NASPI North American SynchroPhasor Initiative

Synchrophasor Technology Roadmap
March 13, 2009

This technology roadmap represents the views of the Leadership Team of the North American SynchroPhasor Initiative (NASPI), a group of 20 utility, consulting, academic, government, vendor and other leaders working to advance the adoption of synchrophasor technology. This roadmap first articulates a vision of what the Leadership Team hopes to realize with phasor technology deployed on the bulk power system over the next decade. Next, it identifies a series of specific measures the NASPI team will undertake in the coming year to bring this vision to fruition. The roadmap does not address institutional issues (such as who will own phasor data processing and communications networks, or how they will be funded) because those issues require further consideration.

This roadmap is a draft and additional suggestions and input are welcome.

TECHNOLOGY ROADMAP

Phasor Measurement Units – The Leadership Team expects the range of PMUs installed and networked into an interconnection-wide phasor measurement system to be in the ranges below (the numbers in each date column represent the number of roadmapping participants believing that many PMUs will be installed and networked in the United States portion of that interconnection in that future year):

Interconnection	Number of PMUs	2014	2019
East	200-400	5	--
(today = 105)	400-600	8	2
	600-1,000	1	12
	> 1,000	--	2
West	200-400	4	--
(today = 56)	400-600	8	8
	600-1,000	1	8
	> 1,000	--	--

Additional PMUs (and devices performing phasor data collection functions) may be installed without being networked for real-time data delivery into a data processing system.

The number of PMUs deployed will depend on several factors:

- Whether the tools and data are recognized as providing value

- Learning how to do effective physical and cyber-security at reasonable cost, whether at the initial installation or how to integrate them inside the electronic security perimeter once the phasor applications become critical for control operations (when they are declared critical cyber assets)
- Whether regulators gain access to the data and use it to initiate investigations or inquiries
- Ease of implementation and integration into the communications and data systems; they should be plug & play and remotely configurable, under detailed interoperability specifications and protocols
- Deployment cost should be a minor issue for new facilities
- Whether reliability standards encourage or punish the use of PMUs and phasor data systems.
- To assure that PMUs once deployed will receive consistent support with O&M, communications links, and consistent data quality, there will need to be a committed owner (department) within each asset owner that recognizes the value of the PMU data feed and is willing to work to sustain it. The technology has to be integrated with utility processes.

Phasors will be deployed at the following locations in 2014:

- Major transmission interconnections and interfaces
- All 500kV and above substations and most 200 kV and above substations
- Key generating plants (all > 500 MW) in generator switchyards, even on some individual generators
- Major load centers
- Large wind generators, solar and storage locations
- Other locations to assure observability in areas with sparse PMU coverage

By 2019, remaining 200kV and above substations, in locations needed for local control actions, and even on the distribution network.

The following functionality will be built into PMUs in the future, with eventual convergence of functions across intelligent electronic devices:

- PMU and DFR capabilities merging for monitoring and visualization
- Remote addressability for firmware upgrades
- Plug-and-play interoperability (interoperability testing will be required to assure this)
- Automated grid control capabilities linked to relays
- Local data storage to hold 2 weeks or more of data
- Linkage to communications architecture to support a variety of applications
- Higher speed data collection and delivery into real-time analytical system supporting tiers of applications (monitoring and alarms, SCADA and state estimation backup and enhancement, automated operations and protection, automated disturbance reports)
- More efficient at processing and publishing compressed data
- Self-diagnosis and return coordinates response
- Dynamic performance and measurement subject to technical standards

- Fully CIP-compliant.

RESOURCE NEED -- The Performance Standards Task Team has been working to develop technical standards, a testing guide, and conformance testing (with recent work by NIST's DOE-funded synchrometrology lab), but additional work and resources are needed to pull all these technical standards together. IEEE is on schedule to adopt a standard for dynamic phasor measurement units in 2010. PSTT also needs support to write the tech specs for phasor and related data streams that reach across all devices and software to feed a variety of grid and analytical applications.

Phasor data concentrators – Local phasor data concentrators aggregate and time-align phasor data from multiple locations and feed the data to applications. Higher-level regional PDCs collect the data from multiple PDCs, conduct data quality checks, and feed the data to analytical applications. Higher level PDCs (such as the current SuperPDC and the NERC-TVA Phasor Concentration System (PCS) now under development) both aggregate and archive phasor data. By 2019 PDCs will be recognized as a function rather than as a stand-alone device or hardware-software package, and will be integrated into other systems and devices.

