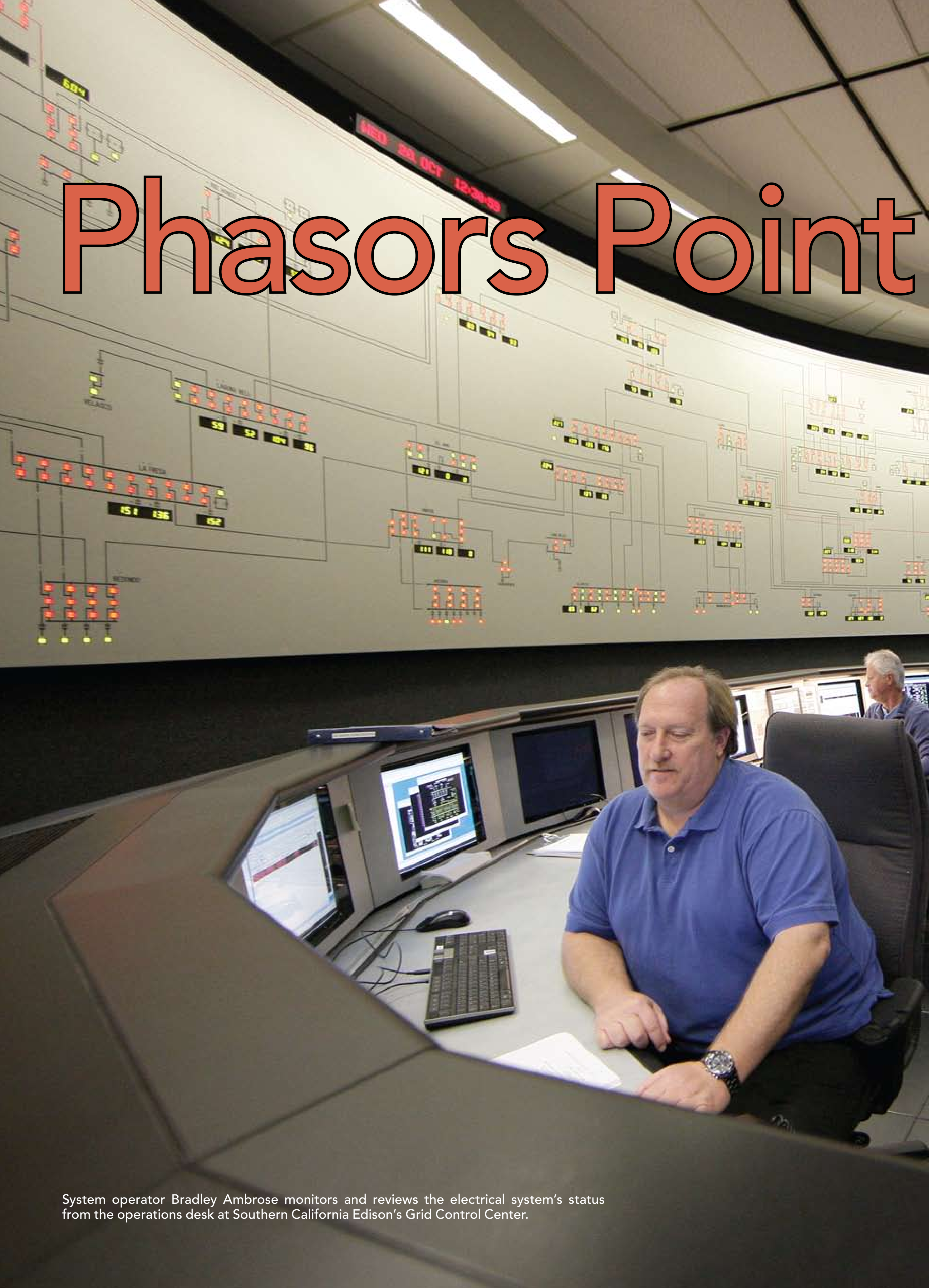
Phasors Point



System operator Bradley Ambrose monitors and reviews the electrical system's status from the operations desk at Southern California Edison's Grid Control Center.

the Way

Southern California Edison now has greater situational awareness, enabling more stable operation of the grid.

