NASPI-2020-TR-024

NASPI 2020 Survey of Industry Best Practices for Archiving Synchronized Measurements

North American Synchrophasor Initiative
Technical Report

NASPI Data Network Management Task Team

November 3, 2020

Acknowledgments

This technical report was prepared by the Data & Network Management Task Team on behalf of the North American SynchroPhasor Initiative (NASPI). Key contributors to designing the survey, interpreting the results, and compiling this report include:

- Teresa Carlon (Pacific Northwest National Laboratory)
- Dan Brancaccio (Quanta-Technologies)
- Matthew Rhodes (Salt River Project)
- John Volpert (Southwest Research Institute)
- Terry Jones (Oak Ridge National Laboratories)

Acronyms and glossary

API	Application Program Interface
DNMTT	Data and Network Management Task Team
Hz	Hertz
NASPI	North American SynchroPhasor Initiative
PDC	Phasor Data Concentrator
PMU	Phasor Measurement Unit
SCADA	Supervisory Control And Data Acquisition
TAI	International Atomic Time
TB	Terabytes
TCP/IP	Transmission Control Protocol/Internet Protocol
TSO	Transmission System Operator
UDP	User Datagram Protocol
USA	United States of America
UTC	Coordinated Universal Time

Table of Contents

Introduction

The North American SynchroPhasor Initiative's (NASPI's) mission is to improve power systems reliability and visibility through wide-area measurement and control by fostering the use and capabilities of synchrophasor technology. This report is prepared by the Data & Network Management Task Team (DNMTT), a working group of NASPI. The mission of the DNMTT is to provide guidance for synchrophasor data networking, archiving and access issues and to review new archiving and networking technologies for the best fit for synchrophasor application realization. This document reports the results of a 2019 survey of the current state and industry aspirations of synchrophasor data archiving strategies. The survey considered thirteen questions of interest to the DNMTT.

Synchrophasor Technology Review

A synchrophasor system utilizes phasor measurement units (PMUs), usually installed at electrical substations, to make measurements of the electrical state of the grid. These units can vary in measurements recorded but are capable of recording phase, frequency and amplitude of both the current and voltage waveforms. Multiple PMUs are time-synchronized to less than a millisecond via precise UTC relative time stamping, making relative phase measurements over vast distances possible. Note that UTC is adjusted for leap seconds. This occasional adjustment to account for the slowdown in the earth’s rotation (there have been five leap second adjustments since 2000) must be handled with great care and consistency across all timestamping devices within the grid in order to avoid dramatic misreadings. For this reason, some have espoused using TAI relative time sampling since TAI is unaffected by leap seconds, but TAI is much less common within the USA.

A collection of time-synchronized PMUs forms a synchrophasor system. The system's data can be used in real-time to understand the overall health of a power system. This data allows system operators to make informed decisions about power system control. The data can also be stored for analysis at a later time. A common use case for such archived data is to understand the cause of a power loss event.

For operators or analysts to examine the data, the data needs to be transmitted and stored in a safe and reliable manner. PMU data reporting rates are typically 30 to 60 data frames per second and could be higher in some cases. The high data rate contrasts with the standard supervisory control and data acquisition (SCADA) systems that report data every four to six seconds. While SCADA system data is valuable to the understanding of power system dynamics, synchrophasor data has its advantages in the sample rate and time synchronization. This allows for visibility into system conditions such as rapid oscillations and voltage instabilities that SCADA system would miss.

Synchrophasor System Elements

A full synchrophasor system has three main components, the PMUs, the Phasor Data Concentrators (PDC) and the synchrophasor archive. PMU's are connected to communications systems to the PDC. A PDC aggregates data from a synchrophasor system. PDCs take input PMU streams, time aligns the data and performs basic data quality checks. The data is transmitted to the PDC using a standard protocol, C37.118, and through a variety of transport methods such as TCP/IP. The data may be stored locally or transmitted to another location for archiving or transmitted to applications for data processing.

Depending on the user's requirements, synchrophasor systems can vary greatly. Data may be stored in multiple locations or could be delivered to a centralized location. Data may be available for immediate use or maybe archived for long-term storage. The possibilities are endless.

Planning effective solutions for data storage, networking and software can be vital to the success of a synchrophasor system. Many factors distinguish systems including:

- SCALABILITY: Many systems are comprised of 1000's of PMU's, creating large datasets that need to be easily accessed for use.
- RETENTION: Data requirements such as data retention time can play a role in data storage requirements.
- ACCESSIBILITY: Consideration should be given to who will need access to the data, and if it is desirable to secure the portions of the data.
- NETWORK: Available data communication systems as well as data integrity will affect the network that best suits applications.
- ANALYTICS: Data analysis software to make sense of the PMU data will need to be decided upon.

Missteps in any one of these areas could render a synchrophasor system ineffective.