Although it would be economical and effective to have only 3 to 5 regional PDCs (or PCS) per interconnection, to run in parallel and as back-ups to each other, most expect that every reliability coordinator (RTOs, ISOs and large utilities) will operate a PCS with a regional data archive function. PMUs and local PCS will have at least 15-30 days of local data storage.

There will be a structured hierarchy of distributed PDCs serving a hierarchy of systems -- utility, control area, reliability coordinator, interconnection level, each serving different data requirements (latency, quality, resolution), with archival and event triggering and data capture requirements driven by applications. Since local PDCs represent a local point of failure for the data stream, we will need to develop back-ups and bypass options for such failures.

NASPInet -- PMUs, PDCs and PCSs will be linked by a NASPI communications network that follows the architecture being developed for the NASPInet. NASPInet will incorporate existing technical standards and not require additional standards development. NASPInet should be in the pilot phase by 2014 and should be fully operational by 2019. Many Leadership Team members expect that transmission and generation owners will own PMUs and phasor gateways and that NERC, reliability coordinators or an independent third party will own and operate the phasor data network and PCS.

Phasor data will need to be cleanly integrated with data from other IEDs, with application-layer interoperability allowing data to flow cleanly between devices and applications. More work is needed to develop the NASPInet to applications layer data interfaces.

Phasor data research – By 2014 we will have used phasor data to gain a basic understanding of baseline grid conditions; that understanding will be near-complete by 2019. By 2014 we will be using pattern recognition of phasor data for basic identification and diagnosis of grid events; by 2019 phasor data will be routinely used to identify abnormal conditions and developments on the grid, trigger alarms and identify and guide operator actions. Operator notification about phasor-based real-time event diagnoses should incorporate a confidence measure that describes the level of assurance concerning interpretation of the anomalous grid conditions and diagnosis.

Successful development of phasor data applications is contingent upon getting data access for researchers (current effort is to secure agreement on a Research Non-Disclosure Agreement).

Analytical tools using phasor data – All current phasor data tools are R&D-grade, not production quality; RTDMS (Real-Time Data Management System), which has been supported as an R&D project by DOE since 2003, is the closest we have to a production-quality application – but no vendor is willing to take it on commercially because the market of RTDMS users is too small. An additional obstacle is that there is no production-quality platform to base diverse phasor data applications upon. There is a chicken-and-egg problem here – there are no killer applications yet for phasor data, and no compelling sources of overwhelming value for phasor data users yet, in part because there are not enough PMUs collecting data, not enough phasor data available, and insufficient data available to researchers to allow them to develop the high-value applications (this refers to the data-sharing issues as much as the data quantity).

By 2014 phasor data will be fully trusted as accurate and useful, and will be routinely used for the following purposes:

- Post mortem forensic analysis of all grid disturbances
- Monitoring and visualization of angle differences, voltage stability, frequency, and thermal overloads
- Power plant monitoring and integration, including intermittent resources and distributed generation
- Power system restoration
- Static model benchmarking
- State estimation
- Automated control of local assets

By 2019, phasor data will be used for:

- Dynamic state estimation
- Alarming for situational awareness tools
- Day- and hour-ahead operations planning
- Planned power system separation
- Real-time automated grid controls and adaptive protection on a wide-area basis
- Congestion management
- Inter-area oscillation damping modulation controls
- System integrity protection schemes

- Dynamic model benchmarking
- Dynamic line ratings and VAR support
- Unit dispatch
- Automatically manage frequency and voltage response from load
- Distribution network monitoring, restoration and self-healing.

KILLER APPS using phasor data would address these functions:
- Dynamic state estimation
- Oscillation monitoring
- Real-time controls
- Post-disturbance analysis
- System reclosing and restoration
- Model validation

NERC Reliability Standards – By 2014, NERC will be in the process of developing reliability standards that use phasor data to improve planning and operations for the following purposes:
- Disturbance monitoring
- Stability model validation
- Data retention and disturbance analysis
- More efficient transmission system utilization by dynamic rating
- Special Protection Systems

By 2019, phasor data and functionality should be incorporated into reliability standards for:
- Generator performance standards such as primary voltage control
- Wide-area monitoring and situational awareness
- Model benchmarking

However, reliability standards should be structured to avoid penalizing asset owners for having unperforming PMUs and experimental phasor applications.

