SYNCHROPHASOR TECHNOLOGY GLOSSARY

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Baselining – using large quantities of historical phasor data to identify and understand patterns in interconnection-wide grid behavior, to enable recognition of precursor conditions that signal potential grid reliability problems. Baselining, trending, and pattern recognition are being used to set system alarms (triggered by changes or threshold levels in grid conditions) to alert operators to emerging operational problems, and will eventually be used to set System Operating Limits (maximum limits for specific grid elements). Baselining is used for validation of models for the entire grid, for types of generators, and for individual generators.

Classes of phasor data services – Different phasor data applications have different requirements for data exchange timeliness; this means that not every application needs high-speed, real-time data delivery.

Classes of phasor data services

NASPInet Traffic Attribute	Real-time streaming data			Historical data	
	CLASS A Feedback Control	CLASS B Feed-forward Control	CLASS C Visualization	CLASS D Post Event	CLASS E Research
Low Latency	4	3	2	1	1
Availability	4	2	1	3	1
Accuracy	4	2	1	4	1
Time Alignment	4	4	2	1	1
High message rate	4	2	2	4	1
Path Redundancy	4	4	2	1	1

Table key:
4 – Critically important, 3 – Important, 2 – Somewhat important, 1 – Not very important

Communications — A mechanism to transport the digital information from the PMU to the location where the data will be used. Communication is typically provided through a private wide-area network (WAN) but can be any digital transport system that offers acceptable security and availability; functional requirements for a synchrophasor system architecture called "NASPInet" have been developed to provide for flexible, fast, vendor-agnostic, and secure communication of phasor measurements from data collection points to various levels of PDCs and phasor application use points

Data Storage — Systems to store synchrophasor data and make it conveniently available for post-real-time analysis can be integrated with the PDC or be stand-alone data historians or, in the case of smaller implementations, be traditional relational data base systems.

Dynamic line ratings – Phasor data can be used to monitor transmission line loadings and recalculate line ratings in real-time. Fixed seasonal summer or winter ratings are typically chosen based on fixed assumptions regarding ambient temperature, wind speed, and solar heating input to arrive at a conservative figure for transmission line conductor ampacity based on a maximum allowable conductor temperature. But real-time phasor data for selected transmission lines can be used in combination with local weather conditions (ambient temperature and wind speed, which can vary widely along a long transmission line) to calculate the actual ampacity of a transmission line, which could be significantly greater than a conservative seasonal rating. Dynamic line ratings can be used to enhance throughput from facilities that constrain generator output, those that constrain service into load pockets, to relieve congestion and reduce congestion costs along key lines, and to monitor lines that serve intermittent generation.

Event analysis – Event analysis uses time-synchronized, aggregated phasor data for forensic analysis of a grid disturbance, to quickly identify what occurred and figure out its causes and contributing events.

Frequency -- System frequency is the key indicator of the load-resource balance. Standard U.S. grid frequency is 60 Hertz (Hz); if frequency gets above 60.5 or below 59.5 Hz, the system is in trouble. The size of frequency deviation correlates with the size of generation loss. Frequency is also a good indicator of integrity of an interconnection during system events involving separation or islanding — if a bus frequency in one part of the system stays at 60.5 Hz while frequency in another part of the system holds at 59.5 Hz for several minutes, it means there has been system separation.

