Synchrophasor Data Management

Current State Assessment

2013 TECHNICAL RMA>QB

Synchrophasor Data Management

Current State Assessment

EPRI Project Manager
P. Myrda

ELECTRIC POWER RESEARCH INSTITUTE

3420 Hillview Avenue
Palo Alto, CA 94304-1338
USA

PO Box 10412
Palo Alto, CA 94303-0813
USA

800.313.3774
650.855.2121

askepri@epri.com

www.epri.com

3002000605
Final Report, December 2013

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

THE FOLLOWING ORGANIZATION(S), UNDER CONTRACT TO EPRI, PREPARED THIS REPORT:

Electric Power Research Institute (EPRI)

THIS IS AN EPRI TECHNICAL UPDATE REPORT. A TECHNICAL UPDATE REPORT IS INTENDED AS AN INFORMAL REPORT OF CONTINUING RESEARCH, A MEETING, OR A TOPICAL STUDY. IT IS NOT A FINAL EPRI TECHNICAL REPORT.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

Acknowledgments

The following organization prepared this report:

Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, California 94304-1338

Principal Investigators
P. Myrda

This report describes research sponsored by EPRI.

This publication is a corporate document that should be cited in the literature in the following manner:

Synchrophasor Data Management: Current State Assessment. EPRI, Palo Alto, CA: 2013. 3002000605.

Abstract

The nationwide deployment of synchrophasor technology has significantly expanded as a result of the funding provided by the American Recovery and Reinvestment Act (ARRA). As installations of phasor measurement units (PMUs) near completion, the power industry is achieving unprecedented wide-area synchrophasor coverage of the North American grid. With over 1000 synchrophasors installed and continuously streaming data, there will be new challenges in managing, storing, and using data. The objective of this project was to investigate the data-management issues expected to accompany this extensive network of installed PMUs. The project team assessed and documented the various approaches used by participating utilities for data management, along with their expected data growth and data-archiving methods. They investigated both short- and long-term data storage; the relationship of synchrophasor data to other power-system data such as energy management system (EMS) data, power-system topography, and environmental data; and the integration and archiving of synchrophasor and other relevant data associated with power-system events. They developed a survey to gather information from utilities and independent system operators that included the number of PMU devices installed and how the resulting data was being stored, used, and archived. The survey was completed by 13 companies. Survey results showed that several practices—including number of phases monitored, sampling rates, and signals—were consistent among the participating companies. Daily storage volume varied widely among companies because of the wide variety of signals monitored and the varying numbers of PMUs installed. The most widely used synchrophasor applications were post-event analysis, system-condition monitoring, and voltage stability.

Keywords

Synchrophasor technology
Phasor measurement units (PMUs)
Synchrophasor data management
Energy management system
Power-system topology
Power-system event analysis

Table of Contents

List of Figures

List of Tables

Section 1: Overview

This new project for 2013 focuses on the management of synchrophasor data. While synchrophasor technology has been available for quite some time, the expansion of the technology has flourished in the industry since the American Recovery and Reinvestment Act (ARRA) provided funding for their installation. With the installations nearing completion, the industry will for the first time have extensive wide area synchrophasor coverage of the North American grid.

Under the Recovery Act Smart Grid Investment Grant (SGIG) and SGDP programs, twelve grant recipients are spending about $400 million, including their cost-share (which is at least a 50% match), to deploy Phasor Measurement Units (PMU) or synchrophasor technologies [1].

Table 1-1
Numbers of PMUs Installed in Recovery Act-Funded Projects

SGIG and SGDP Synchrophasor Project	PMUs Installed*	
	Recovery Act Project	System Total
American Transmission Company	45	92
Center for Commercialization of Electric Technologies	15	18
Duke Energy Carolinas	98	98
Entergy Services Inc.	49	49
Florida Power & Light Company	45	45
Idaho Power Company	8	15
ISO-New England	77	77
Midwest Energy	7	7
Midwest Independent Transmission System Operator	148	148
New York Independent System Operator, Inc.	40	40
PJM Interconnection	56	56
Western Electricity Coordinating Council	336	481
TOTAL	924	1126

With over 1000 synchrophasors installed and continuously streaming data, there are expected to be new challenges in managing, storing and using the data and other related issues. The objective of this project is to investigate data management issues that may arise with this extensive network of phasor measurement units now installed.

The project will assess and document the various approaches utilities have used for data management methods, the expected data growth and archiving aspects also. EPRI will investigate the various approaches implemented by participating utilities and assess their pros and cons. Actual lessons learned will be documented and communicated. In an effort to gain a better understanding of the synchrophasor practices a utility survey was developed. Details about the survey are described later in this report.

The project investigated the storage of data, both short and long term. The project also investigated the relationship of synchrophasor data to other power system data such as system topology, generation dispatch and other operating conditions and externalities. Lastly, there was an assessment of the relationship to power system events and establishing an approach to long term archiving of all relevant data associated with the event including synchrophasors.

Section 2: Survey Questions

To effectively understand the synchrophasor landscape regarding industry practices and gauge the data growth and storage issues a survey was developed to gather factual data from both utilities and independent system operators (ISOs). The survey captured information regarding the company profile, PMU devices installed, data management, data usage and application usage. The actual survey questions follow.

Survey Content

The purpose of this questionnaire is to gain an understanding of the volume of data being generated by your company, how this data is being stored, used and archived.

General Information

Question 1 - Company Information

Company Name:

Name of Person filling out the survey:

Department:

Email Address:

Phone Number:

PMU Information

Please provide information about the actual PMUs you have installed and how they are configured to better understand the data source contribution.

Question 2 - Phasor Measurement Unit Information

This section of the survey is seeking data on number of PMUs installed by manufacturer and the approximate number of signals measured. A signal is a single measurement of a phase voltage or current. For example if your company's approach is to monitor one phase voltage and all three phase currents then you would answer 4 signals.

PMU Type	Number of Devices	Average Number of Signals Measured per Device	Average Number of Digital Status Points per Device
ABB - RES 521			
Alstom - MiCOM P847			
Arbiter - Model 1133A Power Sentinel			
ERLphase – TESLA 3000 or 4000			
GE – Multi Function Relay – D60, L90			
GE – Dedicated PMU – N60			
LogicLab - FR947-EX/PMU			
Macrodyne - 1690			
Qualitrol - PMU-9/18/36			
SEL – Multi Function Relays			
SEL – Dedicated PMU - SEL-487E and the SEL-351A-1			
Siemens - SIMEAS R-PMU			
Other			

Question 3 - How many phase voltage and currents are typically monitored by your PMU's

	1	2	3	NA
Voltage Phases Monitored				
Current Phases Monitored				

Other: ___________________________

Question 4 - Describe Digital Status Points monitored

Question 5 - What is your typical Synchrophasor Sampling Rate?

Phasor Sample Rate - 1,2,3,4,5,6,10,12,15,20,30,60, 120/sec

Data Storage

This section of the survey is seeking to understand the storage volume, management of the data, archiving approach of the incoming data streams

Question 6 - Please identify the data volumes for each area below to the nearest value in the pick list

Daily Storage volume

Volume of data currently stored online (active discs)

Volume of Data currently stored off line (Archived)

Data Retention

This section of the survey is seeking to understand the data retention and destruction policy.

Question 7 - In the boxes below please describe your policy for data:

Archiving:

Retention:

Destruction:

Data Users

This section is looking to understand who in your organization uses synchrophasor data and approximately how often that data is used.

Question 8 - How frequently do each of the following use synchrophasor data?

Data User	Weekly	Monthly	Quarterly	NA
System Operations Staff				
System Operators				
System Planners – Long Range Planning				
System Planners – Disturbance Analysis Staff				
System Planners – Dynamic or Transient Stability Studies				
Protection Engineers – Field				
Protection Engineers – Office				
Maintenance Staff				
Research and Development Staff				
Substation Engineering				
Transmission Line Engineering				

Other

Applications

This section of the survey is looking to gather data related to the use of the synchrophasor data, specifically application areas that may be in use at your company.