In 2014, PMUs and phasor data applications will only be subject to NERC CIP standards if they are being used to control key BPS assets, but most will be installed so they are CIP-compliant or can be phased into compliance; by 2019, all elements of the phasor system will be CIP-compliant.

STRATEGIC PLAN

Benefits -- Identify and articulate benefits of synchrophasor data systems. (Project Manager Task)

Education -- Conduct an education campaign to convince utility and RC execs and regulators of the benefits of synchrophasor data, systems and applications. (Project Manager Task)

Full scale commercial deployment – Evaluate and study the challenges of moving from a small scale research environment to a full scale commercial deployment where real-time operation action depends on the new system.

Increase installed, networked PMUs -- Convince FERC and RCs to require PMUs to be installed at the busbar of every new generator as a requirement of interconnection. Create a time-phased requirement to place PMUs at the interconnection point for every existing generator > x MW over the next five years. Look at use of requests, agreements, tariffs, and contracts as options to move new PMU deployments. (Seek advice from ESG, Project Manager lead)

Data collection – Continue collecting and archiving phasor data. Continue work to resolve data quality problems, whether originating at the PMU (device or communications failures) or the local PDC. Figure out which data quality problems arise from the device and which from the asset owner's lack of support and work to resolve on a case-specific basis; consider publishing heroes and laggards lists with respect to phasor data collection and quality. Also develop sequenced plan to require use of production-quality phasor data for specific applications, probably through NERC reliability standards.

Phasor data research – resolve data access problem for researchers with clear NDA solution that allows access to packaged disturbance datasets (2009) and non-real-time baseline data (2010).

PDCs and PCS, and phasor applications – Focus primarily on RCs and large BAs as the target for phasor data-aided wide-area visualization tools (e.g., RTDMS, state estimation, day-ahead and hour-ahead operations planning, automated controls, separation and restoration analysis) and planning tools (e.g. model validation). Focus on a few BAs for system restoration, development of additional local device controls and system protection.

Projects to expand phasor use and data analysis – See below.

TASKS AND PROJECTS TO GROW PHASOR SYSTEM EXPANSION AND USE

NASPI Tasks

Phasor specifications and technical standards – PSTT (Mehdani et al) will develop a proposal for funding to expand and expedite PSTT's work on specifications and technical standards development, covering devices, data, static and dynamic measurement, and interoperability requirements. Specs need to be broad enough that narrow utility department-specific needs don't preclude acquisition of broader functionality and quality (e.g., anticipate local data storage needs and include now to enable later use). (PSTT and Vahid Mehdani lead preparing project scope of work for DOE and NERC funding consideration)

Phasor data quality tracking – See DMNTT tracking spreadsheet for history of phasor data problems in EI, figure out whether and how to use this info. (DMNTT and Carroll lead, NOW)

Fill in PMU coverage gaps – Identify gaps where additional PMUs are needed and approach individual utilities, generators and RCs to develop case-specific justifications for PMU installation. Look at whether existing relays with PMU-capable functionality can be upgraded to fill PMU needs. (ESG sponsorship, Task Teams, Cummings, with Project Manager lead)

Identify PMU and communications systems maintenance needs – This will vary depending on whether the devices are used primarily for control versus monitoring purposes. (Longer term)

Event post mortems -- Finish PRC-002 and PRC-018 revision to assure deployment of PMUs (or functionally equivalent devices) for disturbance monitoring events and post mortem analysis. (Cummings (NERC), Planning Committee). Note these PMUs need not be networked as long as they have adequate local data storage.

Phasor data potential and current uses – Build table that tracks phasor system uses (rows) against users (columns for BAs, RCs, other), showing potential (shaded) and actual uses (identify user). Fill in links to presentations, articles, etc for each cell (e.g., links to phasor research and tools repositories). Use this in education and outreach efforts. (Project Manager lead with support from Task Teams, NOW)

Reach out to RCWG and ORS – Get support from CAISO (Hawkins), MISO (Bilke) and SCE (Johnson, Bharat and SMART) for Project Managers' 3/17/09 presentation on NASPI to the NERC OC. Use RTDMS real-time live on MISO, RTDMS post-mortem on event, and slides. (NOW) Work on setting up RWCG or ORS live or virtual visit to SCE control room to see extensive phasor applications. (NOW)

<u>Research Projects for DOE Funding Requests</u>
(also potential funding from CERTS/PSERC, by expanding support from PNNL staff)
Most of the projects below are contingent upon resolving the challenge of getting researchers access to all relevant phasor data.

