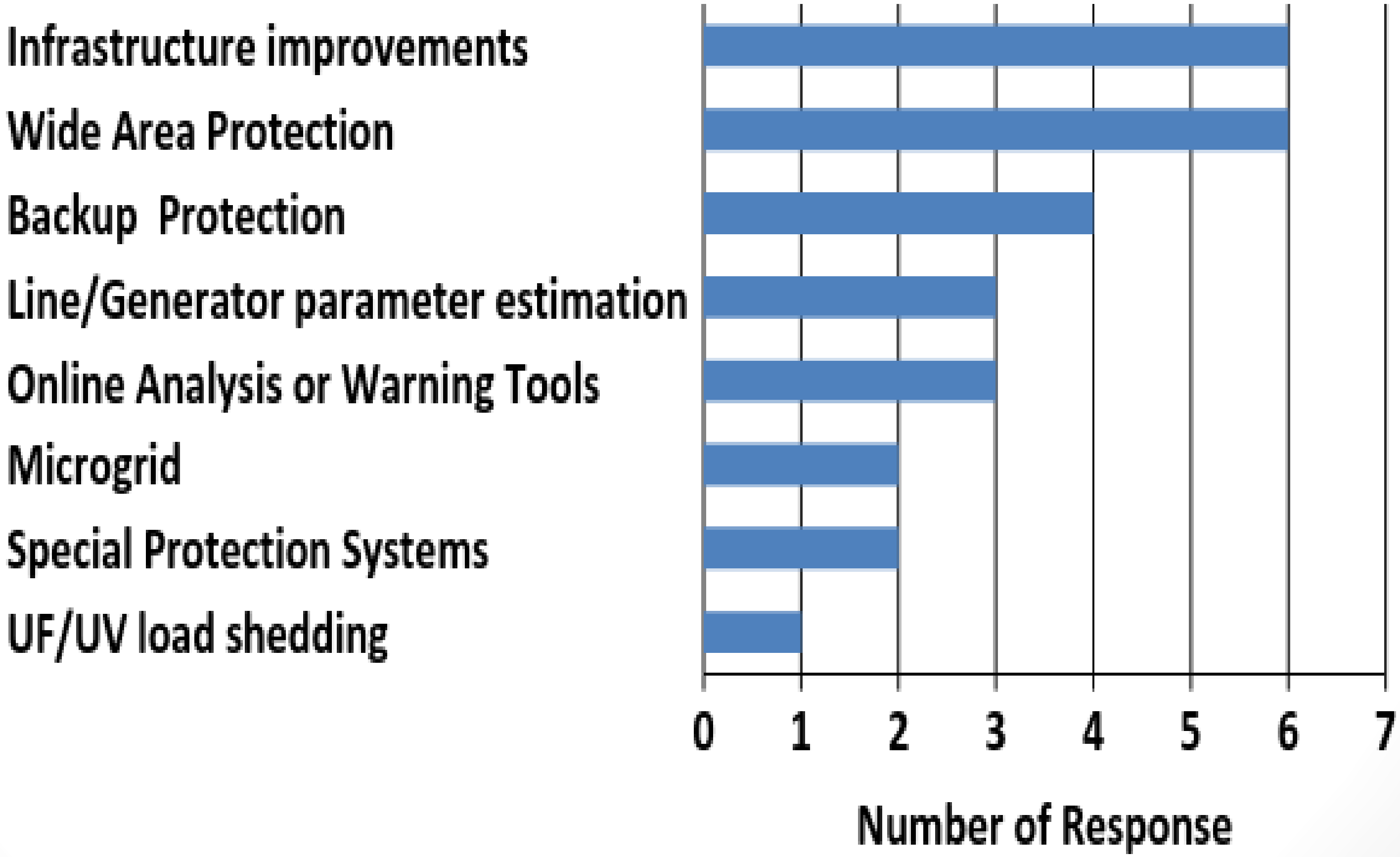
Utility Survey Results

Protection related synchrophasor applications in development

- **System Configuration Protection** - Using PMUs to determine control room actions to prevent system problems before they become too severe such as islanding detection, microgrid control, generator anti-islanding schemes.
- **Transmission Line Parameter Evaluation** - The effort to determine more accurate live line transmission line impedances using synchrophasor data. One utility stated that they are "[e]valuating [the] use of synchrophasors to calculate/measure transmission line impedances for improved line impedance values."
- **Safety Net Protection** - The live monitoring/adjustment of protection schemes. One international utility is currently using synchrophasors to monitor RAS action for correct operation, appropriate speed of operation and the need for delayed action due to system dynamics. Other utilities are also exploring synchrophasor based RAS controls for near term deployment.