Question 9 - For each application please indicate it usage status in your company?

Application	Currently Use	Plan to Use in the near future (1-3 years)	Plan to Use in the near future (4-7 years)	No interest in using
State Estimation				
Situational Awareness for Oscillations				
Oscillatory Stability Management				
General WAMS Alarm Presentation				
Islanding, Resynchronization and Blackstart				
Modal Analysis				
System Disturbance Management				
System Condition Monitoring				
Interconnection of Renewable Resources				
Dynamic Constraint Management				
Post-Event Analysis				
Voltage Stability				
Other				

Question 10 - Provide your opinion on the application performance and value

Application	Does the application perform as expected?	Does the application provide the expected value?
State Estimation		
Situational Awareness for Oscillations		
Oscillatory Stability Management		
General WAMS Alarm Presentation		
Islanding, Resynchronization and Blackstart		
Modal Analysis		
System Disturbance Management		
System Condition Monitoring		
Interconnection of Renewable Resources		
Dynamic Constraint Management		
Post-Event Analysis		
Voltage Stability		

Comments

Section 3: Summary Survey Responses

Respondents were asked to provide information on the respondent, PMU manufacturer, PMU electrical connections, sample rate and other parameters to fully capture the input drivers for the data growth, archiving, retention and decimation. They were also asked to provide usage data on applications currently in use and also future plans.

The survey was completed by 13 companies. The following companies provided responses to the survey.

- BC Hydro
- Bonneville Power Admin.
- Duke Energy
- Entergy Services, Inc.
- ISO New England
- MISO
- New York Power Authority
- NYISO
- Oklahoma Gas & Electric Co.
- PJM Interconnection
- Salt River Project
- Southern California Edison
- Taiwan Power Co

Phasor Measurement Unit Information

PMU Manufacturer Breakdown

The breakdown by manufacturer is shown in the figure below.

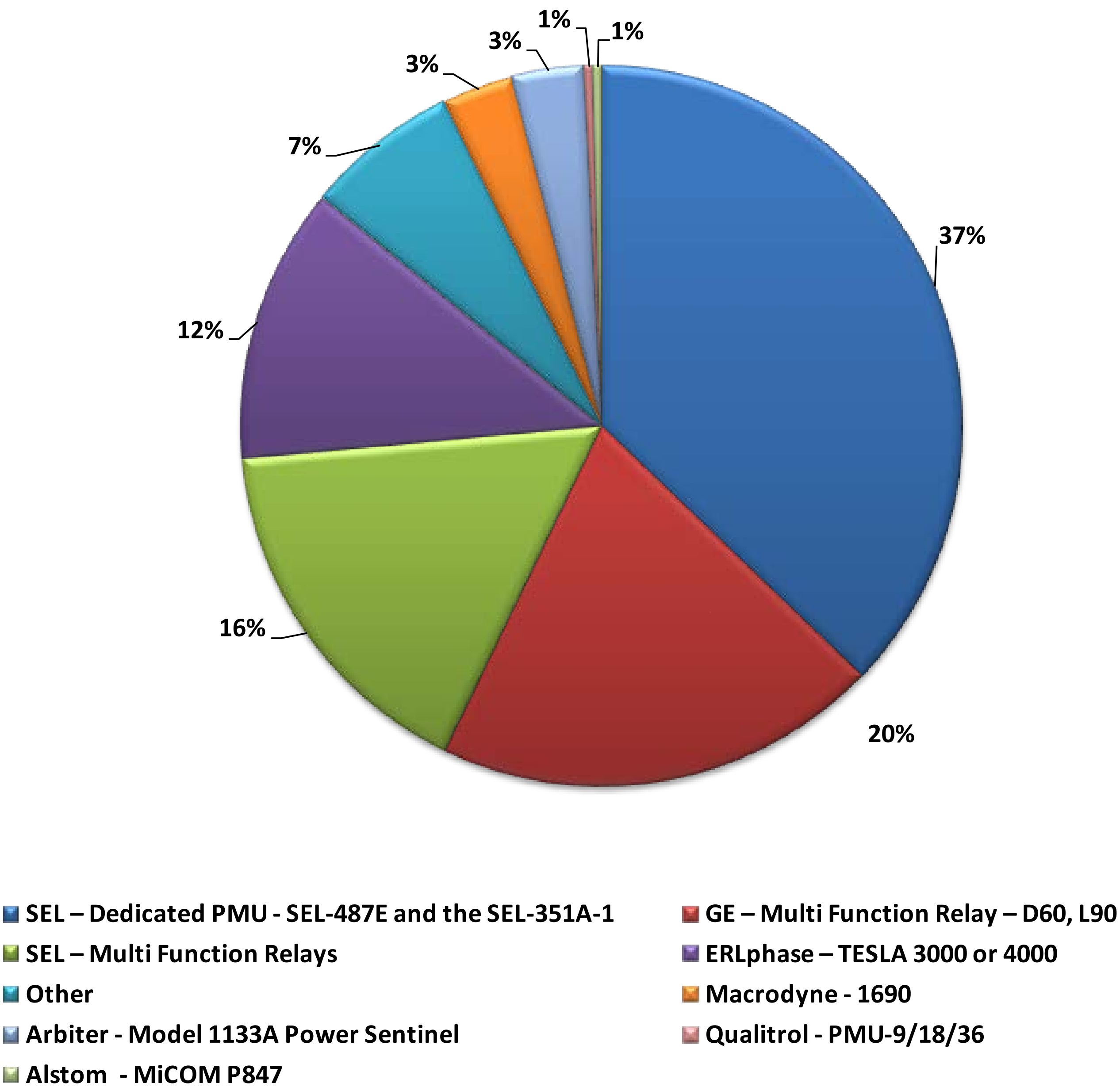

Figure 3-1
Phasor Measurement Units by Manufacturer

Signals Monitored

Signals are a single measurement such as B-phase voltage or phase current. The number of signals monitored which encompasses voltage, current and digital signals was on average was 12 based on a weighted average. The maximum number of signals was 29.

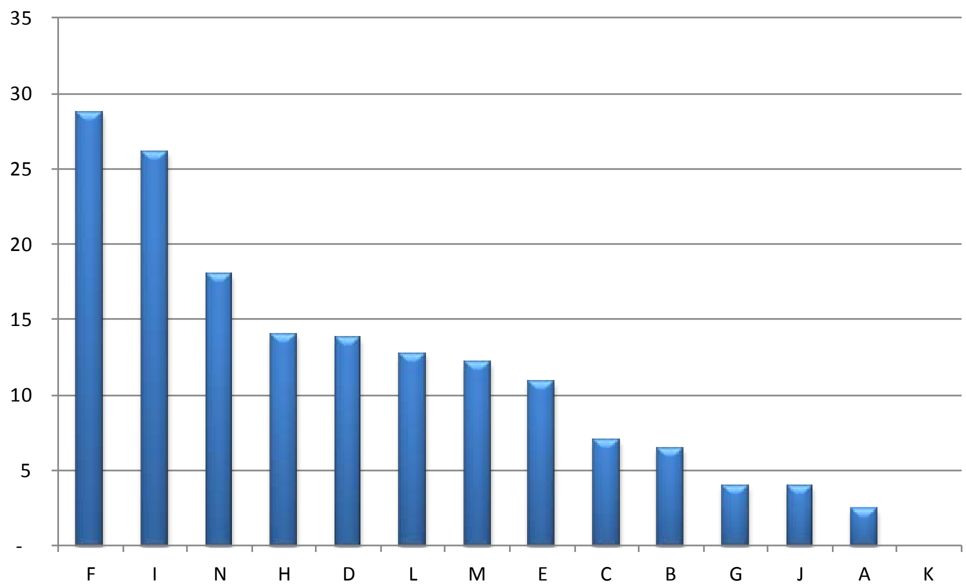

Figure 3-2
Average Number of Signals Measured by Company

Digital Status Points

Digital status points are available to monitor the status of binary conditions in the field. These could be the position of circuit breakers of an associated line connected PMU (open / closed), time clock quality mode (clock sync good), PMU mode (test, normal) or other similar items that may provide context of the condition of the actual PMU data.

