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CIGRE US National Committee 2014 Grid of the Future Symposium

Increase Power Grid Stability and Reliability with Enterprise Historians for Synchrophasor Data Management

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SUMMARY

This paper examines the components of a wide area measurement system (WAMS) and the significance of data historian technology to the success of WAMS. WAMS are increasingly implemented across North America with the goal of improving grid reliability to avoid power outages and disturbances. WAMS produce synchrophasor data, collected by phasor measurement units (PMUs) and aggregated by phasor data concentrators (PDCs), for use by grid operators to increase situational awareness. The data details the magnitude and angle of the phase vector of electrical waves on the transmission grid with highly accurate time stamps, providing real-time insight of the grid.

Because synchrophasors are typically gathered at 60 samples per second, data historian software is required to manage the massive volume and velocity of data from WAMS. Data historians are already in use by most utilities in North America and their scalable architecture allows for expansion to manage synchrophasor data streams. A historian can interface directly with PMUs and/ or PDCs using the IEEE C37.118 protocol, in addition to storing and archiving data from other systems, including SCADA systems, to provide additional measurements and insight into how the grid is performing.

In addition to providing collection and storage capabilities, historians allow access to synchrophasor data for a variety of online and offline applications including real-time operations displays, root cause studies and event analysis (phase angle separation, frequency excursions, etc.). Historians provide grid operators and engineers with the ability to display data in a variety of animated view screens, trends and reports to maximize actionable insights from synchrophasor data. Engineers and operators are able to use these capabilities to increase situational awareness, provide early warning of transmission issues, analyze data to prevent future issues and ultimately improve service for customers.

Data historian software is also able to interface with existing operational and business systems throughout an organization to provide the most comprehensive insight into grid health, creating opportunities for grid operators and engineers to improve grid stability and reliability.

KEYWORDS

Smart Grid – Electricity Transmission – Phasor – Real Time – Data Collection – Observability – Fault Analysis – Reliability Improvement – Power System Stability – Transmission Performance

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The U.S. power industry has made significant strides since the wide-spread Northeast blackout of August 2003 that impacted approximately 50 million people in North America. People from Ohio, to Ontario, Canada and east to New York City were left without power for anywhere from several hours to almost four days (Hoffman, 2013). The catastrophic loss of power cost the United States economy an estimated \$4 to \$10 billion (Final Report, 2004). The event, which started in Ohio and quickly escalated, exposed vulnerabilities of the electric power grid and highlighted the need for increased wide-area visibility and situational awareness among electric power providers.

In the 11 years following the blackout, much has changed. New regulations, including the Energy Policy Act of 2005 and the Energy Infrastructure Security Act of 2007, were enacted to increase compliance with reliability standards while increasing power grid resiliency (Hoffman, 2013). Endless reports detailing the causes and total impact of the blackout were published alongside recommendations for industry improvements. Significant grid modernization investments continue to be made in an effort to avoid similar large scale blackouts; power companies are adopting new technologies that streamline processes, automate actions, analyze data streams and enable smarter decisions in real time. Utilities are gaining more insight on grid conditions that is leading to better management of T&D assets and systems. Transmission efficiency is improving through early warning of issues and increased information about demand. And ultimately, customer service is being improved through the avoidance of outages.