By **Farrokh Habibi-Ashrafi**, **Anthony Johnson**, **Son Vo**
and **Deborah Catanese**, *Southern California Edison*

Phasor measurement technology garnered the attention of electric utilities following a significant disruption on the Western U.S. power grid in August 1996. At the time, Southern California Edison (SCE) was conducting preliminary research on using synchrophasor measurements for electric utility application.

The utility also was collaborating with the Western Electricity Coordinating Council (WECC), U.S. Department of Energy (DOE), California Energy Commission and Electric Power Research Institute to advance the technology for preventing wide-area catastrophic outage events and enabling quicker restoration of systems after major disturbances.

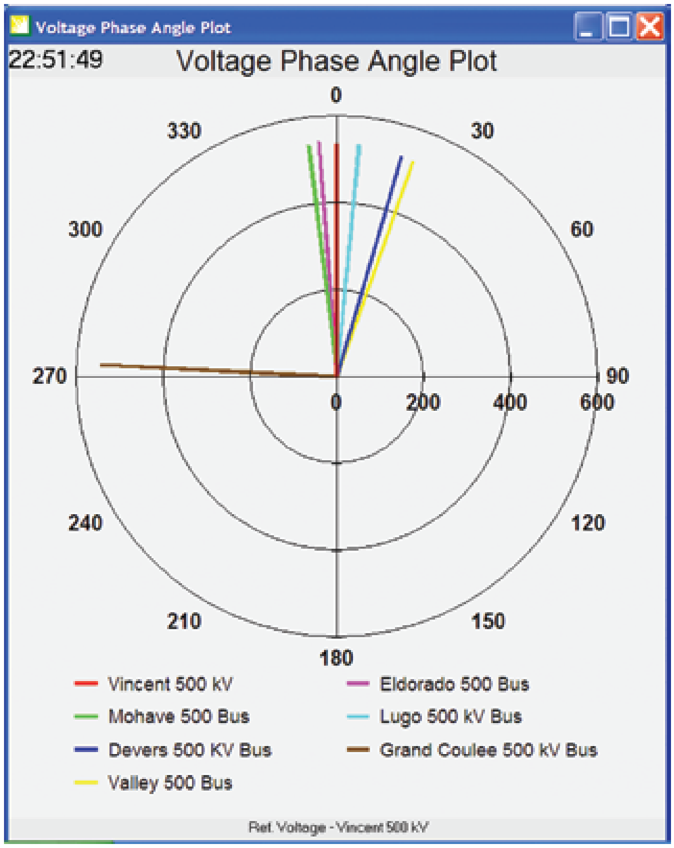
What Phasors Do

By 1996, growing evidence indicated phasor technology could offer several benefits:

- Provide in-depth insight into post-event analysis of disturbances by capturing system dynamics
- Allow instantaneous assessment of system performance and stability (situational awareness)
- Enable data visualization and real-time monitoring of power system electrical quantities
- Determine available transmission capacity in real time.

In response, SCE began deploying phasor measurement units (PMUs) at its 500-kV and 230-kV substations to validate these claims. By 2007, the utility had 18 PMUs and two phasor data concentrators installed, and was monitoring and analyzing system disturbances on its system as well as the WECC grid.

Synchrophasor technology measures system states on the transmission grid by monitoring phase gle and system voltage. This provides electric utilities the ability to determine power flow limits based on the phase angle difference between the 60-cycle voltages at the ends of transmission lines. Being able to measure these voltages in real time enabled SCE to pioneer technologies that quickly alert grid operators of growing phase angle separations (an indicator of stress in the transmission system), so the utility can take the appropriate actions for avoiding large-scale blackouts.



Screen shot of voltage phase-angle plot from SMART phasor wheel.

Data to Information

Subsequently, SCE realized the need for and began developing software that enabled engineers, planners and grid operators to synthesize the data captured by the PMUs on its system.

In 2000, the utility unveiled Power System Outlook (PSO), which provides offline viewing and playback with analytical capabilities for monitoring and analyzing data regarding grid conditions. It also enables the assessment of dynamic behavior of the system by evaluating inter-area oscillation frequencies and damping ratios.

PSO made it possible for SCE engineers to analyze a variety of phasor measurements: voltage, current, power, reactive power, frequency and frequency deviation, rate of frequency change at PMU locations, phase angle differences from selectable bus references and percent of deviation for voltage. PSO also proved capable of feeding data measurements to a voltage phasor display.