The survey results were as follows:

- Five utilities indicated that they do not use digital status points at all.
- Two utilities indicated they collect circuit breaker status associated with the PMU.
- Five utilities indicated they collect multiple digital status points beyond circuit breaker status. Some of these include: time quality /GPS clock status PMU test / maintenance mode, under voltage for both sets of voltage, capacitor/reactor status, and relay transfer switch status.

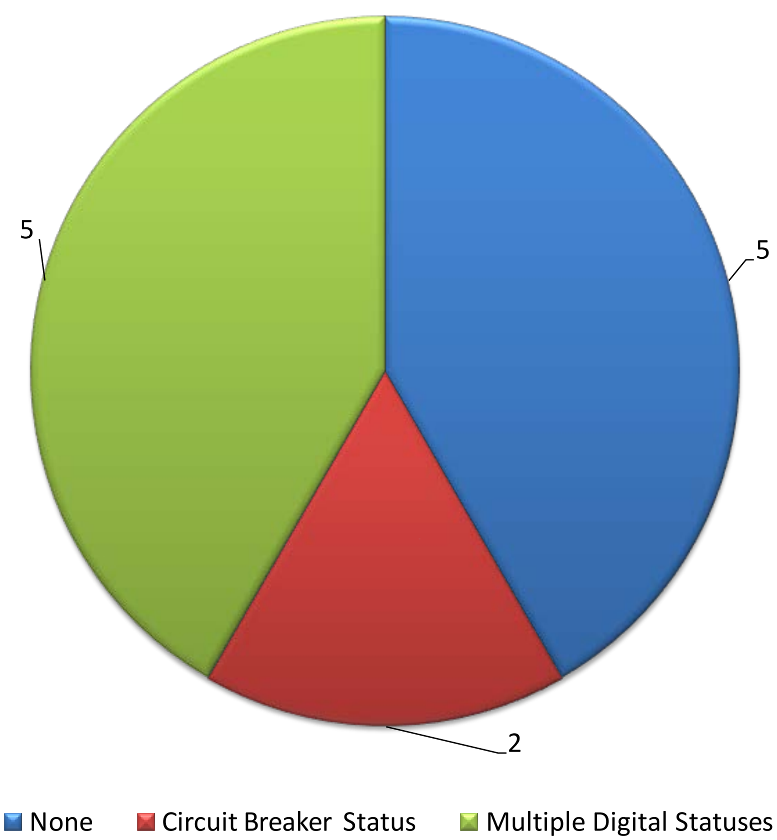

Figure 3-3
Digital Status Point Utilization

Phase Monitoring

The overwhelming majority of companies capture all three voltage phases. Specifically 92% of all respondents capture all three phase voltages

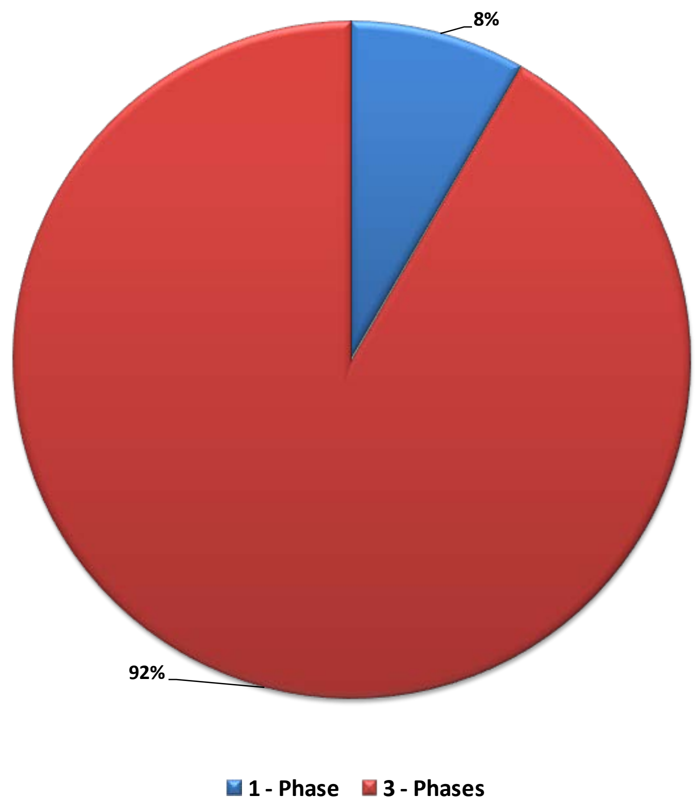

Figure 3-4
Number of Voltage Phases Monitored

The overwhelming majority of companies capture all three current phases. Actually 85 percent of all respondents monitor all three phase currents

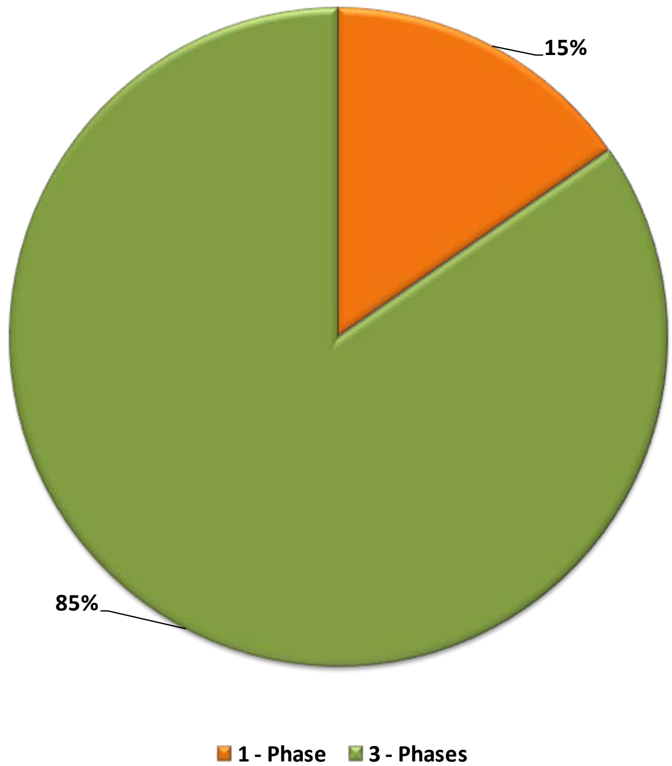

Figure 3-5
Number of Phase Currents monitored

Sample Rate

The majority of the North American utilities use 30 samples per second while the international community uses 20 samples per second. There are a couple of utilities that have adopted 60 samples per second. All things being equal, the higher sample rate will result in a doubling of the data rate and therefore twice the data storage compared to those capturing data at the predominant rate of 30 samples per second.