Key interoperability standards and protocols for synchrophasor technology –

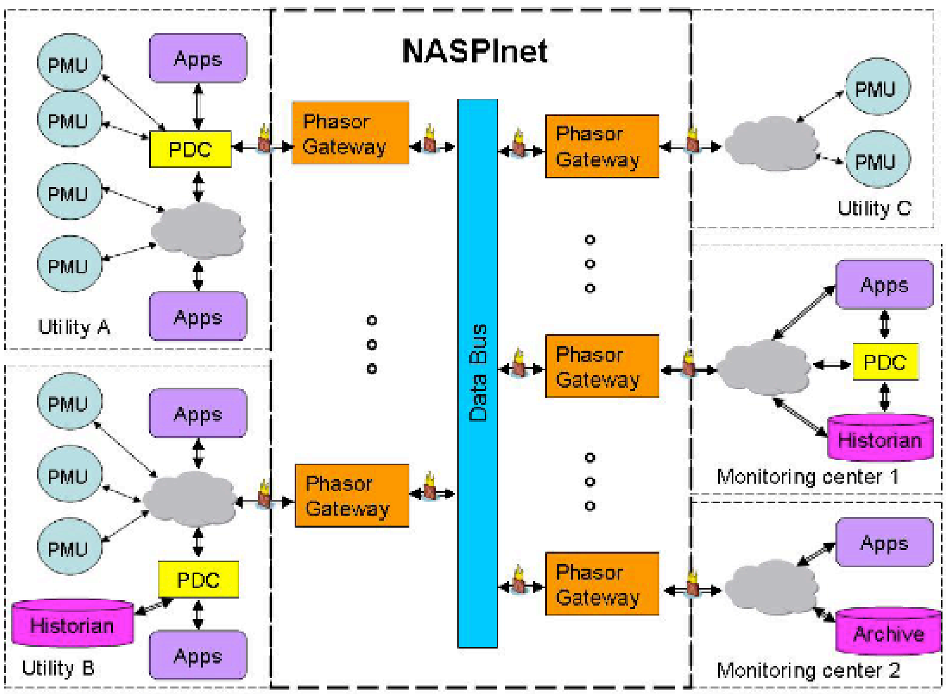
- **IEEE 37.118 –** communications protocol for PMU communications
- **IEC 61850.90-5.1 and 90-5.2**
- **IEC 1588** for time synchronization
- **Data protocols and formats –** GOOSE, COMTRADE, DNP3, UNIX

Model validation – Using phasor data of actual system performance to determine whether existing models of an interconnection's power system, or a power plant, to improve the analytical and predictive quality of those models.

NASPI – North American SynchroPhasor Initiative, the collaboration between DOE, NERC, and the electric industry (utilities, grid operators, consultants, vendors, academics and researchers) to advance the capabilities and adoption of synchrophasor technology. NERC funds the NASPI project manager and three meetings per year of the NASPI community and work by the Grid Protection Alliance to develop key phasor software infrastructure; DOE funds R&D into phasor technology and National Lab staff support for NASPI group analyses and initiatives; industry members volunteer time, expertise, and leadership, and share information and work on standards development, applications improvement, and more. NASPI work is documented at www.naspi.org.

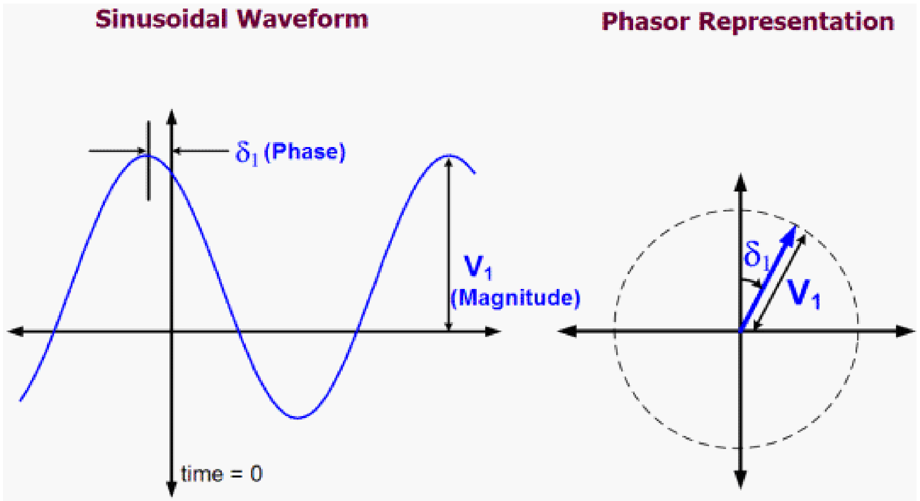
NASPInet – NASPInet is a conceptual architecture (developed by NASPI with DOE funding) for a physical communications transport network that could support hundreds of phasor gateways and thousands of PMUs. NASPInet is also used to mean one or more regional- or interconnection-wide dedicated communications networks carrying phasor data and analyses between PMUs, applications and control centers to support real-time grid operations. Most of the SGIG synchrophasor awards are implementing NASPInet architecture concepts in their projects. Cybersecurity elements are embedded into the NASPInet design.

