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EASTERN INTERCONNECTION PHASOR PROJECT PLAN

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1.0 INTRODUCTION

With the competitive restructuring of the power industry and the division of operational responsibilities among large interconnected power networks, there is a growing need for wide-area visibility and monitoring of the power system to maintain system reliability. This need was clearly identified in the August 14th 2003 Northeast blackout report. Fortunately, emerging technologies such as Phasor Measurement Technology offer new opportunities towards fulfilling this objective for the following reasons:

- The accurately time synchronized data provides wide-area snapshots of system dynamics well suited for analysis and system trending purposes.
- The high data sampling rate (sub-second rate) is well suited for tracking system dynamics such as oscillatory swings under transient conditions for a rapid (potentially real-time) assessment of system conditions.
- Large phase angle differences across regions are direct indicators of system stress and proximity to instability.
- The accurately time tagged data and the high sampling rates are well suited for post-disturbance analysis.

The phasor technology directly measures phasor values (i.e., voltage and current magnitudes and angles) with high accuracy. Such quantities were previously derived via state

2.0 APPLICATION OF PHASOR TECHNOLOGY

TO IMPROVE REAL-TIME OPERATIONS AND RELIABILITY MONITORING

- Synchronized Phasor Data Monitoring for Dispatchers – There are inherent challenges with the state estimation process that has been used to compute phase angles across the power system. The process depends on a network model and is vulnerable to network changes and inaccuracies. Secondly, state estimators are more suited for steady-state monitoring but are too slow for disturbance monitoring. The ability of phasor technology to directly measure these quantities and display them at high rates resolves both of these issues. They also offer a means to corroborate state estimator results.
- Eastern Interconnection Wide-Area Monitoring and Archiving System – The time tagging of the phasor measurements allow for time synchronization between the phasor measurements taken across the system, and are therefore conducive for system-wide monitoring and tracking of system behavior. These measurements, when time synchronized with traditional SCADA data as well, will provide a more comprehensive view of the power system behavior.
- Improved Post-Disturbance Analysis Application for Planners – The accurately time tagged phasor measurements at very high rates can precisely trace system disturbances through their evolution process. This accurate timing information is also crucial for detecting trends

or parameter estimation (model fitting) from a window of observations.

3.0 FOCUS

The immediate focus of the EIPP work-group is to establish an initial phasor network connecting phasor measurement units already in place in the Eastern Interconnection, and to deploy prototypes of real-time phasor monitoring tools within the Interconnection to facilitate the learning process towards a global understanding of the system behavior. The long term plan, to be implemented in multiple phases, is to expand the phasor network to eventually attain full system visibility, and to develop and deploy real-time and off-line monitoring and analysis applications within the operations and planning environments and consequently improve overall system performance.

4.0 IMPLEMENTATION PHASES

The work-group has decided that the Eastern Interconnection phasor project shall be implemented in multiple phases. The tasks within each phase have been defined based satisfactory completion of the tasks in the previous phase. Furthermore, as the phasor project advances through the different phases, the phasor hardware and network requirements will have to evolve as well. The various implementation phases and the corresponding phasor hardware and network requirements are defined in tables I and II respectively. Each of the implementation phases in the project are also briefly described below:

Phase 1A: Eastern Interconnection ISOs, RTOs and stakeholders will survey and identify existing phasor measurement units in the Eastern Interconnection and will establish an initial point-to-point phasor network to gathered phasor data from these units at a central location. The real-time task team will work towards developing prototype applications for real-time viewing of this information at the data collection point. In addition, the off-line task team will work towards building an understanding of the system dynamics within Eastern Interconnection and will identify possible offline applications of interest to the team members.

Key Objectives: Establish and test initial phasor network connectivity

Phase 1B: The aim of 'Phase 1B' will be to develop a wide-area phasor network between participating utilities and share phasor data in real-time with each other. The real-time task team members will define and deploy a prototype real-time monitoring system to archive this data as well as distribute it over the Internet for viewing at remote locations, thereby creating a wide-area situational awareness among the members. The off-line task team will also develop prototype applications to perform off-line post-disturbance analysis on this archived data. The standards and performance team will identify and address any accuracy and performance issues with existing commercial phasor monitoring devices as well as compatibility issues between different phasor formats. A Phasor Network Management Team will be created to evaluate and certify the phasor hardware to ensure reliable system performance. Eventually, this team will be responsible for the upkeep of this network.