Utility Survey Results

- Utility expectations for Synchrophasors

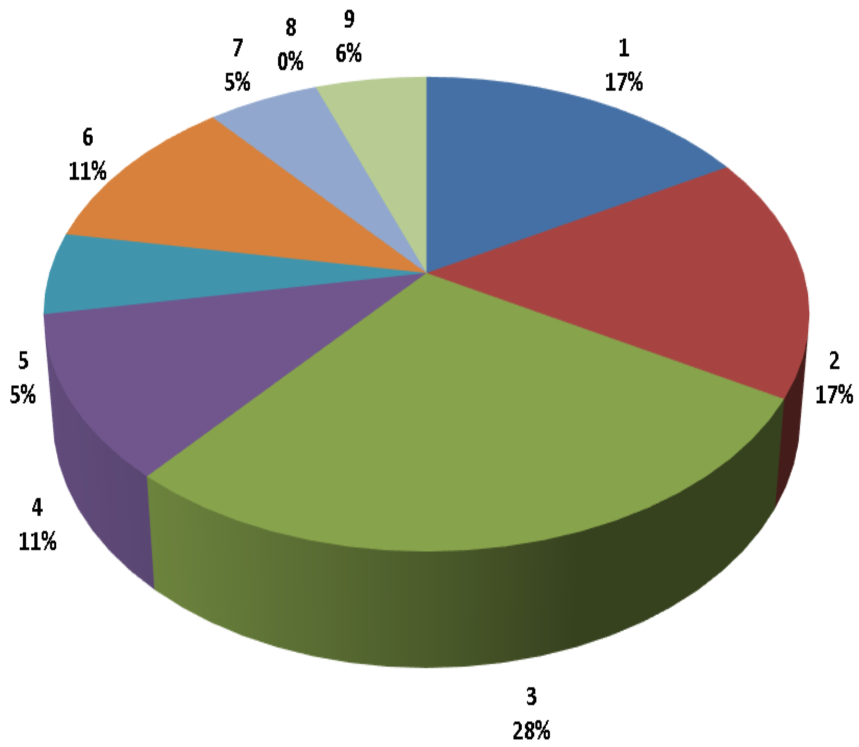


R&D Survey

- 19 Synchrophasor Protection related research projects were rated based on Technology Readiness Level table

Innovation Phase – 50%
TRL 1: Basic Research – 16%
TRL 2: Applied Research – 17%
TRL 3: Critical Function or Proof of Concept Established – 28%

Examples of Innovation Stage Research:
-Wide Area Protection
-Transmission Line Impedance Estimation
-Remedial Action Schemes
-Signal Security
-Time Synchronization Vulnerability



Source:
http://www.bpa.gov/Doing%20Business/TechnologyInnovation/Documents/2014/Collaborative-Transmission-Technology-Roadmap-March-2014.pdf

Vendor Survey

- Industry vendors responded that devices for PMU measurement, PDCs and stand-alone platforms are currently on the market that can perform synchrophasor data processing inclusive of calculations and data stream analytics and control algorithms.

- Vendors believe synchrophasors can be applied today in applications ranging from wide area protection to backup line protection. Also, system models can currently be improved using synchrophasors which can improve protection system design.

- Vendors see the future of synchrophasor protection falling under the development of new RAS and safety net schemes, out-of-step protection, distributed microgrids, backup to existing classical protection schemes and proactive rather than reactive RAS.

Protection Application NASPI Positions

- The EATT Synchrophasor Protection Task Force has selected the following protection applications to develop a NASPI position. These represent the most widely used protective relaying applications.
  - **Distance Protection**
  - **Differential Protection**
  - **Transmission Line Impedance Estimation**
  - **Transfer Trip Protection**
  - **Subsynchronous Resonance (SSR) and Control Interaction (SSCE) Protection**
  - **Oscillatory Stability Protection**
  - **Microgrid Protection**
  - *Out of Step Protection*
    - *Generator Out of Step Tripping (In Development)*
    - *Transmission Line Out of Step Blocking (In Development)*
  - *Wide Area Protection Schemes (In Development)*
    - *Remedial Action Schemes*
    - *Generation Shedding*
    - *Load Shedding*
  - **Protection Related Power System Monitoring**
    - **Delayed Voltage Recovery Monitoring and Protection**
    - **Generation Synchronization Monitoring**

NASPI Positions

- Distance Relaying

The present deployment of PMU technology today does report phasor data at rates sufficient for coordinated backup line distance protection. The phasor calculation latency for protection rated PMUs is shorter than the delayed pickup durations of typical zone 3 distance protection configurations.

- Differential Protection

The current deployment of PMU technology today does not report phasor data at rates sufficient for primary line differential protection. The time window required for the PMU to estimate a phasor value also adds to the latency in the differential calculation, posing a major challenge for this application. In addition, PMU-to-PMU communication is a relatively new concept although achievable.

NASPI Positions

- Transfer Trip Schemes

PMU digital signal communication between substations is achievable using existing synchrophasor technology. Signal latency is a significant obstacle for high speed transfer tripping, such as breaker failure protection. Wide area protection schemes such as RAS may have sufficient latency requirements to utilize synchrophasor transfer tripping.