NASPInet conceptual architecture



Phasor -- a complex number that represents both the magnitude and phase angle of voltage and current sinusoidal waveforms (60 Hz) at a specific point in time (shown in Figure 1-1).

Sinusoidal Waveform and Phasor Representation



Source: CERTS, Phasor Technology Overview

Phasor data applications -- Phasor data applications can be grouped into three categories:

- Applications to support real-time grid operations by providing wide-area visualization and increased state awareness; require real-time data collection and processing with immediate analysis and visualization
- Response-based control applications that use real-time wide area information to take automated control actions on the power system.
- Applications to improve system planning and analysis, including power system performance baselining, event analysis and model validation; use archived data and may be conducted off-line days or months after the data were collected.

Phasor Data Applications Summary with Priorities
(from 10/10 NERC "Real-time application of Phasors for Improving Reliability" report)

Application	**Priority For Real-time Operators**	**Priority For Day-ahead Operations**	**Assent Management and Utilization**	**Comments**
	Real-time operations		**Planning**	
Alarming and setting System Operating Limits; Event detection and	*High*	*Low*	*Low*	Relies on baselining work

avoidance				
Baselining	*High*	*High*	*High*	
Dynamic line ratings and congestion management	*Medium*	*High*	*Medium*	
Fault location	*Medium*	*Low*	*Low*	
Power oscillations	*High*	*Medium*	*Medium*	
Frequency stability	*Medium*	*Low*	*Medium*	May become a higher priority with large-scale wind integration
Operations planning	*Low*	*High*	*Medium*	
Outage restoration	*High*	*Low*	*Low*	
Resource integration	*Medium*	*Low*	*High*	
Special protection schemes and islanding	*Low*	*Medium*	*High*	
State estimation	*Medium*	*Low*	*Low*	
Voltage monitoring and trending	*High*	*Low*	*Low*	
Wide-area controls	*Low*	*Low*	*High*	
Wide-area situational awareness	*High*	*Medium*	*Low*	
Forensic Analysis	*Medium*	*Medium*	*High*	
Generator Model Validation	*Low*	*High*	*High*	
Load Model Derivation	*Low*	*High*	*High*	
System Model Validation	*Low*	*High*	*High*	

Phasor Data Concentrator (PDC) – collects phasor data from multiple PMUs or other PDCs, aligns the data by time-tag to create a time-synchronized dataset, and passes this dataset on to other information systems. A PDC also performs data quality checks and flags missing or problematic data (waiting for a set period of time, if needed, for all the data to come in before sending the aggregated dataset on). Some PDCs also store phasor data and can down-sample it so that phasor data can be fed directly to applications that use data at slower sample rates, such as a SCADA system. PDCs can be located locally to aggregate host site (e.g., substation) data (local PDC), at the transmission owner's control center, or at the regional control center (also called a Super-PDC or super-concentrator).

Phasor Gateway (PG) – Within the NASPInet design, phasor gateways will be the links between PMUs and PDCs to the main NASPInet databus for transport to other PDCs, applications and users. Phasor gateways will be the sole access points for utilities into the NASPInet data bus, managing connected devices, quality of service, cyber-security and access rights, effect data conversions, and interface a utility's own network with the data bus.