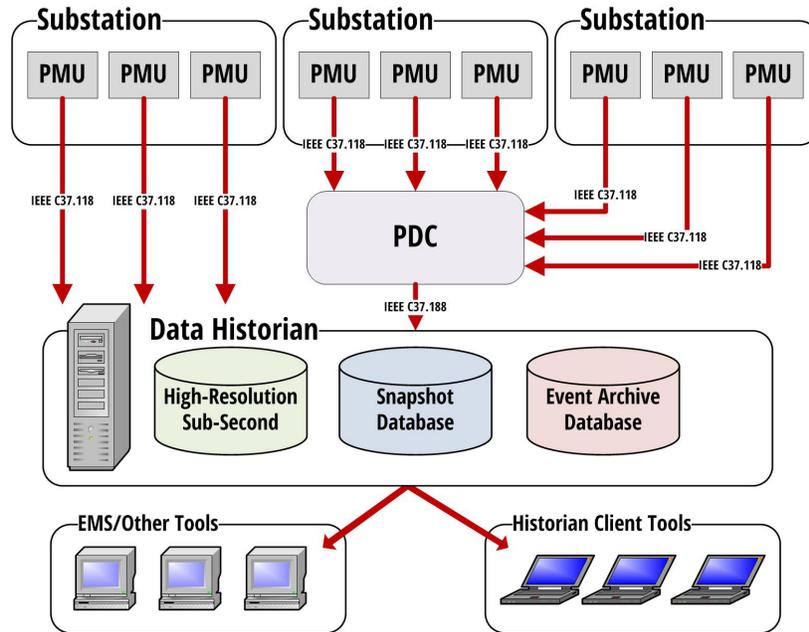
Wide-Area Measurement System Components

One such investment creating significant advancement in the modernization of the power grid centers on the deployment of wide-area measurements systems (WAMS). According to research by Gartner, WAMS improve grid performance and help deter major transmission issues that can disrupt service by providing increased system observability and situational awareness. WAMS are becoming more important today because of the growing diversity of power sources and lower predictability levels of renewable sources (Rhodes, 2013).

WAMS are comprised of phasor measurement units (PMUs), phasor data concentrators (PDCs), communication networks, and centralized data collection and analytic systems (real-time historians). The components work together to provide grid operators with real-time insight on grid conditions. A PMU is a piece of hardware installed at a substation that is responsible for gathering data about voltage, current and magnitude of electrical waves on the transmission grid. While the IEEE C37.118 standard allows sampling rates from 10 to 120 per second, 60 samples per second are typically recorded. Grid operators and engineers use this data for a number of online and offline applications related to grid visibility, stability, resiliency, transmission and forensic analysis, among others.

Once the data has been collected, it is transferred to a PDC and is aggregated into a single data stream for use by power companies across geographic areas. The data is time-coordinated through a GPS time stamp and becomes known as a “synchrophasor,” detailing the magnitude and angle of the phase vector, the time of the sample and the accuracy of the time stamp. The time stamp is used to calculate energy flow and assess “grid health” and also allows utilities across and within regions to correlate and share information, giving them wide-area visibility of grid conditions (Rhodes, 2013). Once aggregated in the PDC, real-time historian software collects and archives the data while making it available for advanced analytics and visualization to improve situational awareness. A historian can also interface directly with PMUs and archive data from other systems, including Supervisory Control and Data Acquisition (SCADA) and Energy Management Systems (EMS), to provide additional measurements and insight into how the grid is performing.

Figure 1



Synchrophasors Require Massive Data Storage Capabilities

The magnitude and velocity of synchrophasor data can easily become overwhelming to even the most experienced grid operators. For instance, 20 PMUs collecting 60 samples per second could create 1 GB of data per day, or 30 GB in one month. A SCADA system is not equipped to handle synchrophasor data because of the sheer velocity of sampling and recording required to identify subtle grid oscillations. Rather, centralized real-time historian software is needed to manage the volume and velocity of data generated from WAMS. Real-time historian software is preferred for WAMS data because of its abilities in data storage, short and long-term archiving, time-series data aggregation, reporting capabilities and analysis functions (Rhodes, 2013).

In order to keep analytical systems and computer networks from becoming too stressed, best practices suggest storing raw synchrophasor data online for a period of about three months. However, time-aligned “snapshot” data and event/disturbance data requires less storage and is typically kept in an online archive for many years. The primary reason to maintain different archives is because the use of the information varies. For example, when a disturbance occurs engineers will typically want to view the trends leading up to the disturbance and overlay multiple disturbance events on the trend.

Historian for Synchrophasor Data Management

Real-time historian software is an essential application to a successful WAMS project, providing power transmission companies with the tools required to gain the highest return on synchrophasor data. When implementing a WAMS, it is important that the utility selects a real-time historian that has a proven capability to manage synchrophasor data. Utilities should ensure that the historian of choice uses highly secure data storage and archiving techniques while meeting NERC CIP requirements in addition to transferring information through the standard synchrophasor protocol IEEE C37.118. Scalable real-time historian software with low latency, high-availability and redundant configurations minimizes data collection, storage and retrieval challenges while creating opportunities for new applications and uses of the data through advanced client tools.

Real-time historians simplify the data collection process by gathering multiple streams of data into one centralized system. Without a real-time historian, engineers would have to analyze synchrophasor data

from multiple different files and sources, all of which would be uniquely formatted and require significant exporting, file parsing and time alignment. It would take days for an engineer to compile such information for analysis. Instead, a historian is able to interface directly to the PMUs and/or PDCs to efficiently and accurately collect the synchrophasor data.

Utilities require different resolutions of synchrophasor data for various use cases including real-time operations, root cause studies and event analysis (phase angle separation, frequency excursions, etc.). Special database provisioning is needed in order to achieve rapid retrieval from historical archives, in addition to real-time services. Real-time historian software is equipped with advanced archiving capabilities to handle the specific data storage and retrieval requirements of WAMS. For example, a historian can be configured to easily retrieve, display and trend raw data, snapshot data and event data.