Key Objectives: Develop prototype applications for real-time monitoring by dispatchers and offline analysis by operating engineers and planners.

Phase 2A: With the real-time and off-line prototype tools developed, the focus of 'Phase 2B' will be to utilize these tools and develop an in-depth understanding of both real-time and post-disturbance operating conditions across the Eastern Interconnection. The off-line team will also perform trending analysis and correlation with time of day, season, peak load, major line outages, etc on archived data. Such analysis will define monitoring guidelines and alarming thresholds for the Interconnection. In addition, both the real-time and off-line task teams will identify additional phasor monitoring points to enhance system visibility while the phasor network. The management team will evaluate the design and performance of the existing phasor monitoring system which includes the phasor devices, the connectivity network and the monitoring and archiving applications. The standards and performance team will help standardize phasor data formats, define satisfactory performance standards for phasor measurement devices as well as establish handling guidelines to ensure the integrity of these measurements is preserved.

Key Objectives: Develop a global understanding of the system behavior across Eastern Interconnection
Evaluate the overall design and performance of existing phasor systems
Identify key gaps in observability to guide full-scale network development

Phase 2B: During this phase, the focus will be to bring the real-time and off-line tools into the operations and planning environment across the Eastern Interconnection. Furthermore, based on the recommendations by the real-time, off-line and the network management teams, the implementation team will develop a project plan to expand the existing coverage of the phasor network. The real-time task team will evaluate the methodologies for incorporating the SCADA data into the phasor monitoring system as well as their visualizations for a more complete system-wide view. In addition, they will also investigate the development of more sophisticated real-time monitoring metrics/schemes to assess system health with respect to various forms of instability (e.g., dynamic instability and voltage instability) and develop an implementation plan to incorporate these metrics into the real-time tool. The off-line team will use off-line tools to conduct model validation tests within the Eastern Interconnection. They may also investigate the use of phasor technology to establish stability nomo-grams within the Eastern Interconnection.

Key Objectives: Deploy standardized phasor applications into the operations and planning environment.

Phase 3: In 'Phase 3', additional phasor measurement units will be deployed across the Eastern Interconnection to obtain full coverage of the Interconnection. The real-time task team will develop enhancements to the existing real-time phasor monitoring system to include SCADA data into the phasor monitoring system as well as any additional metrics that directly assess system stability. Given the large number of phasor measurement units expected to be operation

within the Interconnection, the off-line team will work towards incorporating these measurements into the state estimation process. The phasor management team will define maintenance and upgrade procedures for this network.

Key Objectives: Expand phasor network for full observability
Utilize phasor measurements in the state estimation process

Phase 4: During 'Phase 4', the work-group's focus will be on developing real-time system protection and control schemes that rely on these phasor measurements as inputs. The real-time and off-line task teams will work closely to identify problem areas in the Eastern Interconnection where these schemes would be beneficial, and will develop appropriate schemes that address these problems. The phasor management task team will continually enforce test procedures to ensure proper operation of phasor devices and will work towards resolving any system maintenance and upgrade related issues that may arise.

Key Objectives: Research and develop phasor based applications for real-time protection and control

