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Lessons Learned in PMU (SynchroPhasor) at AEP

C. SCHNEIDER, A. VENO, B. JOHNSON, D. SAURIOL, K. CHAN
American Electric Power
USA

SUMMARY

As part of its system and asset health management initiative, American Electric Power (AEP) has entered into an expansive asset monitoring program that includes aggregation and analysis of asset condition and performance data from a variety of information streams. There are numerous benefits to this asset monitoring program. One example is failure prevention, which provides financial and safety benefits to AEP. Other benefits include: reduced maintenance costs, increased situational awareness of issues (wiring, bad traditional sensors, grounds, etc.), and asset renewal justification. The asset monitoring program brings data together from several sources. One source is from the installation of new asset monitors that provide real-time data to asset condition algorithms. Another source of information is the traditional asset management data maintained in the asset management system. This type of data is related to offline manually performed measurements, visual inspections, and nameplate information. Additionally, loading and temperature data for assets is collected and analyzed from AEP's supervisory control and data acquisition (SCADA) system. The Asset Health Center software provides health, replacement priority, and maintenance scores for assets within the AEP system utilizing the above mentioned data sources. Additionally, these smart monitor devices provide instantaneous alarms to AEP's Transmission Operations Center, which enables the utility to prevent equipment failures.

Another data source for system and asset monitoring is relay data. There are many aspects of relay data used by various groups to monitor the system and assets at AEP. For example, relay data can be used to determine faults, measure voltages and currents, count number of operations, and provide various other useful data points. AEP is beginning to expand its use of relay data regarding Phasor Measurement Units (PMU) & SynchroPhasor data with key stakeholders. This paper will explain the lessons learned by AEP regarding data benefits, improvements, and processes surrounding PMU (SynchroPhasors).

KEYWORDS

Asset health, Phasor Measurement Unit (PMU), SynchroPhasor, RTOs, grid, monitoring

cmschneider@aep.com

I. Introduction:

Regional Transmission Organizations (RTOs) have been tasked "to ensure the safety, reliability, and security of the bulk electric power system" [1]. AEP along with many other utilities provides system data to the RTOs that manage their service territories. For AEP, the three main RTOs include: Pennsylvania New Jersey Maryland Interconnection LLC (PJM), Electric Reliability Council of Texas, Inc. (ERCOT), and Southwest Power Pool (SPP). AEP provides PMU data daily to these key stakeholders.

The AEP Transmission Operations (TOps) group is also a key stakeholder for PMU data. The TOps group is beginning to analyze and evaluate PMU data to eventually make grid decisions, linear state estimation, and event analysis. Having this data available, for analysis and optimization of the grid is a tremendous benefit to AEP's TOPS group.

Another key stakeholder of PMU data are the internal AEP teams that conduct event analysis. With PMU data, the Transmission Field Services (TFS), engineering standards, and Advanced Transmission Studies & Technology (ATST) teams can conduct event analysis to help pinpoint areas in the bulk electric system that have a reliability issue or a disturbance that would damage equipment and weaken the power grid. For example: system oscillations can be caused by distributed energy resources (DER) such as solar and wind farms. PMU data can be used to locate the oscillation source and evaluate the impact of the oscillations on the grid and power equipment.

Many key stakeholders rely on this data to make critical decisions to maintain the safety, reliability and security of the grid. It is vital that PMU data has a standard process for implementation across AEP.

II. What is a PMU?

The Phasor Measurement Unit (PMU) is a function of a relay that reports the magnitude and phase angle of an analog and/or derived phasor with respect to the global time reference, as per the SynchroPhasor standards (IEEE 1344, IEEEC37.118). The current standard is IEEEC37.118-200 - "**Description:** Synchronized phasor (SynchroPhasor) measurements for power systems are presented. This standard defines SynchroPhasor, frequency, and rate of change of frequency (ROCOF) measurement under all operating conditions. It specifies methods for evaluating these measurements and requirements for compliance with the standard under both steady-state and dynamic conditions. Time tag and synchronization requirements are included. Performance requirements are confirmed with a reference model, provided in detail. This document defines a phasor measurement unit (PMU), which can be a stand-alone physical unit or a functional unit within another physical unit. This standard does not specify hardware, software, or a method for computing phasors, frequency, or ROCOF." [2]

AEP utilizes two specific relays the GE L90/D60/N60 and SEL4xx relays for SynchroPhasor applications.