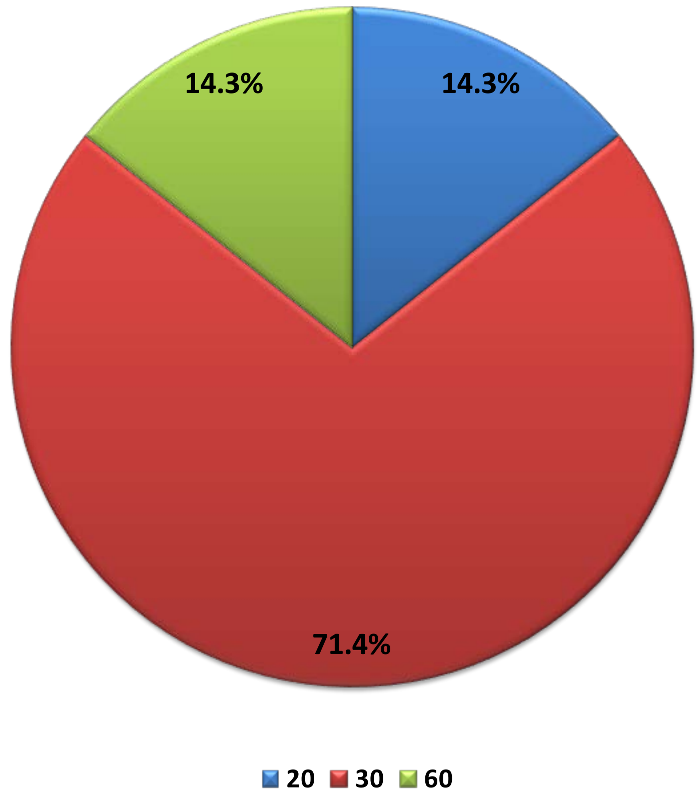

Figure 3-6
Data Sample Rate

Data Volume

Daily Storage Volume

The average daily storage volume per company was 16.4 GB per day. The maximum was 100GB per day and the lowest 10MB.

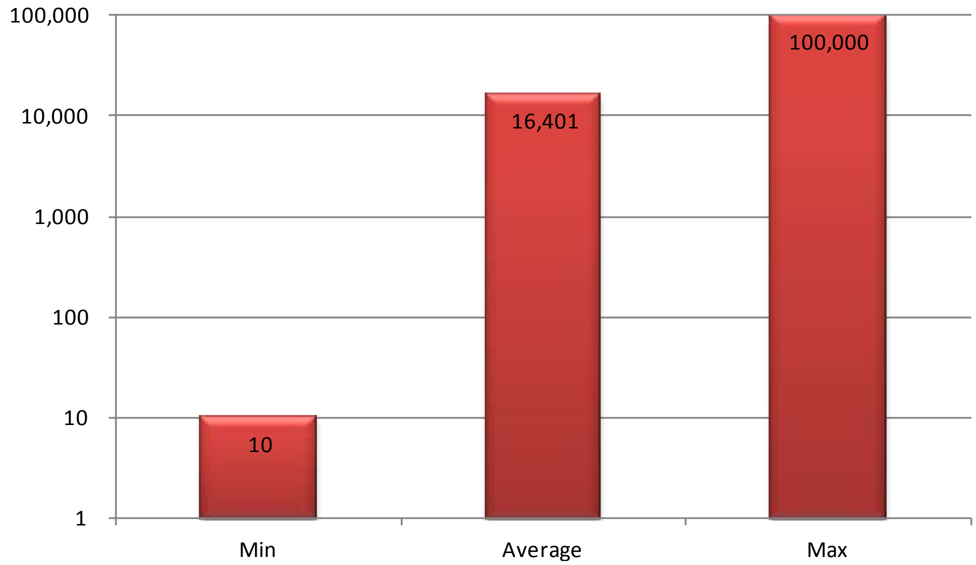

Figure 3-7
Daily storage volume in MB per Day

Volume of data currently stored online (active discs)

The average volume of data currently stored online using active discs was 20,358 GB. The minimum was 5 GB and the maximum was 100,000 GB.

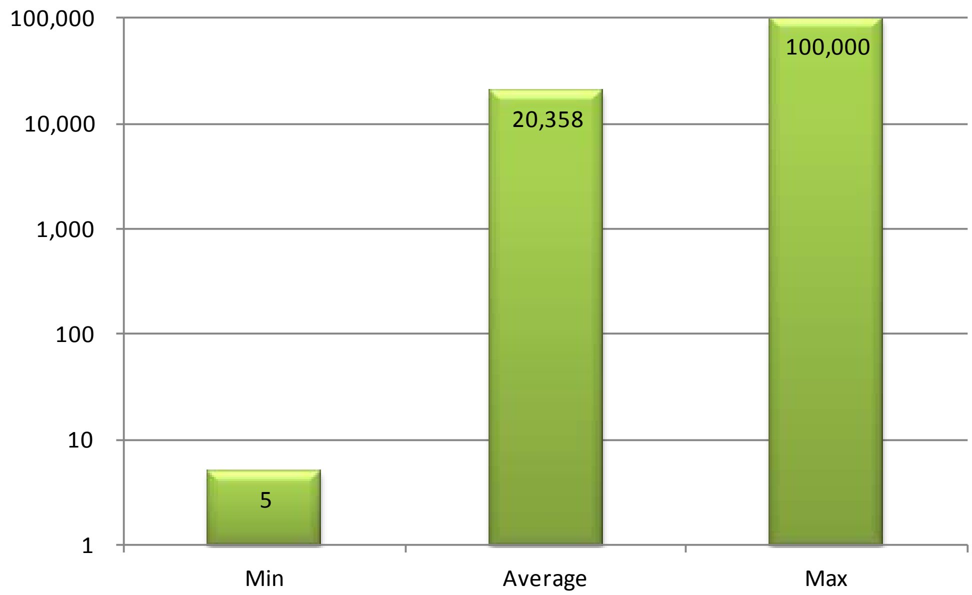

Figure 3-8
Data Volume Currently Store in Active On-line Discs in GB

Volume of Data currently stored off line (Archived)

The average volume of data currently stored off-line (archived) using was 5,183 TB. The minimum was 100TB and the maximum was 20,000 TB.

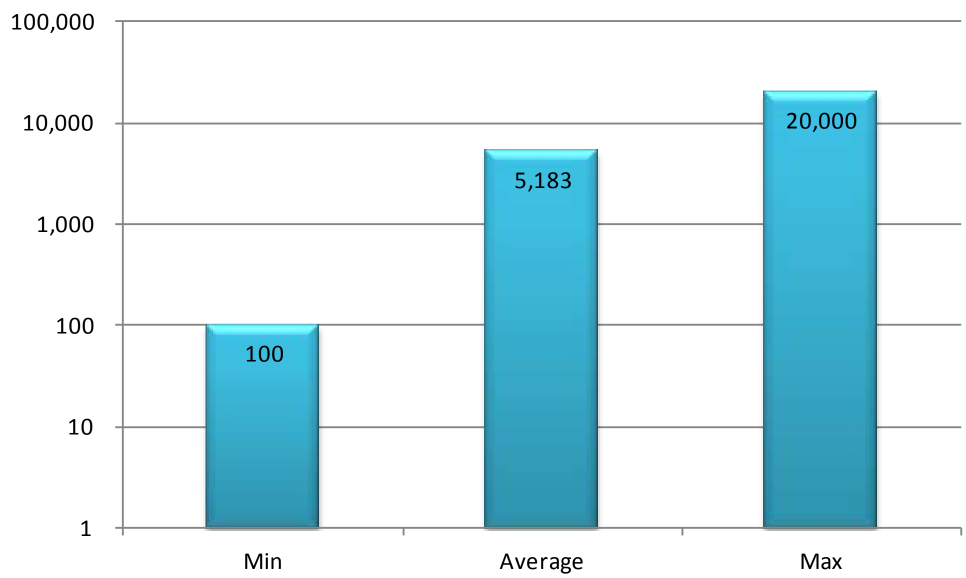

Figure 3-9
Data Volume stored off-line (Archived) in TB

Data Archiving, Retention, Destruction

This section of the survey is seeking to understand the data retention and destruction policy of the participating companies. In general the policies in this area are weak at best. Only about 50% of the participants actually responded to the questions. The following material therefore should be use with appropriate caution.

Archiving

Data archiving is the process of moving data that is no longer actively used to a separate data storage device for long-term retention. Data archives consist of older data that is still important and necessary for future reference, as well as data that must be retained for regulatory compliance. Data archives are indexed and have search capabilities so that files and parts of files can be easily located and retrieved.