Baselining Eastern and Western Interconnections – develop project scope of work to conduct parallel 2-year analyses of baseline BES conditions using collected historic phasor data; do research of Eastern and Western Interconnections as separate projects. Seek DOE funding; recruit qualified researchers; include university fellowship funding. Estimate cost of research project. (Kosterev (BPA) lead with input from Overholt (DOE), Beard (TVA), Project Manager)

Pattern Recognition of Grid Disturbances – Develop project scope of work to conduct parallel 2-year interconnection-specific data mining around BES grid disturbances, to begin identifying patterns of precursor conditions that indicate upcoming grid problems. Recruit qualified researchers; include university fellowship funding. (Leads Dagle (PNNL), Mahendra, Donnelly (Quanta), RITT)

Define PDC functional requirements – expedite technical standards development relative to the new Phasor Data Collection System and NASPInet. (PSTT lead, identified during 10/08 NASPI meeting)

Test phasor gateway specifications from NASPInet – (identified during 10/08 NASPI meeting)

Define requirements for combined applications using phasor data – (identified during 10/08 NASPI meeting)

Model Validation – Design plan to expedite use of phasor data for model validation, to improve both components (generator and transmission asset types, even down to specific key assets) and system interactions. Use historic phasor data to validate interconnection planning models. Estimate cost of research project. (Huang (PNNL), Allen (NERC), Mahendra, SRP-ASU prof)

Improve NASPI website – PMs, consistent with the coming education and communications campaign.

Manage and administer research datasets -- Build an event data repository, possibly added onto the SharePoint frequency response database. (Longer term, OITT lead)

Monitoring and Control Tools – Design scope of work to develop phasor data-based tools for grid monitoring and control, particularly to detect imminent cascading and effect protection and islanding. (Longer term project)

Security requirements and phasors – needs more work. (Longer term)

Dynamic state estimation – needs more work. (Huang and professors)

Develop use cases as part of a demonstration project

Stimulus Money Project Proposals

RC phasor saturation demo – Develop a proposal for extensive PMU, communications, processing and applications deployment within one of the RCs. Potentially include a new dedicated fiber network for all BPS communications linking the phasor, generation and transmission assets, to facilitate both phasor and smart grid (BPS-level) applications. Estimate number of jobs, trucks, new equipment purchases and other stimulus-related elements that would be required to implement the full phasor system and smart grid communications network employment. Anticipate 6 month planning period, 12-month installation effort.

RC phasor backbone demo – Build a communications network to link standard configuration PMUs, PDCs, and applications to deliver fast data traffic between RCs and major BAs. This should serve as the foundation for NASPInet implementation in a few years. (Ask DMNTT to start developing scope of work)

Phasors for Renewable Generator Interconnection – Pick an RC, put a networked PMU at every large renewable generator and key substation in the RC. Design and initiate a research project for data analysis to identify impacts of intermittent generation over short- and ultra-short time spans. Link to intermittent generator analysts and share data patterns with RCs to design methods to feed patterns into intermittent generation forecasting and grid analysis. Estimate cost of research project. (Makarov, Kosterev, Hawkins leads)

NASPInet demo – NASPInet architecture specifications will be completed in April. Using an advisory committee from both NASPI and communications and security experts, build a small demo linking PMUs, communications, phasor gateways and PDCs using the NASPI architecture to see whether it will work. (DMNTT, Dagle (PNNL), additional non-NASPI experts).

FORMAT FOR PROJECT SCOPES OF WORK

Project Scopes of Work should be completed in draft by around March 6, so we are prepared to respond to potential DOE calls for project submittals. In the Scope of Work write-ups, please include the following:

- Goals of the project/research
- Background explanation for the project
- Sufficient description of the task(s) to make clear what we want the researcher to do, with as much detail as you can provide
- Describe data needed to perform the work
- Describe anticipated deliverables for the project tasks
- Description of the qualifications required for a capable researcher to perform the task
- Who will oversee project
- Estimated time required to perform the analysis
- Ballpark cost of the analysis (this is for our information and won't go out with the scope of work)