A SynchroPhasor is a phasor that is stamped with an extremely precise and accurate time reference. In essence, it is a solid-state relay in conjunction with a global positioning system (GPS) clock. They continuously measure voltage and current phasors along with other key parameters, recording them with a time stamped message. All of this data is then transmitted to a local or remote receiver at rates of up to 90 samples per second. SynchroPhasor data that is transmitted to RTOs has some basic requirements for latency and data quality. If the data is received too late by the RTO, it is not useful to grid operators. Missing data can also cause problems, thus a. Current RTO requirements for latency and data quality are described in Table 1.

Table 1: Current and Future RTO Requirements for SynchroPhasor data

	Current RTO Requirements	Future Improvements
Latency	Current readings at maximum latency of 500 milliseconds	Improve to 350 milliseconds over next 2-5 years
Data Quality	Handshake agreement @ 95% uptime for good data	Improve to 99% over next 3-5 years

III. Benefits of PMU Data

1. Regional behavior may be understood from local measurements
2. Phasor measurement data can be used to supplement or enhance existing control center functions and provide new functionalities
3. Phasor measurement data associated with a GPS time stamp can deliver a synchronized voltage and current phasor measurements across a wide region
4. By measuring the phase directly, the power transfer between buses can be computed directly
5. Disturbance monitoring –Transient and Dynamic responses

IV. Lessons Learned and Knowledge Gained

Previous Process and Architecture prior 2018

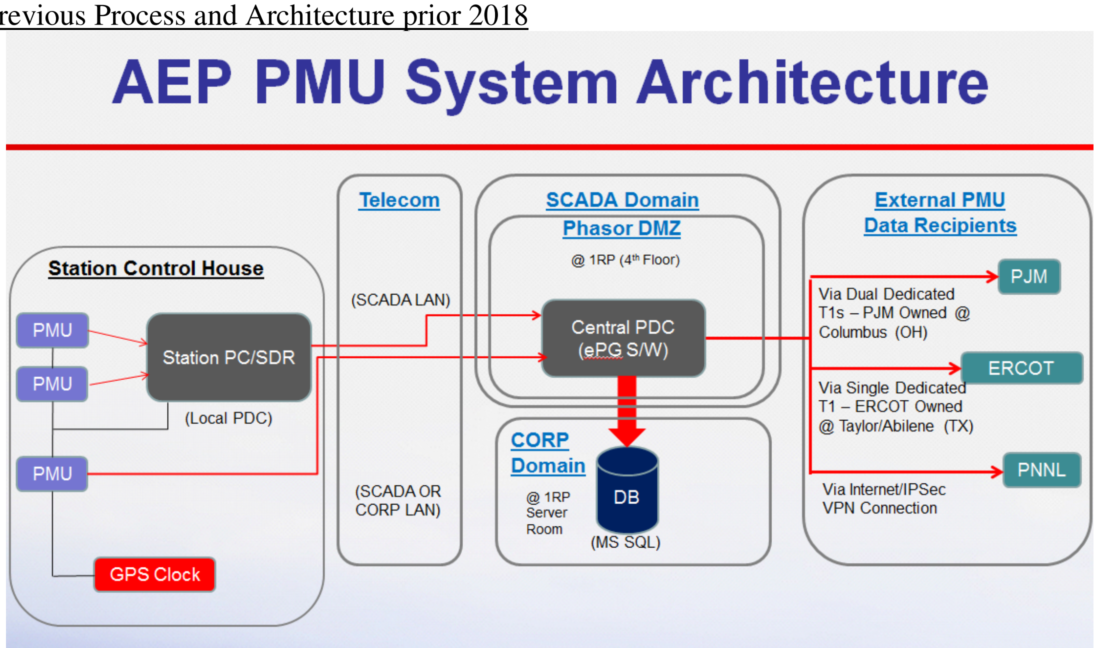

Figure 1: Pre-2018 AEP PMU architecture

AEP has proactively made good protection relay choices to enable the future of PMUs. The relays chosen as standard have PMU capabilities that just need "turned on" or enabled for the relay to start streaming PMU data.