Phasor Measurement Unit -- PMUs measure voltage, current and frequency and calculate phasors, and this suite of time-synchronized grid condition data is called phasor data. Each phasor measurement is time-stamped against Global Positioning System universal time; when a phasor measurement is time-stamped, it is called a synchrophasor. This allows measurements taken by PMUs in different locations or by different owners to be synchronized and time-aligned, then combined to provide a precise, comprehensive view of an entire region or interconnection. PMUs sample at speeds of 30 observations per second (up to 120 and 240 samples per second), compared to conventional monitoring technologies (such as SCADA) that measure once every two to four seconds. A PMU also performs pre- and post-processing of the data collected, including proprietary phasor computation algorithms, anti-alias filtering, and other measures. Any device that incorporates this functionality — such as digital fault recorders (DFRs) and digital relays — is considered a PMU device.

Power oscillations -- Detection of power system oscillations and ambient grid damping are among the premier applications that require the high-speed data that PMUs provide and conventional SCADA does not. Low-frequency oscillations occur when an individual or group of generators swing against other generators operating synchronously on the same system, caused by power transfers and high-speed, automatic turbine controls attempting to maintain an exact frequency. Low-frequency oscillations are common on most power systems due to either power swings or faults; undamped oscillations can swing out of control and cause a blackout (such as the Western Interconnection event on August 10, 1996). Small-signal oscillations appear to have been increasing in the Eastern and Western interconnections, causing an urgent need to better understand the problem, detect when oscillations are occurring, and find ways to improve oscillation damping and implement system protections against collapse. Two phasor data tools are being developed for identifying power oscillations – oscillation detection (identifies amping of large oscillations from phasor data) and mode meters (detect early damping of small-signal oscillations).

RTDMS – Real-Time Data Monitoring System, a WAMS application developed by Electric Power Group using DOE R&D funding for real-time grid monitoring and visualization across much of the Eastern Interconnection and many utilities and RTOs. No longer receives DOE R&D funding, but is a stand-alone market offering by EPG in competition with other commercial vendors' WAMS products. DOE now pays EPG to provide RTDMS as a common visualization platform across the Eastern Interconnection.

Special protection system (SPS) – An SPS is a suite of automated control measures designed to detect a particular, stressful power system condition and take a predetermined set of actions (such as generator-tripping, line-opening, or load-shedding) to prevent instability, overload or voltage collapse. Each SPS is tailored to a specific power system and potential emergency condition. Some SPS may also be called, **Remedial Action**

Schemes, although RAS tend to address less drastic emergency conditions. An SPS may cause **islanding,** the separation of an interconnection into stand-alone sections within which load and generation are balanced.

State estimation – A state estimator takes measured grid condition data (voltage and line loading) and runs it through a computer model of that system to calculate the operating levels and operational constraints of an electric system. It checks to verify that all of the real measured data are correct, estimates all line flows, loads, transformer taps and generator outputs, and conducts a security assessment to analyze contingencies (potential bad events such as generator or major line losses) and the required corrective actions for each. State estimators are now being built to take phasor data as well as SCADA data.

Synchrophasors are precise time-synchronized measurements of certain parameters on the electricity grid, now available from grid monitoring devices called phasor measurement units (PMUs).

WAMS – Wide-area measurement system -- Phasor systems are being used for wide-area measurement systems (WAMS) in the Eastern and Western Interconnections of North America and in China, Quebec, Brazil, and Europe

WASA – Wide-area situational awareness

WAV – Wide-area visibility -- synchrophasor systems allow the collection and sharing of high-speed, real-time, time-synchronized grid condition data across an entire system or interconnection. This data can be used to create wide-area visibility across the bulk power system in ways that let grid operators understand real-time conditions, see early evidence of emerging grid problems, and better diagnose, implement and evaluate remedial actions to protect system reliability.

Current SCADA systems observe grid conditions every 4 to 6 second, which is too slow to track dynamic events on the grid. They also do not monitor key indicators such as phase angles, SCADA data are not consistently time-synchronized and time-aligned and those data are not shared widely across the grid. Thus SCADA does not give grid operators real-time, wide area visibility into what is happening across a region or interconnection.