Slightly less than half (43%) of the respondents did not provide a response which is indicative of the general commentary at industry events such as NASPI where company representatives say "they are just keeping all the data on-line for now". While this is a suitable stop gap measure for the near term in the long term more responsible data archiving policies will need to be established.

For those companies that did respond the typical data archiving time period is 3 years. Most companies indicated anywhere from daily archiving

The shortest duration for moving data to an archive that was identified in the survey was 30 days before archiving. The majority of responses indicated a policy of 3 years before moving to an archive. The maximum length indicated was 7 years before moving to archive. One company indicated that all data was on-line.

Retention

Data Retention is defined as the act of retaining or to keep possession or ownership of individual facts, statistics, or items of information (2013 Merriam-Webster, Incorporated)

About half of the respondents indicated that they retain their data for 3 years. However about half of the respondents also indicated that they retain their data for 30 days.

Also about half the respondents indicated they retain all events. Many indicated permanent retention of events while others indicated a period of 7 years. One company indicated that all events are retained permanently.

Lastly one company indicated that all data is retained.

Most utilities have not develop firm polices around PMU data retention

It is apparent that data retention is one area in need of attention to clarify the requirements and expectations for synchrophasor data management.

Destruction

Data Destruction the act or process of damaging something so badly that it no longer exists or cannot be repaired (2013 Merriam-Webster, Incorporated)

Once again 3 years was the response by about 50% of the respondents. In other cases about 33% indicated that the data would get destroyed after 30 – 34 days.

One company indicated that no data gets destroyed.

Various methods of destruction were identified. In some cases the action was for the data would get overwritten.

Staff Data Usage

The survey sought to determine who in the utility organization uses synchrophasor data. The survey identified 11 departmental functions and asked how often each department accessed the data. The predominant user of the data is still the Research and Development staff. They are followed by the System Planning and Operations Staff. The breakdown of usage by department is shown in Figure 3-9 below.

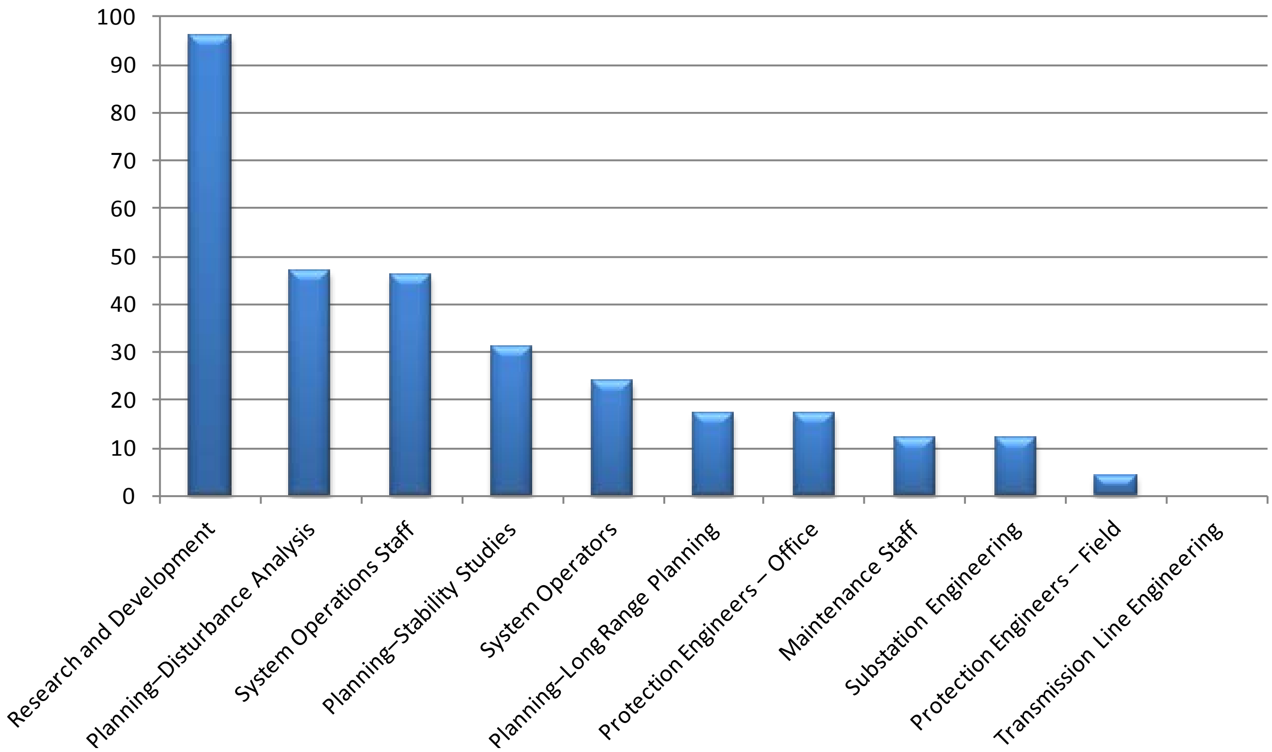

Figure 3-10
Data Usage by Department

Maturity Factor

In an effort to determine a "maturity factor" regarding the usage of synchrophasor data outside the Research and Development group the data was further analyzed to determine which companies have moved beyond primarily an R&D mindset to a broader level of engagement by line organizations. The figure below illustrates that in most companies the R&D department is still a major user of the data. Only two of the surveyed companies indicated that R&D was not a major consumer of the data. In most cases the R&D group was actually a frequent user of the data rather than just a casual or non-user.

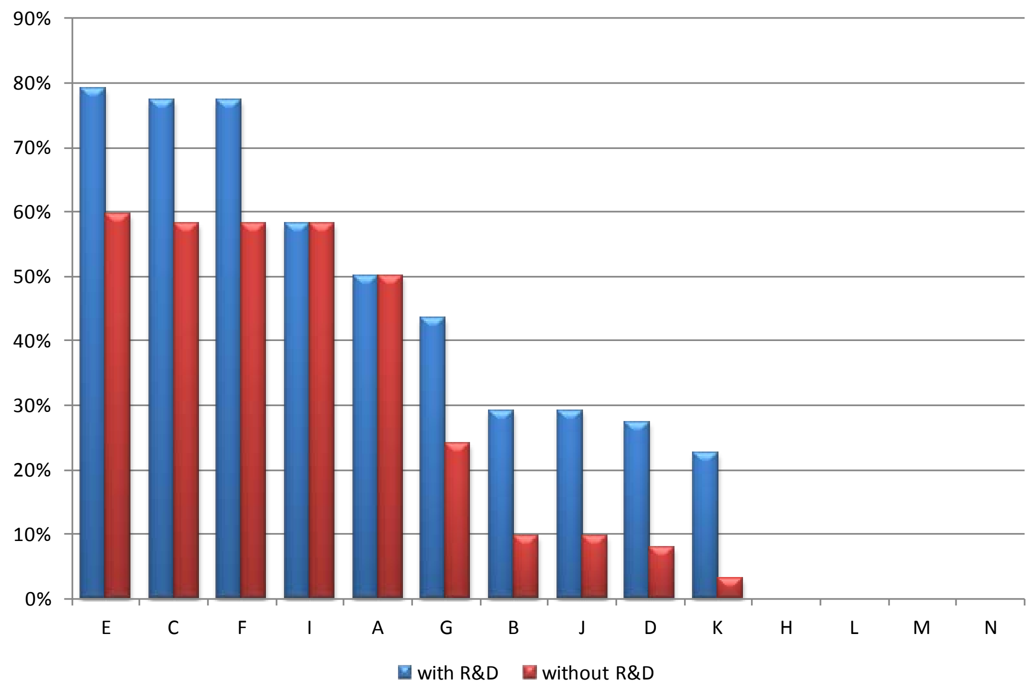

Figure 3-11
Data usage with and without R&D included

Applications Usage

Currently Use

The survey gathered the current usage for twelve applications. Of these twelve only three were in use at a predominant number of utilities. The three applications were Post-Event Analysis, System Condition Monitoring and Voltage Stability. Of these three, Post Event Analysis was the most prevalent being used at 89% or responding companies and System Condition Monitoring and Voltage Stability being in use at 56% of responding companies.

