Progress Toward a High-Speed Data Network for the Eastern Interconnection – The Eastern Interconnection Phasor Project

Matt Donnelly, Paul Barber, and Jim Dyer

Abstract—**The Eastern Interconnection Phasor Project seeks to improve power system reliability through wide area measurement, monitoring and control. The project is being executed by a work group comprised of transmission owning utilities, hardware and software vendors, system operators, reliability councils and government. There are currently four data concentrators and over two dozen suitable measurement units installed within the purview of the project. Project participants are currently installing hundreds of additional hardware devices and developing and deploying software applications to make use of the newly-available information. Future plans call for a comprehensive network of instruments spanning the entire interconnection and feeding applications such as state estimators, voltage monitoring and alarming applications, and planning tools. Participation by interested stakeholders is welcome.**

Index Terms—**Power system measurements, power system monitoring, power system reliability.**

I. Introduction

MOST would consider the US Department of Defense global positioning system (GPS), now approaching its ten-year anniversary, to be the enabling technology for accurately time-synchronized measurements within the power system. However the industry has found that it takes much more than an accurate and inexpensive time source to bring together a wide area, time synchronized measurement network. The participants in the Eastern Interconnection Phasor Project (EIPP) believe that all of the factors necessary to bring the vision of improved power system reliability through wide area measurement, monitoring and control are now in place. These factors include not only GPS technology, but the availability of appropriate measurement hardware, the emergence of standards for the transfer of data, recent cascading failures in both eastern and western grids, pending reliability legislation, useful software applications, and a sense of urgency on the part of a large group of stakeholders.

Some of the first relay applications for synchronized measurements were described by Thorpe, Phadke et.al. in 1988 [1]. Phadke provides a history of phasor technology in the US along with an extensive bibliography in [2].

In addition to relaying applications, synchronized power system measurements have found widespread use in power system planning and have been recently used in the operations environment as well. Hauer et.al. provide an overview of some of the planning applications in [3]. Martinez et.al. describe one of the operations applications in [4].

This paper describes the history, organization, accomplishments and future direction for the EIPP. Before discussing the EIPP, the authors examine some of the applications for time synchronized measurements and briefly touch on relevant recommendations from the August 14 blackout report.

II. Applications for Time Synchronized Measurements

There are numerous applications for high fidelity information such as can be extracted from instruments deployed under the EIPP. For purposes of discussion, the authors have divided these applications into three broad categories. This section is by no means intended to be comprehensive. EIPP participants fully expect that as more and better data become available the industry will see a growing body of literature on the potential applications.

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A. *Planning*

Some of the planning applications often cited as being reliant on or enhanced by the inclusion of time-synchronized wide area measurements are post-disturbance analysis, model validation, development of nomograms, the study of dynamic stability, and PSS tuning. A few of these applications deserve special attention in the context of the EIPP.

Some of the instruments slated for early incorporation into the EIPP data network provided valuable information to the investigators charged with reconstructing the August 14, 2003 blackout. The instruments with accurate time stamps proved to be particularly valuable in developing the timeline of events. This case is a simple illustration of the use of time-synchronized data for post-disturbance analysis.

One can further compare the data collected from these instruments during a power system disturbance against data collected from a simulation of the same event or sequence of events. Differences between the observed response and the expected response can help to reveal modeling inaccuracies and can therefore give system planners quantitative information that can be used to improve the models or to simply get a better idea of the error bounds inherent in the model.

B. *Operations*

The area of power system operations proves to be the ultimate focal point for industry efforts to improve data collection and information systems. Some of the applications that may be enabled through the use of time-synchronized wide area measurements are improved state estimates, improved operator displays incorporating information from the power system "external" to the immediate control area, automatic arming of remedial action or special protection schemes, FACTS device operation/control, improvements in system restoration, adaptive islanding, and automatic control schemes.