Table I: Eastern Interconnection Phasor Project Plan

	Phase 1		Phase 2		Phase3 and beyond	
	July 2004	December 2004	July 2005	December 2005	December 2006	
Focus	•Project Planning •Implementation of Initial Network	▪Wide Area Situational Awareness ▪Gain Familiarity with Phasor Technology	▪Learning and Analysis -Real-Time Alarming on Phasor Data -Post-Disturbance Analysis ▪Evaluate Performance and Design of Existing Phasor System	Deployment of Real-Time and Offline Tools into the Operations and Planning Environments Respectively	▪Work Towards Full System Observability ▪Enhancement of Real-Time Monitoring Tools ▪State Estimation	Protection and Control
Network	Initial Connectivity		Expanded Regional Coverage		Full Observability	
IMPLEMENT-ation Task Team	▪Survey and Identify Existing Phasor PMUs/PDCs in the EI ▪Establish Initial Point-to-Point Phasor Network	Establish Peer-to-Peer Phasor WAN	Integrate Phasor Network with Existing Reliability Monitoring Networks (e.g., NERCnet)	▪Develop Project Plan to Expand Coverage based on Recommendations by Other Team Members	▪Integrate Phasor Data with SCADA Data ▪Develop Project Plan to Expand Existing EIPP Phasor Network for Full System Observability	
Real-Time Task Team	Develop Prototype Application for Phasor Monitoring by Dispatchers	Deploy Prototype EI Phasor Monitoring System -Real-Time Monitoring -Data Archiving -Event Archiving	▪Standardize Real-Time Monitoring System Displays for Reliability Coordinators ▪Identify Monitoring Holes and Need for Additional Coverage	▪Define Real-Time Monitoring Metrics for: -Dynamic Stability Monitoring -Voltage Stability Monitoring ▪Evaluate Combining SCADA and Phasor Data for Monitoring Applications	▪Incorporate Advanced Monitoring Metrics into Existing Real-Time Monitoring System ▪Incorporate SCADA Data into Phasor Application for Monitoring Purposes	Develop Applications for: -System Protection Schemes -Power System Stabilizers -Underfrequency Load Shedding
Offline Task Team	▪Investigate Existing Phasor based Offline Analysis Tools ▪Prioritize Offline Analysis Tools of Interest to the Eastern Interconnection ▪Develop Better Understanding of EI Dynamics based on Available EI Phasor Data	▪Develop Prototype Offline Analysis Tools for Post-Disturbance Analysis -Spectral Analysis -Prony Analysis ▪Use Phasor Data to Corroborate State Estimation Process	▪Perform Post-Disturbance Analysis of Data – Oscillatory Modes, Voltage Swings, etc. ▪Perform Trending Analysis based on Archived Data – Correlation with Peak Loads, Day/Seasonal Trends ▪Identify Monitoring Holes & Additional Coverage	▪Utilize Offline Analysis Tools to perform Model Validation Tests ▪Develop Stability Nomograms using Phasor Measurements	Develop State Estimation Application	
Standards and Performance Task Team	▪Survey Prevalent Phasor Data Formats ▪Characterize Phasor Equipment Offered by Different Vendors	▪Identify Accuracy and Performance Issues with Phasor Measurement Devices ▪Address Compatibility Issues Across Different Data Formats	Standardize Phasor Formats Define Quality Standards for Phasor Instrumentation Define Guidelines for Managing Phasor Data	Define Performance Guidelines for Advanced Monitoring Applications		
Phasor Network Management Team		Establish a 'Phasor Network Management Team' for Evaluation and Certification of Phasor Hardware to Ensure System Reliability	Evaluate Performance and Design of Existing Phasor System	Make Recommendations on Network Enhancements to Ensure Phasor Hardware Performance as well as Robustness in the Network	Define Maintenance/Upgrade Procedures for EI Phasor Network	▪Implement Calibration/Self-Test Procedures for Installed Phasor Instrumentation ▪Resolve System

					Maintenance/Upgrade Issues ▪Address Security Issues in Sharing Phasor Data
PMUs PDCs / Servers	7 PMUs 2 PDCs	30 PMUs 4 PDCs / 1 Server	40 PMUs 6 PDCs / 2 Servers	50 PMUs 10 PDCs / 4 Servers	350 PMUs 20 PDCs / 8 Servers	500 PMUs 50 PDCs / 10 Servers

Table II: Network and Hardware Requirements

	Phase 1 December 2004		Phase 2 December 2005		Phase3 and beyond	
Number of PMUs	7	30	40	50	350	500
Delay Requirements (Seconds)	TBD	TBD	TBD	TBD	TBD	TBD
System Reliability Requirements	Non-Redundant System	Redundant System	Fully Redundant System With 99.99% Availability	Fully Redundant System With 99.99% Availability	Fully Redundant System With 99.99% Availability	TBD-Relay Type
Band width Requirements	150 kbps	250 kbps	500 kbps	1 Mbps	8 Mbps	10 Mbps
Communications Security Requirements	TBD	TBD	TBD	TBD	TBD	TBD
PMU / PDC / Server Expandability Requirements	First Generation PMU / PDC / Server		Second Generation PMU Second Generation Server		Second Generation PDC	Third Generation PMU / PDC
Integration With Existing Systems	Stand Alone Phasor Network		SCADA		SCADA, DFRs	SCADA, Substation Automation, DFRs, SERs

INTERCONNECTIONS OF THE NORTH AMERICAN ELECTRIC RELIABILITY

COUNCIL IN THE CONTIGUOUS UNITED STATES, 1998