Technology Innovation Project

Closing Project Brief

TIP 353: Improving Operator Situation Awareness by Phasor Measurement Unit (PMU) Data Visualization

Context

Operators in electric power system control centers serve a critical role in ensuring the integrity of the nation's electric grid and to prevent disruptions (e.g., blackouts) to the supply of electric power at any time, for any reason. The enormity and complexity of the grid itself is mind-boggling. However, recent advances in both display technology and measurement of various aspects of the grid have made display of truly dynamic system data both possible and affordable.

The application of phasor measurement unit (PMU) data in the power industry is currently an area of intense interest. The key driver for PMU technology is to use the precise time sources provided by Global Positioning System satellites to accurately measure the relative voltage and current phase angles at buses across an interconnect.

Presenting PMU data to power system operators in a format that is truly useful for them and that affords improved situation awareness and fast and accurate decision making is a different problem, however.

The problem has therefore shifted from scarcity of relevant data to overabundance of them and ultimately to human limitations in processing all the available information. Human judgment and decision making are still critical in operation of the electric grid, despite advances in automation and computers now performing many routine tasks. The role of a human operator is particularly critical during unforeseen (unforeseeable) events that computers have not been programmed to handle

Description

To keep human operators “in the loop” and to empower them to access relevant information and make appropriate decisions and take correct and timely actions in response to events requires that the information is displayed to them in a form that is inherently usable. Cognitive Work Analysis (CWA) is a conceptual framework that allows for analysis of all factors that affect human-information interaction. The products of this system of analyses can then be directly transformed to design requirements for information systems.

The CWA approach is work-centered, rather than user-centered. It analyzes the constraints and goals that shape information behavior in the workplace regardless of the individuals who are involved in the work. It is an inherently holistic approach that simultaneously examines the environmental, organizational, social, activities, and individual dimensions. CWA provides concepts and templates for comprehensive analysis of complex phenomena but does not reduce their complexity.

CWA has proven to be an effective approach to the study of human-information behavior for the purpose of designing information systems.

The project was conducted through three phases:

Phase 1: Cognitive Work Analysis (CWA)

CWA is a system of analyses with six main stages*;

Phase 2: Development of Visualization Solutions for PMU Data

We take the results of the CWA from the first task and iteratively develop prototype algorithms and displays to better convey PMU results, possibility augmented with SCADA measurements, to the operators and engineers.

Phase 3: Empirical Evaluation and Validation of the PMU Data Visualization Solutions

Display solutions are tested empirically in human-in-the-loop (HITL) simulations. Validation of our display innovations is conducted by robust experimental designs and part-task simulations using experienced power systems operators as participants.

Benefits

The algorithms and techniques that we develop can provide BPA with better operator situation awareness in real-time and better off-line study analysis tools. This should have direct benefit to BPA in better operation and planning of the transmission system. The new visualizations will be developed by applying the CWA human factors technique in the control center environment.

The human factors guidelines for design and evaluation of power system visualizations can benefit BPA beyond the scope of this project—visualization of PMU data—if applied to other areas of the organization.

Accomplishments

The main objectives achieved by this research are to (1) perform a thorough CWA on power system operators to identify their information needs and uses, (2) develop visual displays of PMU data that directly support their SA and decision making, per results from the CWA and using EID techniques, (3) empirically test and validate the displays to demonstrate improvement in operator performance with the aid of the new PMU data displays, and (4) to provide BPA with human factor guidelines for evaluation of all future visualization solutions in BPA control centers.

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Project Start Date: October 2015

Project End Date: March 2018

Deliverables

Project deliverables include:

- All the visualization solutions developed in this project.
- Documentation on the usage of the displays.
- Quarterly and stage gate reports documenting the research process behind the development of the solutions.
- Verification and validation studies of the solutions and the results delivered through reports.
- Recommendations for implementation of the solutions in BPA control centers.
- Final report describing the execution and achievements of the entire project in detail, as well as charting out the future steps for this work. We will also provide human factors guidelines for evaluation of all future visualization solutions.

Reports, References, Links

* G Lintern. The foundations and pragmatics of cognitive work analysis: A systematic approach to design of large-scale information systems. 2009

http://www.cognitivesystemsdesign.net/home.html

Funding

Total Project Cost: $630,000

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Conclusions

The key to a successful CWA is engagement with the subject matter experts (SMEs) in the work domain of interest. We had several very valuable opportunities to observe the dispatchers at the Dittmer control center (DCC) and speak with them about their work, different tasks they do, and the tools at their disposal. These observations provided a good foundation for the CWA. However, more detailed data from the DCC dispatchers would be necessary to 'fill in the blanks'. The limited number of dispatchers who responded to an online survey and their responses were too varied for clear conclusions.

Nevertheless, the CWA afforded several key insights for our subsequent efforts in PMU data visualization. The primary insight was that the PMU visualizations should allow the dispatchers to move away from the current alarm-driven, reactive, mode of operations to analytical, proactive, mode. Second, we designed our visualizations to be displayed on the video wall so that the information they provide could be shared by all dispatchers at all times.