The EIPP Work Group is focused first and foremost on simple improvements to the operations environment such as improving the ability of system operators to understand and predict system behavior. In many cases we will be able to significantly improve the operator's work environment by simply presenting the operator with a more comprehensive view of the external system.

EIPP Work Group members are cognizant of the fact that operators currently process an enormous amount of information from within their own control area without the clutter of extra screens and more data. It is the challenge of everyone associated with the project to ensure that the new information is presented in a manner that is intuitive and useful to the operator.

To this end, the Work Group is pleased to have support and collaboration from reliability councils including the North American Electric Reliability Council (NERC), industry, the vendor community, and researchers to achieve the goal.

C. *Relaying*

As described in [1], some of the first applications to make use of GPS synchronized instruments were in the field of protective relaying. Out-of-step relaying, underfrequency load shedding, fault location and adaptive relaying are some of the applications from this category that have been mentioned as possible candidates.

The EIPP Work Group has not specifically addressed relaying applications as of the date of this publication. There is every reason to believe, however, that these applications will continue to play a significant role in future project development as most commercially available distance relays currently incorporate GPS timing and are capable of delivering data suitable for use within the EIPP.

III. August 14 Blackout Recommendation

Following the events of August 14, 2003 in which a substantial portion of the eastern grid was involved in a widespread blackout, the governments of Canada and the United States formed the U.S. – Canada Power System Outage Task Force. The Task Force worked closely with NERC and industry to develop a report on the causes of the August 14 blackout and recommendations for improved reliability. Many sections of the report could be referenced to support the goals of the EIPP, however the most direct reference is Recommendation #28, "Require use of time-synchronized data recorders[5]." This recommendation highlights the need for the type of measurements that can be provided by the EIPP. It is consistent with a recommendation from a NERC report on the same subject wherein it is recommended to "Install additional time-synchronized recording devices as needed[6]."

Further, Recommendation #22, "Evaluate and adopt better real-time tools for operators and reliability coordinators[7]," describes the need to utilize data collected from time-synchronized recorders and other sources to better inform and guide the actions of system operators.

Recommendation #22 of the above-referenced joint US-Canada report also includes a concise statement illustrating why EIPP participants feel a sense of urgency and timeliness with respect to the project.

"The need for improved visualization capabilities over a wide geographic area has been a recurrent theme in blackout investigations. Some wide-area tools to aid situational awareness (e.g., real-time phasor measurement systems) have been tested in some regions but are not yet in general use. Improvements in this area will require significant new investments involving existing or emerging technologies.

"The investigation of the August 14 blackout revealed that there has been no consistent means across the Eastern Interconnection to provide an understanding of the status of the power grid outside of a control area. Improved visibility of the status of the grid beyond an operator's own area of control would aid the operator in making adjustments in its operations to mitigate potential problems. The expanded view advocated above would also enable facilities to be more proactive in operations and contingency planning[7]."

IV. Industry and Government Response – The Eastern Interconnection Phasor Project

The U.S. Department of Energy (DOE) has been instrumental in enhancing power system measurement systems and analytical techniques for over ten years. Much progress has been made to date with a Wide Area Monitoring System (WAMS) currently operational within the western US. The Western Electricity Coordinating Council (WECC) WAMS system is being used in planning, post-disturbance analysis, operations and control applications.

Leveraging the experience gained in the western system, DOE launched the EIPP in the 2003 fiscal year. The Consortium for Electric Reliability Technology Solutions (CERTS), comprised of research entities from industry, academia and the federal laboratory system, executes the program for the DOE. Phil Overholt, DOE Transmission Reliability Program Manager, leads the project.

Following the events of August 14, the EIPP took on a relatively high profile within DOE and within industry. An industry work group was formed in the fall of 2003. The vision of the EIPP Work Group is to improve power system reliability through wide area measurement, monitoring and control. The Work Group's mission is to create a robust, widely available and secure synchronized data measurement infrastructure over the eastern interconnection with associated analysis and monitoring tools for better planning and operation, and improved reliability[8].