Initially a protection relay would be installed without PMU functionality turned on. If it was determined by that the PMU data was needed for that location, then a multi-step process was initiated. First, the relay at the requested location was reviewed to ensure the PMU capability was available. If the relay is capable, then the AEP Telecom team performed an analysis to ensure that there was the proper data bandwidth available at the substation to enable the PMU functionality and data flow. Finally, after all verifications were completed, the protection relay and Central PMU data processing server settings were set to enable the data stream. At this time, data was routed from the relays through the Station Data Repository (SDR), through the AEP corporate local area network (CORP LAN) to the Central PMU server. The Central PMU server would then send the data in streams to various stakeholders. The three streams prior to 2018 were to PJM, SPP, and ERCOT. This data flow is pictured in Figure 1.

With regards to where PMU data streams are located on the AEP grid, a PMU Placement Strategy document has been created. This strategy is a baseline that AEP uses to place PMUs at various locations on the grid. The strategy has the flexibility to change based on stakeholder requests.

Over recent years, the number of PMU installations has grown exponentially. AEP's architecture was not able to keep up with the demand, required by all the new PMU data streams. There was no backup for the PMU server. There was no backup for the PMU historical database. The system worked well with 100 PMUs or less, but as AEP's PMU footprint and usage criticality have grown, the required operational systems needed to be overhauled.

2018 Process and Architecture

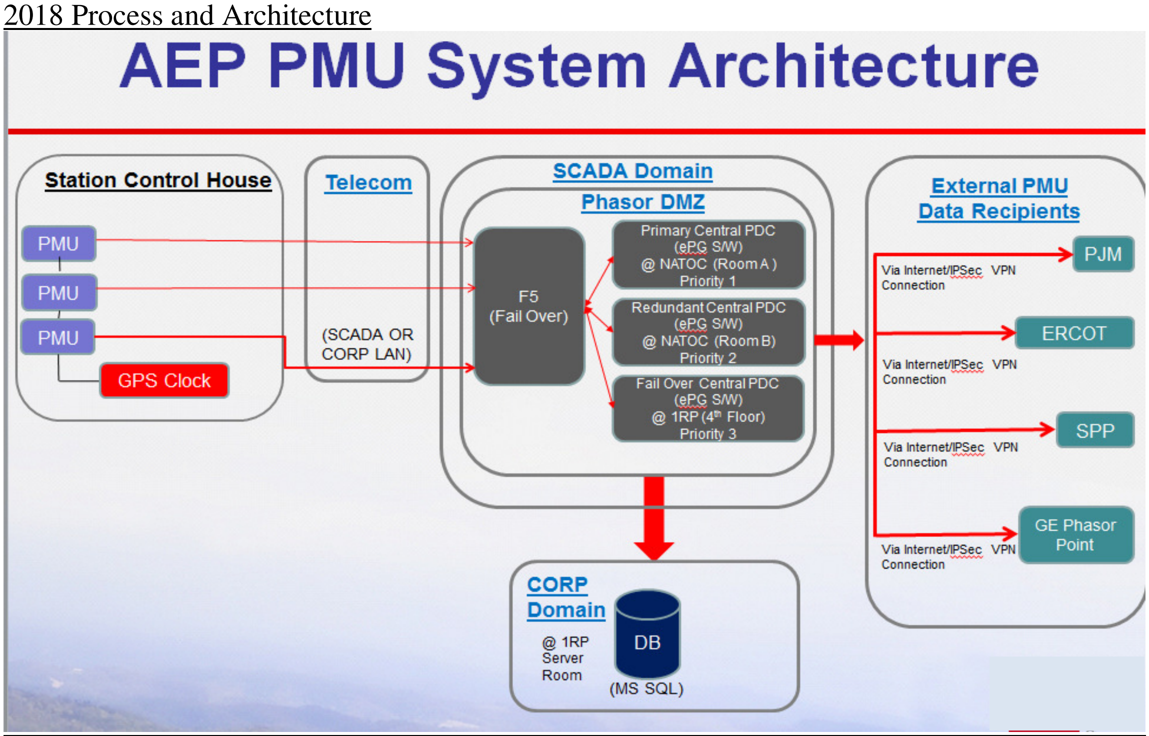

Figure 2: 2018 AEP PMU Architecture

As of July 2018, AEP had over 205 PMUs in service, with the AEP PMU system more than doubling in the past few years. This growth has caused AEP to re-evaluate the PMU architecture and processes.