- Transmission Line Impedance Estimation

The estimated impedance values using PMU data has shown to improve fault location practices over conventional impedance values monitored or estimated. This application of PMUs plays into all network models developed for protection, planning, and operation of the bulk power system, and can provide improved models for system studies. Line parameter estimation should be explored by utilities with double-ended PMU coverage for transmission circuits.

NASPI Positions

- Subsynchronous Resonance (SSR) and Control Interaction (SSCI)

Subsynchronous resonance and subsynchronous control interaction frequencies tend to range from 15-30 Hz. Particularly at higher frequencies, anti-aliasing and PMU filtering become a significant concern. PMUs reporting at 30 frames per second will not suffice for this application and PMUs reporting at 60 frames per second will either risk attenuating the signal or passing higher frequency content through, resulting in bad data. PMUs with a sharp roll-off of frequency response that filter out frequencies past the Nyquist rate are required for SSR applications. Higher reporting rates such as 120 frames per second can help in overcoming these issues and should be considered for SSR and SSCI applications. It appears that PMU technology at these reporting rates may be sufficient for subsynchronous oscillation monitoring, detection, and control.

NASPI Positions

- Oscillation Stability Protection

Oscillation frequencies for local and inter-area oscillations are relatively low (< 5 Hz) and accurately measurable by PMUs reporting at 30 or 60 samples per second. Furthermore, undamped growing oscillations either in a pre-contingency or post-contingency condition have been proved in actual systems to be detectable with PMUs. Marginally damped or slightly negatively damped oscillations will manifest over a relatively long period of time. This allows for automated controls or even system operators to take action upon robust detection of the unstable oscillations occurring. It is apparent that this is system dependent but also that PMUs may be a cheap and sustainable tool for remedial actions to mitigate these instabilities.

NASPI Positions

- Microgrid Protection

PMU technology has potential for providing automated controls and RAS action for microgrid control, particularly for islanding conditions. Higher-resolution, time-synchronized data from PMUs provides added benefits over RTU-based approaches. Issues around interoperability can be addressed moving forward. There are currently no major hurdles for continued exploration of PMUs in microgrid applications.

Synchrophasor Signal Latency

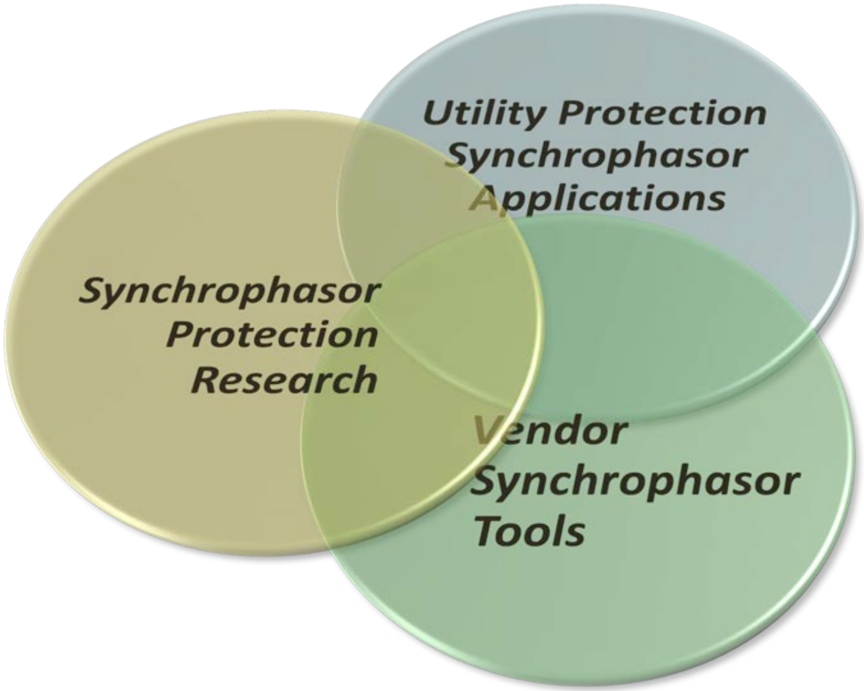
Synchrophasor Signal Latency

- Beyond the PMU reporting latency, minimizing the communication and signal processing delays of PMU data to achieve the smallest latency.
- **Architecture Optimization** – Methods to reduce signal communication latency.
  - Reduce the number of devices between PMU and control algorithm.
  - Algorithms to determine the best PMU signal path and PMU signals to transmit over each path.
  - Creation of protection control regions with the minimum number of PMUs to minimize latency.

Current SynchProt Landscape

Utility Synchrophasor Protection Applications

Future SynchProt Landscape



Next Steps

- Develop remaining protection application NASPI positions
- Formalize overall NASPI position and conclusions
- Release draft for external reviews and comments

Questions

- If you have any questions or would like to participate in this effort please contact:
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