Sarma Nuthalapati and Arun G. Phadke

managing the grid

using synchrophasor technology

IT ALL STARTED WITH THE WORK on computer relaying technology at American Electric Power (AEP), which led to the development of phasor measurement units (PMUs) beginning in the mid 1970s. The seminal phasor measurement paper, published in 1983, was "A New Measurement Technique for Tracking Voltage Phasors, Local System Frequency, and Rate of Change of Frequency" by Phadke, Thorp, and Adamiak. The first prototype PMU was built at Virginia Tech in the early 1980s, and these prototypes were deployed on an experimental basis in the substations of utilities that funded these initial efforts. There were many lessons learned from these early installations.

In the early 1990s, commercial-type PMUs were developed, and much effort was put into in developing IEEE standards for PMUs and wide-area monitoring systems (WAMS). Today, funding is provided by government agencies to install PMUs and understand the benefits of the synchrophasor technology in managing the grid through demonstration projects. The North American Electric Reliability Corporation's report, "Real-Time Application of Synchrophasors for Improving Reliability," published in October 2010 (http://www.nerc.com/docs/oc/rapirtf/RAPIR%20final%20101710.pdf), clearly indicates that the lack of wide-area visibility prevented early identification of the 14 August 2003 U.S. Northeast blackout. The U.S.–Canada report on the investigation into the blackout hypothesized that if a phasor system had been in operation at that time, the blackout preconditions—in particular, the growing voltage problems in Ohio—could have been identified and understood earlier. The key benefits of PMU technology include

- ✔ wide-area visualization
- ✔ oscillation detection
- ✔ generator model and parameter validation
- ✔ island detection
- ✔ voltage instability monitoring
- ✔ identification of potential malfunction of devices in the grid
- ✔ event analysis.

There are already some large-scale implementations of synchrophasor technology in managing the grid across the world (China has 2400, India has 1800, and North America has 2000 PMUs). Efforts are in place to take this technology into control center operations and develop good operational procedures to better manage the grid with wide-area visualization tools using PMU data.

The *IEEE Power & Energy Magazine's* Editorial Board agreed that it was appropriate and timely to dedicate this issue of the magazine to synchrophasor technology for managing the grid. We have collected experiences from across the world in implementing this technology. The following topics are presented:

- ✔ the deployment of synchrophasor technology in the western region of the United States
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- ✔ the deployment of synchrophasor technology in the Electric Reliability Council of Texas (ERCOT) region of the United States
- ✔ the use of wide-area monitoring in the continental European power system
- ✔ WAMS initiatives and experiences in India
- ✔ recent developments and applications of PMU/WAMS in China.

In addition to these topics, we also include an article detailing the efforts of the U.S. Department of Energy (DOE) in promoting synchrophasor technology in the United States by funding several implementation projects. The "In My View" column by Arun Phadke recalls his PMU memories—how all this started way back in the 1970s, how it has progressed thus far—and offers an appropriate closing piece to this issue.

The first article, "Synchrophasor Technology and the DOE" by Overholt, Ortiz, and Silverstein, provides a summary of the support given by the U.S. DOE for various projects that deployed synchrophasor technology in different utilities under the American Reinvestment and Recovery Act. These projects committed several hundred million dollars in direct federal and private funds to PMU technology investments. This article also covers efforts by the North American SynchroPhasor Initiative, the National Science Foundation,

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and other agencies that support synchrophasor related activities.

"Challenging Changing Landscapes" by Madani, Giri, Kosterev, Novosel, and Brancaccio, our second article, presents the efforts in the Western Electricity Coordinating Council (WECC) of the United States utilizing synchrophasor technology in grid management. The article summarizes various applications deployed throughout WECC and presents some key implementation success factors.

Our third article, "Strategies for Success with Synchrophasors" by Jones, Cano, Chen, Robinson, Thomas, and Gardner, presents the ongoing activities in the Eastern region of the United States in using synchrophasor technology. The activities by PJM, New York Independent System Operator, and Dominion Virginia Power and Electric Power Group in applying this technology are presented.

"Synchrophasors Across Texas" by Koellner, Burks, Blevins, Nuthalapati, Rajagopalan, and Holloway, our fourth presentation, reviews ERCOT's applications of synchrophasor technology. A Phasor Measurement Task Force was formed in ERCOT where stakeholders were invited to participate and industry experts were invited to attend and present material from which the group could learn. This article presents the details of the task force and efforts by ERCOT to utilize synchrophasor technology.

The fifth article, "Monitoring Continental Europe" by Sattinger and Giannuzzi, looks at those parts of the Europe using synchrophasor technology and illustrates examples of some applications that were deployed in the region.

"The View from the Wide Side" by Soonee, V.K. Agrawal, P.K. Agarwal, Narasimhan, and Thomas, presents the efforts in India's implementation of synchrophasor technology and reviews the challenges encountered in WAMS implementations.

Our final article, "Advancing China's Smart Grid" by Lu, Shi, Wu, and Sun, looks at China's experiences with synchrophasor technology was well as the applications that use the data.

These articles provide an overview of the synchrophasor technology being used in different parts of the world in managing the power grid. It is evident that this technology is now mature and is helping to improve the grid's reliability. Several projects that are part of government-funded technology demonstration projects have provided the confidence in this technology and will help power system grid operators to use this technology in large-scale implementations. We are very pleased to offer this issue on synchrophasor technology in managing the grid with the hope that utilities can benefit from these articles and move forward in using this technology for grid management.

We would like to thank all the authors for their time and effort in preparing the articles for this issue and to the editorial board of *IEEE Power & Energy Magazine* for the opportunity to present these experiences. Special thanks to Editor-in-Chief Mel Olken for his support.

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