V. EIPP Organizational Structure and Progress

The EIPP Work Group created five task teams and an Executive Committee to execute the project goal of creating a time synchronized data monitoring network within the eastern interconnection.

The Phase 1 Implementation Task Team is charged with successfully completing the interconnection of at least 30 instruments and four data collection sites in 2004. Many of these "Phase 1" instruments are already operational within the eastern interconnection but the resulting data is not accessible by other EIPP members.

The scope of the Real-Time Applications Task Team includes deployment and training for tools enabling operators, reliability coordinators and others engaged in operational aspects of grid reliability to effectively monitor and assess the real-time operations of the bulk power grid on a wide area basis. This Task Team oversees the operations applications for wide area information.

The Off Line Applications Task Team is responsible for deployment and training of tools enabling planners, analysts and others to support the assessment of system performance, model validation and to enhance decision-making related to bulk grid reliability.

The scope of the Standards and Performance Task Team includes coordinating and acting as liaison to standards efforts, determining consistent and satisfactory performance of synchronized measurement devices, and insuring the security of the data in accordance with best practices and the terms of the data sharing agreements.

Finally, the Business Management Task Team is charged with ensuring that contractual and legal issues are resolved to the satisfaction of all parties involved so that the sharing of data between participants, when and where appropriate, is possible.

Each Task Team is led by an industry representative – either an employee of a transmission owner or independent system operator. Work group membership currently includes representatives from over 30 entities including transmission owners, reliability councils, system operators, vendors, government and other interested stakeholders. More information on the project and its organization can be found at the web site, http://phasors.pnl.gov.

VI. Project Plan and Methods of Participation

The EIPP Work Group intends to take a phased approach to implementing its plans for a comprehensive information network.

A. *Phase I Plan and Implementation*

Phase 1 focuses on existing assets installed within the eastern interconnection. There were over two dozen instruments capable of meeting the technical requirements of the EIPP operational within the eastern interconnection as of the inception of the project. The typical instrument had been installed in the 1990's as part of a utility research project or test plan. Data from the typical instrument was used in post-disturbance analysis applications, system planning or, in some cases, not used at all.

Phase 1 began in the fall of 2003 and is expected to be completed by December 31, 2004. In Phase 1 of the project, the existing instruments along with some newly-installed units are to be tied to an information network and data from multiple instruments is to be made available to system operators and reliability coordinators.

The EIPP Work Group includes representation from the North American Electric Reliability Council (NERC). NERC staff members and other EIPP participants are working together, where appropriate, to design, implement and manage the data network.

Prior to the 2004 summer peak, EIPP participants hope to have networked ten to twelve instruments from the areas designated by star symbols in Figure 1. Further, operator displays will be created and tested within one or more control rooms to test some of the human factors involved with operator acceptance of time-synchronized or phasor data. The reader may gather more information about the Phase 1 plan by reviewing the presentations from the March 29, 2004 EIPP Work Group meeting[9][10].

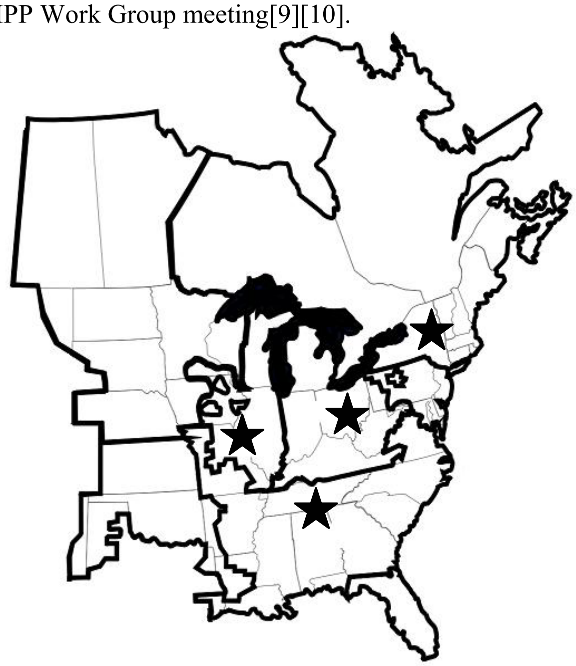

Figure 1. Proposed locations for EIPP Phase 1 data concentrator units.