When supplying data to RTOs, issues emerged of data quality, latency, and up time. To help resolve some of these issues, several solutions were implemented in 2018.

One solution was related to telecom strategy. The ATST group worked with the Protection and Control standards team and AEP telecom team to give a higher priority to PMU data, fixed several router issues, and a project was created to modernize the fiber infrastructure.

Another solution was related to the PMU architecture and reliability. Direct connection of PMUs to the Central PMU server eliminated the possible failure and/or downtime of the SDR computer. A failover system was implemented with an F5 big-IP Local Traffic Manager that allows the system to failover automatically to a secondary server if the primary server becomes unavailable. By implementing this backup architecture, downtime from central server availability is minimized, resulting in overall higher up-time to the RTOs. The final aspect is working with the Transmission Operations team to implement a backup server database for historical PMU data. This new architecture is showing in Figure 2 above.

The final part of the PMU architecture and process improvement solution has been working with the Transmission Field Services on improvements to technology and PMU process. The ATST team has been trained on many functions related to PMU possible issues related to data quality and uptime. The field services group can then be contacted directly to work on GPS clock fixes, relay setting problems, power issues, and any other station related actions.

V. Next Steps in AEP SynchroPhasor

AEP's goal is to continue to install new PMUs across the footprint for the usage by the various stakeholders. AEP will evaluate new PMU placement strategies based on additional feedback from the stakeholders at the RTOs and TOps.

The current AEP PMU data goal is 99% data quality and 99% data uptime to the RTOs and TOps. AEP will be focusing on real time tools and alerts to help analyze issues in real time rather than reactively as has historically been the case. These new real time tools and alerting systems will assist AEP in utilizing PMU data to the fullest extent possible. The telecom modernization projects across the AEP footprint will allow for increased bandwidth and more stability for PMU data moving forward.

A new tool named GE PhasorPoint has been implemented by the AEP Transmission Operations team to allow them to analyze the grid in real time. This new tool in conjunction with PhasorAnalytics will create more opportunities to use PMU data for analysis and studies so AEP can better protect and maintain the grid.

AEP is also looking to incorporate Linear State Estimation. LSE is an advanced PMU application that builds off traditional state estimation techniques to not only estimate the system state but also validates incoming measurements, and calibrates the measurements through filtering. With the dedicated synchrophasor measurements, communication and system model topology, the entire system can be designed to be independent of the conventional EMS/SCADA system. This provide a backup to the conventional SE solution if it fails to converge as well as provides another solution upon which to validate results. This will be a multi stage approach over some period of time. There is currently a core team assigned to this project with vendor evaluations currently underway.

VI. Conclusion

The existing grid needs to be kept safe and reliable. To help ensure this, real time data on the health and condition of the grid is necessary. AEP has gone "all-in" on PMU functionality and data flow.

AEP has made many improvements and changes to increase the availability and reliability of the PMU system to their stakeholders. Key improvements include:

1) Telecom improvements including bandwidth increase, prioritization, and router replacement
2) IT architecture improvements including server redundancy, failover functionality, and server backups
3) Process improvements including relay training, increased field engagement, and better PMU monitoring functionality

Overall, the PMU data and reliability have been increasing over the last few years even as AEP has continued to grow its PMU locations across the grid. The process of learning and improving is never ending for this expanding technology that has so many uses.

BIBLIOGRAPHY

[1] "Who we are mission-vision." PJM © 1999-2018. All rights reserved. http://www.pjm.com/about-pjm/who-we-are/mission-vision.aspx

[2] "C37.118.1-2011." © Copyright 2018 IEEE – All rights reserved. https://standards.ieee.org/findstds/standard/C37.118.1-2011.html