The Northeast blackout of August 2003, which affected 50 million utility customers in eight states and Canada, validated the need for more advanced synchrophasor applications that could at least monitor events on the grid as they occur. As utilities in the Eastern United States began aggressive phasor development and implementation programs, SCE became an active member of the North American Synchrophasor Initiative (NASPI). The utility also developed a system operations tool called SCE Synchrophasor Measurement Analysis in Real Time (SCE SMART).

SCE SMART built on the analytical functions of the PSO software by adding enhanced real-time tools for event recording and continuous data archiving. This provides operators and engineers with synchronized data on system stress and stability at an unprecedented 30 scans/second. SCE's grid control center then stores streaming, event and compressed data files and uses the software to monitor voltage, frequency, power imports and path flows on the system.

Screen capture of the strip charts produced by Synchronized Measurement and Analysis in Real Time (SMART), SCE's real-time operations tool for phasor visualization.

Intermittent Resources

Using the PSO and SCE SMART


Phasor applications are visually displayed on a large wall monitor at Southern California Edison's Grid Control Center with operator Mario Kiresich keeping watch at the desk.

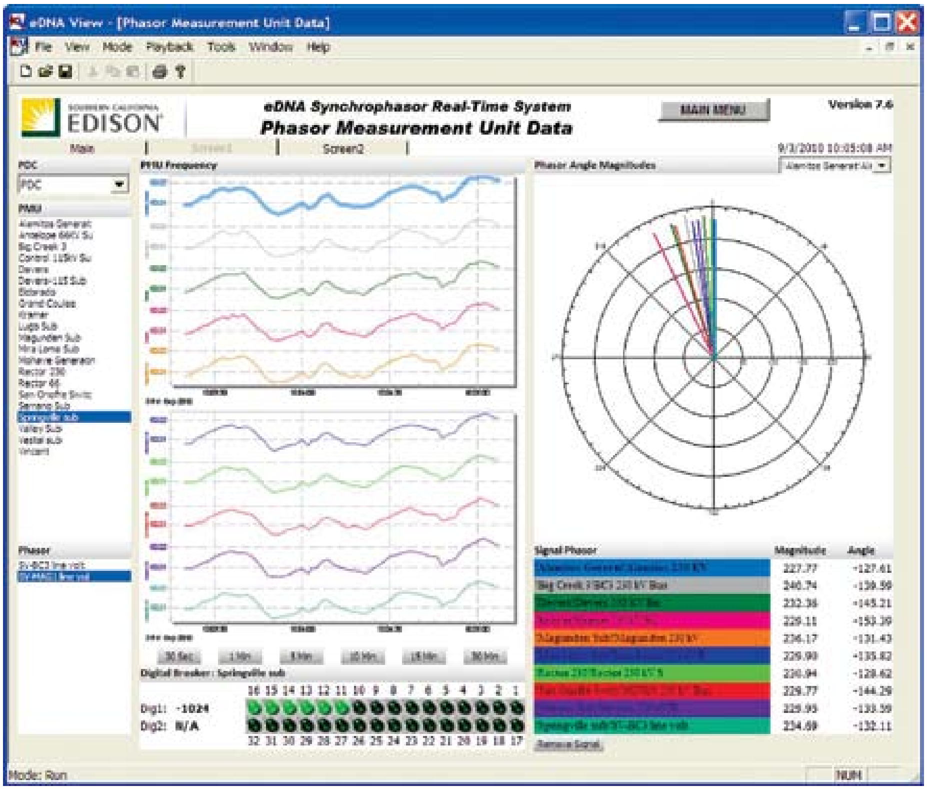
software, SCE has been investigating the impacts of integrating greater amounts of intermittent renewable energy into its grid. The software is playing a prominent role in SCE's Tehachapi Renewable Transmission project, which is expected to produce 4, 500 MW of wind generation.

A primary feature of phasor data is its model validation capabilities, and SCE is using its phasor data to enhance the modeling and simulation work using a real-time digital simulator (RTDS) at the utility's Advanced Technology laboratories. The study examines the impact of the intermittent nature of renewable resources on the grid, and phasor data greatly improves and validates the accuracy of the models.

Research projects such as these empower SCE engineers to investigate other phasor applications such as intelligent control of bulk power components, remedial action schemes and eventually closed-loop control.