Organizations gain additional value by using the enterprise real-time historian to display synchrophasor data in view screens, trends and reports that grid operators can easily understand. With access to the synchrophasor data through a historian, grid operators are able to react to disturbances quickly and with more information to avoid potential service outages. Some visualization methods include phase-angle compass charts, trend plots and geospatial contour maps. These visualization and analytic tools are designed to identify grid stress points in real time, allowing for quick and informed decision-making by grid operators and engineers. In addition, the historian software makes this information available to all authorized personnel within the enterprise to improve understanding of conditions across the entire grid network, resulting in increased situational awareness and more stable operation.

Historians can also provide early warning of issues through alert notifications that are sent to grid operators, enabling immediate responses to maintain grid stability and to avoid further problems. A data point stored in the historian not only has a value, a timestamp and a status, but also contains a range of values that will notify a user if the point is reaching alarm status, currently in alarm or exiting alarm status. If a value exceeds a specified threshold, an alarm in the form of an email, a sound or a visual alert, will be sent to the appropriate personnel. Alerts can also be created with an expression, wherein an alert would be triggered if two or more data points reach specified thresholds. Alerts are characterized by the value's deviation from its normal operating range, with high values referring to a value that is above the normal range. One way of characterizing an alert is as follows: High Out-of-Range, High Alarm, High Warning, Low Warning, Low Alarm, and Low Out-of-Range. Configuration difficulty and customization capabilities vary depending on the historian software being used.

After an issue has been identified by the data historian, operator reactions are determined by the plant's protocol. However, alarm notification emails can be configured to include reports, trends and any other information necessary for determining the correct action. For example, the customizable email could include a list of steps to be taken should a value reach a certain threshold. Some systems work with a remedial action scheme that details appropriate actions.

For example, engineers can use real-time historian software to create view screens that display frequency and rate of change of frequency, magnitude and angle of a phasor in real-time. Appropriate personnel are immediately notified when collected measurements begin to diverge or deviate from normal conditions. Grid operators can then take action to correct grid oscillations or other problems that could lead to service interruptions. The engineers and operators are also able to use real-time historian view screens and historical trending capabilities for further analysis to prevent similar issues in the future.

When dealing with real-time monitoring and alarming, PDC latency can be of concern and varies with the communication network. PDC latency of a few seconds is acceptable. However if the latency is any longer, all data for the station would be marked unreliable until new data is retrieved. The operator monitoring the system would be immediately notified of the latency.

The historian accommodates information from other sources such as energy management systems and non-electrical system data (weather, traffic, fire, earthquake, etc.). This system provides the grid operators with visibility into power system dynamics and a real-time wide area view of the grid.

Conclusion

With power outages costing the U.S. economy between \$18 and \$33 billion a year, it is critical for electric utilities to take every action to deter avoidable outages and ensure that an event like the blackout of 2003 does not occur again (Economic Benefits, 2013). WAMS and synchrophasor data management projects are expanding across North America and will continue to prove invaluable as the grid becomes more resilient and reliable.

Some common benefits from synchrophasor data management projects include improved situational awareness, improved observability and early identification of transmission issues and instabilities. Because of improved situational awareness and observability, transmission capacity can be determined in real-time and energy loss can be minimized as transmission lines can be ran at optimal levels. Synchrophasor technology provides early warnings of potential grid issues and immediately alerts grid operators of any disruptions, leading to an improved service experience for consumers. Grid operators can also determine the cause of faults and their sequence of events by analyzing the high-fidelity, time-stamped synchrophasor data. Engineers and operators can review reports and trends over time to ensure that mistakes are not repeated. Planning, operations and maintenance costs are reduced through grid reliability and efficiency improvements.

Synchrophasor measurements were developed in the late 1980s, however, the technology adoption rate has been slow until recently. With a growing interest in diversifying energy sources, reducing outages and building a more resilient and reliable grid, synchrophasor projects are being funded by the U.S. government and are becoming more widely implemented. According to the Department of Energy, the number of installed PMUs has grown from less than 200 in 2009 to more than 1,700 today (Hoffman, 2014).

As WAMS projects are being deployed, the demand for advanced, secure technology solutions is continuing to expand. Because of the high-velocity data streams associated with synchrophasor projects, highly reliable and scalable enterprise real-time historian software is required for effective data management including collection, storage, visualization, analysis and reporting. Successful management of the data allows grid operators and engineers to make quick and informed decisions that solve grid transmission problems and help prevent the occurrence of disturbances and wide-spread blackouts. Ultimately, synchrophasor technology is only as useful as the resulting actionable insights.

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