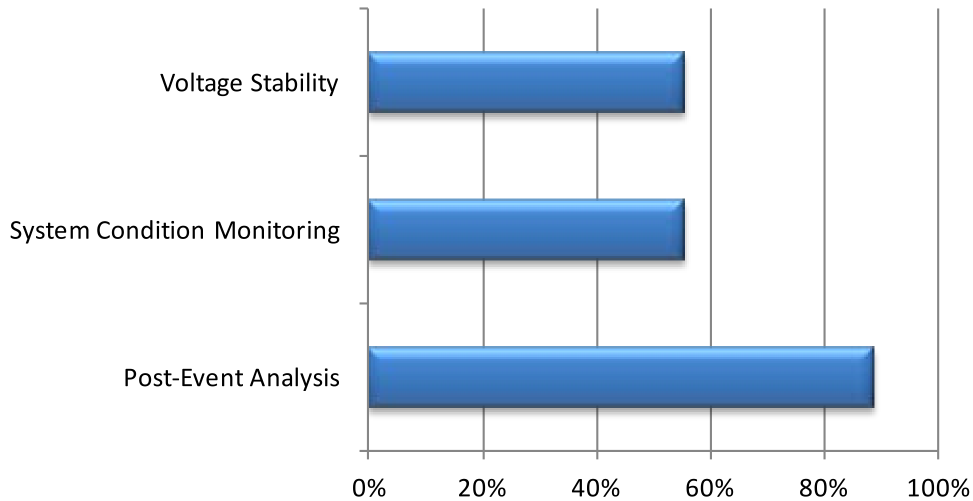

Figure 3-12
Applications Currently in use by Respondents

Plan to Use in the near future (1-3 years)

The next category was "Plan to Use in the near future" and seven applications fell into this category. They are:

- State Estimation
- Modal Analysis
- System Disturbance Management
- General WAMS Alarm Presentation
- Situational Awareness for Oscillations
- Oscillatory Stability Management
- Islanding, Resynchronization and Blackstart

Among this list 67% of responding companies reported interest in using

- State Estimation
- Modal Analysis
- System Disturbance Management

The remaining application had interest from 44-56% of responding companies.

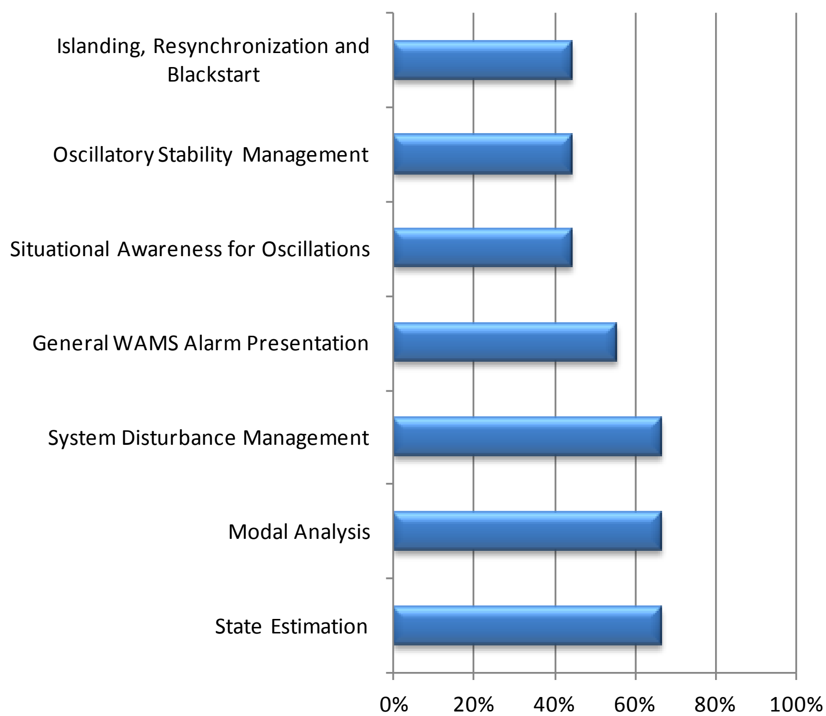

Figure 3-13
Applications Expected to be in Use in 1-3 years

Plan to Use in 4-7 years

The lowest ranking applications were:

- Interconnection of Renewable Resources – 44%
- Dynamic Constraint Management – 33%

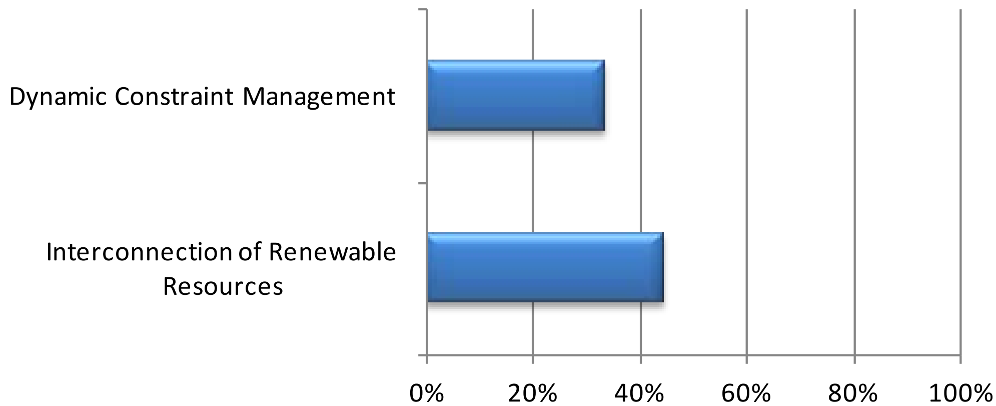

Figure 3-14
Applications Expected to be in Use in 4-7 years

The following table summarizes the responses regarding the use of various applications at respondent companies.

Table 3-1

Synchrophasor Application Usage Summary Table

Application	Percent
Currently Use	
Post-Event Analysis	89%
System Condition Monitoring	56%
Voltage Stability	56%
Plan to Use in the near future (1-3 years)	
State Estimation	67%
Modal Analysis	67%
System Disturbance Management	67%
General WAMS Alarm Presentation	56%
Situational Awareness for Oscillations	44%
Oscillatory Stability Management	44%
Islanding, Resynchronization and Blackstart	44%
Plan to Use in 4-7 years	
Interconnection of Renewable Resources	44%
Dynamic Constraint Management	33%

Section 4: Other Data Sources

While PMU data has frequently been pointed to as a critical new source of information to help power system operators actually run the grid in real time and software tools have been developed to assist them in this area, usage of PMU data in planning or post event analysis mode frequently requires the data to be associated with other grid data to be useful. Some of this external data may include power system topology through time, generation dispatch, load, event information or environmental data such as weather and / or temperature, humidity parameters.

Data Sources

Power System Topology

Power system topology, connectivity of the grid at any point in time, is probably one of the most important external data sources required to effectively use PMU data outside of real-time.

Capturing Topology

The typical approach to capturing system topology is through the use of system snapshots. These snapshots typically store to a file the current state o f the power grid. This included the current state of circuit breakers, line flows, voltages and other relevant system parameters useful to understand or analyze the system at a later time. These snapshots are frequently used to capture system events for post mortem analysis, system peak load or light load conditions or other conditions.

In general, system snapshots tend to be an infrequent event in the context of system operations. However in the context of synchrophasors and their use for post event analysis or other time delayed analysis there is the need to put the data in the context of the system state at the time period of interest. The ability to link the synchrophasor data with the system status is currently not a well established practice within the utility industry.