A First in Voltage Control

The utility's static VAR compensation (SVC) project at its Rector Substation is the first application of its kind to use synchronized phasor measurements in a closed-loop dynamic control scheme. The objective of the project is to integrate the synchrophasor voltage data from the PMU installed at Big Creek and use it in the SVC controller to manage the complex system generation and maintain voltage stability on the system at Rector. Thus far, SCE has been successful at avoiding over-



Display of synchrophasor information derived from SCE's data historian, eDNA.

control system whether or not the electrical system is stressed. When the system is stressed and a fault occurs, at least two out of three relays on the line will have to detect the fault to allow the trip. If the system is not stressed, any relay detecting a fault will initiate the trip.

With the assistance of the California Independent System Operator, SCE plans on expanding the scope of the data it analyzes to include reliability data from other WECC entities on the state's transmission grid. SCE also receives data from Bonneville Power Administration (BPA) in the Pacific Northwest, allowing the utility's operators and engineers to monitor the vital north-south transmission corridor. As a result, SCE has been able to develop the advanced phasor measurement and analysis system now deployed at its grid control center.

voltage conditions at the Big Creek Generation Station, where a PMU monitors and streams data back to the utility's grid control center for use by system operators.

Presently, SCE is working to develop a voltage and VAR control system at one of its bulk power substations using phasor measurement technology. The objective of this program is to coordinate multiple reactive power (VAR) devices so they do not counteract each other's functionality. This program will automate voltage control function at bulk power substations, while optimizing VAR resources.

Adaptive Protection System

While the use of phasor data for protection is still in its early stages, SCE is participating in a DOE grant to examine the potential use of the data in this capacity. SCE is one of two utilities working on a Virginia Tech demonstration project that uses phasor data to monitor system stress and to develop, test and deploy an adaptive protection system for commercial application. The project will integrate highly redundant bulk power protection with information derived from phasor data, reconfiguring the system to require either two-out-of-three voting or single-relay tripping according to the amount of system stress.

This process is based on the fact that conservative relay settings can result in over-tripping. Under normal (unstressed) conditions, an unnecessary outage on a line does not necessarily impact system reliability, whereas during stressed conditions, an unnecessary line outage can adversely impact system reliability, resulting in cascading outages and, eventually, a widespread blackout. To be confident there is indeed a fault on the line, the control process will use phasors to inform the

Supporting Data Exchange

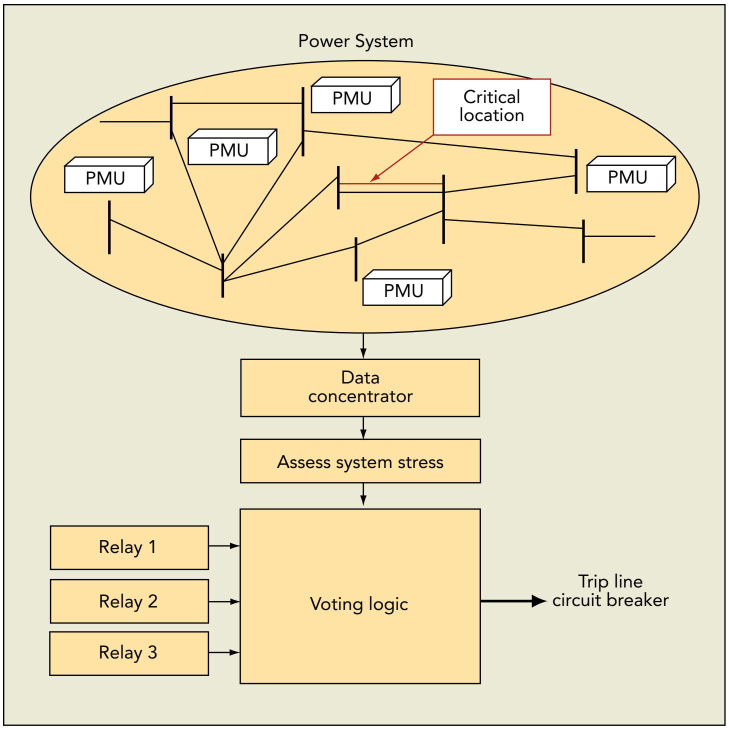
More research is needed to fully understand and use the data provided by PMUs and other time-synchronized devices. SCE SMART and PSO are highly advanced software packages, and although they are not commercially available products, SCE freely provides PSO to electric utilities, independent system operators and universities to encourage the development of advanced synchrophasor technologies and applications.