B. Phase II and Beyond

Phase II activities are designed to achieve more complete coverage of the entire eastern interconnection and to drive the value of the network to the operations environment. Phasor information networks in Phase II may be used, for example, to arm remedial action schemes, to augment state estimators, and to provide operators with an intuitive system monitoring tool.

The following actions will be undertaken in Phase II of the plan.

• Assist stakeholders in the selection of location(s) for Phase II hardware including PMUs and PDCs.

• Deploy applications to facilitate the real-time analysis goals defined in Phase II. These applications include state estimation, voltage/frequency control and system security functions.

• Provide training opportunities to the user community for both off-line and real-time applications. The training curriculum will include an introduction to measurement and instrumentation concepts followed by immersion in analysis methods and techniques on topics tailored to the audience.

• Guide and support standards activities for communications, protocols, and develop guide specifications for use by utility procurement specialists when purchasing equipment related to the project.

During Phase II and beyond, hundreds of time-synchronized instruments will become part of the dynamic information network. This expectation does not appear to be unreasonable given the large number of GPS-compatible relays already installed in the eastern interconnection. As the market opportunities begin to become apparent throughout Phase 1 and in the early stages of Phase II, EIPP participants anticipate that the vendor community will respond with hardware and software to fill the needs of the industry.

VII. CONCLUSIONS

The authors have described some of the applications in the areas of relaying, planning and operations enabled by the availability of time-synchronized wide area information. A compelling business case was then discussed in the context of the August 14 blackout report. The report recommends that industry immediately embark on a course of action resulting in greater use of time-synchronized and wide area information.

Concurrently, the hardware and software supporting the infrastructure for these measurement systems are becoming more economical as multiple vendors are engaging the market. The EIPP Work Group is well positioned to capitalize on this timely convergence of improved technology, compelling need, national attention resulting from the blackout and governmental support.

The EIPP Work Group is a government-led, industry-run group of engineers, system operators and other stakeholders working together with a shared vision to improve power system reliability through wide area measurement, monitoring and control. The activities of the Work Group are carried out through five Task Teams and an Executive Committee. The Work Group expects to have a time-synchronized monitor network in place before the 2004 peak summer load. Further, the Work Group intends to grow the monitor network to 30 instruments by the end of 2004 and several hundred instruments in 2005.

With this network of information readily available, the industry can expect to benefit through enhanced relaying, planning and operation of the interconnected power grid.

VIII. Acknowledgment

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X. Biographies

Matt Donnelly (M'91, SM'98) was born in Phoenix, AZ in 1960. He received his B.S. degree from the University of Arizona in 1981 and his M.S. and Ph.D. degrees from Montana State University in 1989 and 1991, respectively. He is currently with the Pacific Northwest National Laboratory, a U.S. Department of Energy multi-program laboratory, where his research interests include monitoring and analysis of power systems.

Paul Barber received his BS degree from the US Military Academy and MS degrees in electrical engineering and civil engineering from the University of Illinois. He earned a Ph.D. degree in electric power engineering from Rensselaer Polytechnic Institute in 1988. Dr. Barber pursued a 28-year career in the US Army Corps of Engineers and spent 12 years on the faculty at the US Military Academy. He currently acts as a consultant and is active in numerous NERC activities.

Jim Dyer was born in Brooklyn, NY in 1945. He attended Long Beach City College and in 1993 he attended the University of Idaho's Public Utilities Executive Course. In 1998, after 31 years, Jim retired from Southern California Edison where he managed the System Operation Division.