At the current time most energy management systems have the ability to periodically save the solved state estimation case in a "snapshot" of the grid. While business practices vary among utilities this practice is on the order of single digit minutes. One company reported every 10 minutes while another every 6-8 minutes as their practice. Regardless of the specific time interval there is a significant difference in time intervals between PMU data and the energy management system data storage periodicity.

Merging together of PMU data during a system disturbance along with EMS data adds a level of detail that gets lost when only using EMS data. During an event circuit breakers can open and reclose a number of times and never get captured in the EMS snapshot. However linking these data together is not a trivial task and requires diligent merging of data sets. Further work in this area is warranted.

Another disparity between current practices of EMS data storage and PMU data is that some utilities keep EMS data in circular buffers that over-write after some period of time. However based on feedback in the survey most companies are keeping PMU data for very long periods of time, typically at least three years or longer. This is in stark contrast to the EMS data and here too further work is warranted to establish consistent practices on data storage across the operating data sources to assure appropriate data is kept at an appropriate periodicity.

Event Management and Post Event Analysis

One of the key elements for event management is to be able to capture all of the related data associated with the event. In the case of an event, whether it results in a blackout of a major excursion of the power grid operating parameters it is necessary to capture the data prior to the event and also a period of time after the event disturbance to be able to adequately perform a post event analysis. The notion of capturing all related data includes but is not limited to the following.

- Digital Fault Recorder, Long Disturbance recorder data
- Sequence of Events logs
- Operator Logs
- Synchrophasor data
- System state at the time of the event

The ability to capture all this data from the various sources and assuring related data does not get accidentally deleted can be a challenge. Methods to assure integrity are important and one solution is to enlist the capability of a document management system. These tools create referential integrity between these disparate file types and links them together using relational database mechanisms to assure the individual components are not deleted.

From a synchrophasor data management perspective, the use of a document management system (DMS) would reduce the data storage requirements since all key data could be stored and maintained via the DMS and eliminate the need for multiple copies of primary data such as DFR records or logs, etc. The DMS process can be an efficient mechanism for day to day archiving of a wide variety of data associated with operations including synchrophasors and their associated system data files.

Environmental Factors – Weather, Temp, Humidity, Wind

Other outside data sources may also need to be imported from external sources such as weather. Data such as temperature, wind speed and direction may be needed to study the potential benefit of adding dynamic line rating to a transmission line. Once again having easy access to relevant environmental parameters would allow these types of studies to be carried out with ease.

Section 5: Conclusions

A number of practices tend to be consistent across the surveyed companies. These included the number of phases monitored, sampling rate and signals. One area that was noticeably different was in the use of digital status points. Only about half of the companies capitalize on the precise time stamp associated with PMU based digital status. This may be one design area to re-evaluate by those companies not using this feature.

The predominant sample rate is currently 30 samples per second. However there are two companies currently sampling at 60 samples per second. Also there are some organizations advocating 120 or higher samples per second. Transitioning to these higher sample rates would have a direct impact on the amount of data to store and also on the required bandwidth needed to adequately transport the data.

Daily storage volumes varied widely due to the wide variety of signals monitored and the varied numbers of PMUs are each company.

When it comes to archiving, retention and destruction policies here to the approaches varied but there tended to be a popular default of 3 years for most companies for archiving and retention. Data destruction also varied with most respondents indicating no destruction or others at 3 years. This is an area that needs attention to assure that regulatory and business policies are being adhered to.

Additionally, many in the industry look at the price of hard drives at local electronics stores and see 4TB hard drives for $200.00 USD and are led to believe that the cost of storage is irrelevant. While the cost of the physical media may be irrelevant the associated services performed by IT staff are not.

The current prices for on-line storage of actively managed discs at reputable hosting facility are about $2400 per year for 1500GB of storage. Also assuming that all utilities migrate towards a fairly consistent approach to measurement and storage then the annual amount of disc space needed to store all the currently installed synchrophasor data is about 4,815 TB / Year. The annual cost for storing that amount of data is approximately $7.9 million USD and the amount of data is increasing at the rate of 13 TB/Day.

While the Research and Development staff is still significantly involved in the usage of synchrophasors, the system planning and system operations staff are the next largest groups involved with the data as would be expected.

From a synchrophasor application perspective, the most widely used applications are Post-Event Analysis, System Condition Monitoring and Voltage Stability. Of these three, Post Event Analysis was the most prevalent. A wide range of applications is being considered in the 1-3 year range though.

The need to link synchrophasor data with other power system data was presented along with the challenges in trying to accomplish it presents potential new research arenas.

Further Research

Two areas that may warrant additional research are:

- The merging together of PMU data during a system disturbance with EMS provides a level of detailed data that gets lost when only using EMS data. However linking these data together is not a trivial task and requires diligent merging of data sets and possibly new database techniques.
- The duration of data stored in the EMS as compared to PMU data is vastly different along with the technique used to actually store the data. EMS tending be circular buffers that get overwritten at some interval while PMU data tending to get store in detail for years.

Appendix A: Raw Survey Responses

The responses to the survey that follow have been randomly anonymized to prevent exposing any company's response to the survey. There is not relationship between tables and the company letter listed. Specifically the company listed as A in question 1 is different than company A in question 2, etc.

Companies that provided responses to the survey

- BC Hydro
- Bonneville Power Administration
- Duke Energy
- Entergy Services, Inc.
- ISO New England
- MISO
- New York Power Authority
- NYISO
- Oklahoma Gas & Electric Co.
- PJM Interconnection
- Salt River Project
- Southern California Edison
- Taiwan Power Co

2. This question of the survey is seeking data on number of PMUs installed by manufacturer and the approximate number of signals measured. A signal is a single measurement of a phase voltage or current. For example if your companies approach is to monitor one phase voltage and all three phase currents then you would answer 4 signals

Table A-1
PMUs Installed by Manufacturer

Company	ABB - RES 521	Alstom - MiCOM P847	Arbiter - Model 1133A Power Sentinel	ERLphase - TESLA 3000 or 4000	GE - Multi Function Relay - D60, L90	GE - Dedicated PMU - N60	LogicLab - FR947-EX/PMU	Macrodyne - 1690	Qualitrol - PMU-9/18/36	SEL - Multi Function Relays	SEL - Dedicated PMU - SEL-487E and the SEL-351A-1	Siemens - SIMEAS R-PMU	Other
A				<10				<10			30		<10
B								20					
C													16
D				10					<10	20	20		20
E								<10			<10		<10
F											50		
G											130		
H			40	100							110		
I		<10								<10			
J													
K				20	120			<10		20			
L				20	130			<10		20			
M											120		
N										140			40

Table A-2
Signals Measured Raw Data

Company	ABB - RES 521	Alstom - MiCOM P847	Arbiter - Model 1133A Power Sentinel	ERLphase - TESLA 3000 or 4000	GE - Multi Function Relay - D60, L90	GE - Dedicated PMU - N60	LogicLab - FR947-EX/PMU	Macrodyne - 1690	Qualitrol - PMU-9/18/36	SEL - Multi Function Relays	SEL - Dedicated PMU - SEL-487E and the SEL-351A-1	Siemens - SIMEAS R-PMU	Other
A										2			4
B				6				10			6		6
C								7					
D													16
E				20					7	6	16		7
F								30			24		>32
G											4		
H											14		
I			20	>32							23		
J		4								4			
K													
L				>32	10			10		10			
M				12	12			2		16			
N											18		

Table A-3
Digital Status Points Monitored

Company	ABB - RES 521	Alstom - MiCOM P847	Arbiter - Model 1133A Power Sentinel	ERLphase - TESLA 3000 or 4000	GE - Multi Function Relay - D60, L90	GE - Dedicated PMU - N60	LogicLab - FR947-EX/PMU	Macrodyne - 1690	Qualitrol - PMU-9/18/36	SEL - Multi Function Relays	SEL - Dedicated PMU - SEL-487E and the SEL-351A-1	Siemens - SIMEAS R-PMU	Other
A													
B													64
C								0					
D								0			0		
E										16			32
F											4		
G				0						2			
H				>32	15			0		10			
I													
J		3								3			
K			0	0							0		
L											5		
M											7		
N								0			0		0