North American Synchrophasor Initiative

The NASPI community works to advance the deployment and use of networked phasor measurement devices, phasor data-sharing, applications development and use, and research and analysis. Prominent synchrophasor applications today support power systems in areas such as wide-area monitoring, real-time operations, power system planning, and forensic analysis of grid disturbances. Phasor technology offers great benefits for integrating renewable and intermittent resources, automated controls for transmission and demand response, increasing transmission system throughput, and improving system modeling and planning.

NASPI is a voluntary group of representatives from the utility industry, manufactures and vendors, academia, national laboratories, government experts and standards-making bodies. The group meets twice a year to share information and solve technical, operation, institutional, standards development, and other strategic issues and obstacles.

NASPI is a collaborative effort funded by the U.S. Department of Energy with support from the Pacific Northwest National Laboratory and the Electric Power Research Institute.

Survey Results

Below is a summary of the results of a survey that was conducted by the NASPI Data and Network Management Task Team, DNMTT. The purpose of this survey was to gain an understanding of existing industry archiving processes for synchronized measurements. This information will help NASPI document existing archiving standards for industry guidance and promote the development of new archiving and network standards that will enable faster advancements in synchronized measurement tools. The survey consisted of thirteen questions. Seventeen members responded to the survey. Respondents were able to make multiple choices per question. The result tables for each question below shows the available responses and the frequency count of responses.

Question 1: Describe your overall synchronized measurement network architecture (i.e., PDC network configuration)?

Response	Count
Routable communications UDP or TCP/IP	13
Substation PMUs to substation PDC to Control Center PDC	9
Substation PMUs direct to Control Center PDC	9
Serial Communication	1
Foreign Substation PMU – TSO PDC – own TSO PDC	1

All respondents use a form of routable communication such as UDP or TCP/IP and there was an even split of those that have a synchrophasor PDC network that includes a substation PDC infrastructure and a direct to Control Center PDC. While many respondents are using multiple network architectures; only 5 had a single architecture.

One respondent chose not to respond to this question leaving a total of sixteen responses.

A total of eleven respondents specified transport methods.

Three respondents (27%) stated using routable communications UDP or TCP/IP but did not specify any defined architecture. This may be due to lack of respondent information, a desire for infrastructure confidentiality or perhaps a direct PDC-less system.

For signal transport method responses, 100% used routable communications UDP or TCP/IP with two respondents (18%) specifying the use of serial communication in addition to routable communication. This may be an artifact of first-generation PMUs without Ethernet capability.

A total of twelve respondents specified defined architectures

There was an equal split in the use of individual architectures with three (25%) using intermediate substation PDCs only and three (25%) using direct control center transmission only. There were five (42%) respondents who used a mixture of architectures possibly for dedication of certain synchrophasor signals for direct control room use. One respondent specified a unique structure: foreign substation PMU to TSO PDC to own TSO PDC. This would be a foreign utility PMU transported through TSO connections to the respondent utility PDC.

Many entities are using well known PDC architectures and a mixture of architectures to achieve their synchrophasor data needs with a minority, three (17%) possibly using unique and/or advanced synchrophasor transport methodologies due to the lack of an architecture response.

Question 2: What product do you use for your archive?

Response	Count
eDNA	1
OSISoft PI Archive	6
Relational Database (SQL, Oracle, SQL variants)	2
openHistorian	3
PingThings	1
Files	1
Proprietary	6
DataNXT	2
SynchroWAVe	3
PhasorPoint	4
Other	3

Disclaimer: Question 2 is not meant to showcase the total number of users of individual vendors but to show the diversity of vendor archive solutions available.

Six (35%) of the respondents use in-house proprietary software while six (35%) of the respondents use OSISoft PI for their archive solutions.

Other unique archive solutions used include Kx for Sensors and kdb+, AWS S3 and Glacier (Cloud-based solution), and Hadoop.

Nine (75%) of the respondents reported using multiple archive solutions.

The use of proprietary and mixtures of archive solutions is very prominent. In addition, there is a total of 13 vendor solutions available just from these survey results showing there is a diversity of options available.

Question 3: What is the format of your archived synchronized measurements (i.e., file folder, binary, SQL database)?

Response	Count
Binary	3
Big Data	1
Time Series Based	5
SQL/KDB+/SynchroWAVe/PI/Parquest Database	6
CSV	2

Most respondents had a custom storage style. Even those that responded with the same response category stored its data in slightly differently ways. For example, the time-series respondents were using a mixture of custom storage methods such as compression methods, proprietary methods, flat files, and others.

Question 4: Archive Type?

Response	Count
Fixed Size	9
Fixed Duration	6
Expanding	2

Most respondents are keeping a fixed amount of data before deletion. Only two respondents are expanding their data storage to keep longer-term data. Also, only one respondent has chosen to keep a 2-week data repository.