SCE uses InStep Software's eDNA as its enterprise data historian to make its transmission and distribution data available companywide. Once its synchrophasor measurement technologies matured, the utility needed to integrate synchrophasor data with the eDNA to ensure the PMU captured data would be accessible to SCE personnel.

In 2009, SCE, GE and InStep Software collaborated to develop an interface between the BPA-developed Phasor Data Concentrator (PDC) and InStep Software's eDNA suite to make phasor data available on demand to GE Energy's energy management system software and state estimator subsystem, a crucial real-time tool for electric utility control centers.

The interface reading data stream from the PDC into the eDNA loss-less (compression technique) historian services has a minimum data sampling rate of 30 samples/second and uses the IEEE Synchrophasor C37.118 protocol, the transmission standard for reporting phasor measurements in power systems.

This interface's sub-second raw data is stored in eDNA's raw data historian for up to 90 days and 1-second snapshot data can be stored in the eDNA snapshot historian for as long as 10 years. The PDC-eDNA interface also can detect disturbance events and store the event data in the event historian along



Wide-area monitoring, protection and control (WAMPAC) schematic diagram for advanced remedial action scheme applications.

with the event record so users can query the event for post-analysis.

Understanding the need for current and past phasor data exchanges between utilities, SCE has been working with InStep to develop advanced tools to extract data from the eDNA historian to support the COMTRADE file standard to store disturbance record information for data exchange. The tool presently supports the BPA DST format, popular among West Coast utilities and used by SCE's PSO program, but needs to be defined according to the IEEE COMTRADE format being proposed by the National Institute of Standards and Technology's Smart Grid council as the standard for phasor data exchange.

An Investment in the Future

As the grid's transmission corridors and networks become increasingly congested, utilities must be able to monitor the condition of their systems to detect initial signs of instabilities well enough in advance to employ appropriate corrective actions in real time to prevent widespread outages. Based on SCE's extensive synchrophasor work, the utility is in the procurement stages for deploying a wide-area monitoring, protection and control (WAMPAC) system. The WAMPAC system will combine wide-area situational awareness with a centralized remedial scheme and IEC 61850 GOOSE standard communications over SCE's wide-area network.

SCE is dedicated to advancing synchrophasor systems and the many emerging smart grid technologies that will play a critical role in preventing the wide-area catastrophic outages that plague large interconnected power grids and threaten the livelihood and economic stability of individual customers, communities and regions worldwide. TDW

Farrokh Habibi-Ashrafi (farrokh.habibiashrafi@sce.com) is a senior engineer for Advanced Technology at Southern California Edison, where he works on developing synchrophasor applications for disturbance monitoring, protection control and power system operations. Ashrafi also has expertise in the integration of renewable resources, power system dynamics, electronic transients and remedial action schemes. He holds a doctorate in electrical engineering from the University of Southern California, is a member of IEEE, a consultant for Jet Propulsion Laboratories and a professional engineer.

Anthony P. Johnson (anthony.johnson@sce.com) is a consulting engineer at Southern California Edison's Advanced Technology laboratories, with expertise in smart grid applications. He has been at SCE for more than 18 years. Johnson is co-lead for the North American Synchro Phasor Initiative operation implementation team and an active member of the Power Systems Engineering Research Council industrial advisory board. He holds a master's degree from Montana State University, and is a member of IEEE and a professional engineer.

Son Vo (son.vo@sce.com) is an IT specialist/engineer for Southern California Edison's IT power system controls and supports the transmission and distribution business unit, using his expertise in power system controls, energy management systems, substation automation and eDNA data historians. Vo has been at SCE for 24 years. He earned a BSEE degree from California Polytechnic Pomona and is a member of IEEE.

Deborah Catanese (deborah.catanese@sce.com) is a senior communications specialist for Advanced Technology at Southern California Edison, where she writes, edits and manages content for articles and technical papers in utility and engineering publications, grant proposals, rate case testimonies, use cases and marketing materials. Catanese graduated summa cum laude with a bachelor's degree in journalism from California State University, Northridge.

Companies mentioned:

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