Table A-4
Sampling Rate

Company	Samples per Second
A	30
B	30
C	60
D	30
E	20
F	30
G	30
H	30
I	60
J	30
K	20
L	30
M	30
N	30

Table A-5
Data Storage Volume

Company	Daily Storage volume (Amount per Day)	Volume of data currently stored online (active discs)	Volume of data currently stored off line (Archived)
A	2.5 GB		
B	20 GB	10 TB	
C	5 GB	5 GB	100 GB
D	100 GB	20 TB	20 TB
E	20 GB		5 TB
F	500 MB	2 TB	2 TB
G			
H			
I			
J	1 GB		2 TB
K	5 GB	100 TB	
L	10 GB	10 TB	
M			
N	10 MB	500 GB	2 TB

Table A-6
Data Users – Part I

Company	System Operations Staff	System Operators	System Planners – Long Range Planning	System Planners – Disturbance Analysis Staff	System Planners – Dynamic or Transient Stability Studies	Protection Engineers – Field
A						
B	Weekly	Weekly	Quarterly	Monthly	Monthly	N/A
C						Monthly
D	N/A	N/A	Weekly	Weekly	Weekly	N/A
E	Monthly	N/A	N/A	Quarterly	N/A	N/A
F	Weekly	N/A	Quarterly	Weekly	Weekly	N/A
G	Monthly	Daily	Monthly	Monthly	Monthly	N/A
H	Quarterly	Weekly	N/A	Quarterly	Quarterly	N/A
I						
J	Weekly	N/A	N/A	Weekly	N/A	N/A
K	Monthly			Monthly		
L	N/A	N/A	N/A	N/A	N/A	Quarterly
M						
N						

Table A-7
Data Users – Part II

Company	Protection Engineers – Office	Maintenance Staff	Research and Development Staff	Substation Engineering	Transmission Line Engineering
A					
B	N/A	N/A	N/A	N/A	N/A
C	Monthly		Weekly		
D	N/A	N/A	Weekly	N/A	N/A
E	Quarterly	N/A	Weekly	N/A	N/A
F	N/A	N/A	Weekly	N/A	N/A
G	N/A	Weekly	Weekly	Weekly	N/A
H	N/A	N/A	Weekly	N/A	N/A
I					
J	Weekly	N/A	N/A	N/A	N/A
K			Weekly		
L	Quarterly	N/A	Weekly	N/A	N/A
M					
N					

Table A-8
Application Usage – Part I

Company	State Estimation	Situational Awareness for Oscillations	Oscillatory Stability Management	General WAMS Alarm Presentation	Islanding, Resynchronization and Blackstart	Modal Analysis
A	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years
B	Currently Use	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years
C	Plan to Use in 1-3 years	Currently Use	Currently Use	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years
D						
E	Currently Use	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Currently Use	Plan to Use in 1-3 years	Plan to Use in 1-3 years
F	Plan to Use in 4-7 years	Currently Use	Currently Use	Currently Use		
G	Plan to Use in 1-3 years	Currently Use	Plan to Use in 4-7 years	Currently Use	Plan to Use in 4-7 years	Currently Use
H	Plan to Use in 1-3 years	Plan to Use in 4-7 years	Plan to Use in 4-7 years	Plan to Use in 1-3 years	Plan to Use in 4-7 years	Plan to Use in 1-3 years
I	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 4-7 years	Plan to Use in 1-3 years
J						
K	Plan to Use in 1-3 years	Currently Use	Currently Use	Currently Use	Currently Use	Currently Use
L						
M						
N						

Table A-9
Application Usage – Part II

Company	System Disturbance Management	System Condition Monitoring	Interconnection of Renewable Resources	Dynamic Constraint Management	Post-Event Analysis	Voltage Stability
A	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 4-7 years	No interest in using	Currently Use	Plan to Use in 1-3 years
B	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	No interest in using	Currently Use	Plan to Use in 1-3 years
C	Currently Use	Currently Use	Currently Use	Plan to Use in 4-7 years	Currently Use	Currently Use
D						
E	Plan to Use in 1-3 years	Currently Use	Currently Use	Plan to Use in 1-3 years	Currently Use	Currently Use
F	Currently Use	Currently Use	Currently Use			Currently Use
G	Plan to Use in 1-3 years	Currently Use	Plan to Use in 4-7 years	Currently Use	Currently Use	Currently Use
H	Plan to Use in 1-3 years	Plan to Use in 4-7 years	Plan to Use in 4-7 years	Plan to Use in 4-7 years	Currently Use	Plan to Use in 1-3 years
I	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 1-3 years	Plan to Use in 4-7 years	Currently Use	Plan to Use in 1-3 years
J						
K	Currently Use	Currently Use	Plan to Use in 4-7 years	Plan to Use in 1-3 years	Currently Use	Currently Use
L						
M						
N						

Table A-10
Application Performance – Part I

Company	State Estimation	Situational Awareness for Oscillations	Oscillatory Stability Management	General WAMS Alarm Presentation	Islanding, Resynchronization and Blackstart	Modal Analysis
A	Not sure	Yes	Yes	Not sure	Not sure	Not sure
B						
C	Yes			No		
D						
E		Yes		Yes		Yes
F						
G	Yes	Yes	Yes	Yes	No	Yes
H						
I		Yes	Yes	Yes	Yes	Yes
J						
K						
L						
M	Not sure	Not sure	Not sure	Not sure	Not sure	Not sure
N	Yes					

Table A-11
Application Performance – Part II

Company	System Disturbance Management	System Condition Monitoring	Interconnection of Renewable Resources	Dynamic Constraint Management	Post-Event Analysis	Voltage Stability
A	Yes	Yes	Yes	Not sure	Yes	Yes
B						
C						
D						
E		Yes		Yes	Yes	Yes
F						
G	Yes	Yes	No	No	Yes	Yes
H						
I	Yes	Yes	Not sure	Not sure	Yes	Yes
J						
K						
L						
M	Not sure	Not sure	Not sure	Not sure	Yes	Not sure
N					Yes	

Table A-12
Application Value – Part I

Company	State Estimation	Situational Awareness for Oscillations	Oscillatory Stability Management	General WAMS Alarm Presentation	Islanding, Resynchronization and Blackstart	Modal Analysis
A		Yes		Yes		Yes
B						
C	Yes			Not sure		
D						
E	Not sure	Yes	Yes	Not sure	Not sure	Not sure
F	Yes					
G						
H						
I						
J						
K	Yes	Yes	Yes	Yes	Not sure	Yes
L						
M	Yes	Not sure	Not sure	Not sure	No	Not sure
N						

Table A-13
Application Value – Part II

Company	System Disturbance Management	System Condition Monitoring	Interconnection of Renewable Resources	Dynamic Constraint Management	Post-Event Analysis	Voltage Stability
A		Yes		Yes	Yes	Yes
B						
C						
D						
E	Yes	Yes	Yes	Not sure	Yes	Yes
F					Yes	
G						
H						
I						
J						
K	Yes	Yes	Not sure	Not sure	Yes	Not sure
L						
M	Not sure	Not sure	No	No	Yes	Not sure
N						

Export Control Restrictions

Access to and use of EPRI Intellectual Property is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or permanent U.S. resident is permitted access under applicable U.S. and foreign export laws and regulations. In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI Intellectual Property, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case-by-case basis an informal assessment of the applicable U.S. export classification for specific EPRI Intellectual Property, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes. You and your company acknowledge that it is still the obligation of you and your company to make your own assessment of the applicable U.S. export classification and ensure compliance accordingly. You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of EPRI Intellectual Property hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 30 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together...Shaping the Future of Electricity

Program:

IntelliGrid

3002000605

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com