Question 5: Current Storage Capacity (TBs)?

Response	Count
0-29	3
30-75	4
76-150	7
>150	0

The size of storage needed can vary according to many factors, such as the number of PMUs, compression methods, resolution, and frequency of PMU data.

Question 6: Current Storage Duration (in years)?

Response	Count
<0.5	2
0.5-1.5	2
1.5-2.5	3
2.5-3.5	5
3.5-4.5	1
7	1

Most respondents are keeping their data for more than a year, with only two indicating for less than that. Many respondents indicated that exciting events are saved in different locations for permanent review.

Question 7: Data accessibility?

Response	Count
Online	14
Only Offline	1

Most, if not all, respondents can access PMU data online. The only offline response referred to archived data. Old archived data was only available offline for many other responders. One respondent stated that data is accessible only to operators.

Question 8: Data Granularity?

Response	Count
Raw	10
Compressed	6
Down Sampled	2

Many respondents are recording data in a raw format. This may be due to the low cost to storage as well as the immediate access to data that raw files provide.

Question 9: Data Sampling Rate (Hz)?

Response	Count
10	2
25-30	10
50-60	4
100-120	3

Most respondents are sampling at half the line frequency (25-30 Hz). Also noted was that, 6 (35%) of the respondents sample at multiple sample rates.

Question 10: Describe tools used for synchronized measurement data quality assurance and lost signal alarming and mitigation?

Response	Count
Uses Commercial Software	10
Uses Custom Software/Methods	2
Sends Alarms on poor data quality	1
No Response/No Tool	5

Most respondents used commercial software like EPG RTDMS, EPG DataNXT, PI Datalink, and XM Data Quality App to name a few. Most do not send alarms. One respondent indicated they had extensive PMU coverage, and the loss of data from isolated units was not problematic, not requiring alarming.

Question 11: What types of data do you archive?

Response	Count
Synchrophasors	17
Line Frequency	1
Digital Fault Records	4
Relay records	3
Power Quality	2
Application Data (oscillation detection, etc.)	1

All respondents record synchrophasor data. Of the 17 respondents 64% report recording only synchrophasor with 3 respondents mixing other data sources such as Digital Fault Recorder and Power Quality data into their archives.

Question 12: Do you store synchrophasor data with non-time synchronized data?

Response	Count
No	14
Yes	2

Of the 16 respondents to this question of mixing synchronized and non-synchronized data, only 2 responded were in the affirmative. One stored the non-synchronized and synchronized data in the same database in a flexible data model. The other affirmative respondent stored all data on the PingThings PredictiveGrid platform or in a side SQL Database depending on frequency.

Question 13: What features would you like to see in a next-generation synchrophasor data service platform?

Response	Count
On-board data analytics	10
PDC-less collection	4
Multiple data source collection (non-synchrophasor)	8
Data output streaming services	5
Cloud storage	4
Easy access by multiple parties and standard API to enable advanced data analytics	1

Most respondents were interested in on-board data analytics and multiple data source collections. Both of these items are features that some respondents have already implemented. This shows the respondents' need for quick access to raw data and summary data for simplified decision making. This also speaks to the respondents' desire to have capabilities to quickly develop and obtain quick new insights into what information their synchrophasor data can provide.

Conclusions

This survey indicates that utilities are desiring more advanced methods to archive, access and analyze their synchrophasor and other system data on more efficient data platforms and that they are already actively seeking and experimenting with new methods of archiving to achieve this goal.

Existing network transport protocols are well established and reliable for today's needs but there are more diversity and creativity in combining data network architecture styles and exploring new synchrophasor data transport methodologies. While typical static architectures are still widely used, there is a growing diversity of creative archive strategies that either integrate or highly promote deep data analytics.

Data format storage is highly diversified at the time of this survey leading the surveyors to believe that archive strategies are directed around understanding the end-use of data and allowing for advanced data analytics. While the surveyors do not have a baseline with which to compare, based on surveyor knowledge, the duration, size and retention policy of data has expanded greatly over time, with respondents storing more data (76-150 TBs) for a longer time durations (2.5-3.5 years). Also, data is highly available online and in a raw format which allows for more specialized data analytics. Data sampling rates are expanding from the typical

30Hz frequency to 60Hz and mixtures of sampling rates are more highly practiced indicating a more granular specialized understanding of data end uses.

While the majority of synchrophasor archives are dedicated to synchrophasor data there are trends indicating the archive mixing of other data types, especially Digital Fault Recorder (DFR) data. This shows a leading trend of utilities finding value in combining data sources for more intelligent data analytics. Moving towards the future of data archive strategies, the majority of utilities surveyed desire to perform on-board data analytics with multiple data sources indicating a powerful industry trend to get fast access and intelligence from their data by more efficient means.