editors' voice

Innocent Kamwa

grid communications

the wide-area control and situational awareness

TELECOMMUNICATIONS NETWORKS are at the core of transforming the power grid into the smart grid. The latter, according to the most familiar definition, is the superposition (or integration) of information and communications technologies infrastructure and electric infrastructure to leapfrog the latter from the last century to modern days (https://www.nist.gov/ctl/smart-connected-systems-division/smart-grid-group/smart-grid-framework). Communication network technology was introduced in utilities initially to support the deployment of supervisory control and data acquisition (SCADA) systems. These SCADA systems allowed operations personnel to remotely monitor and control generation, transmission and distribution, power plants, and substation equipment from utility operations centers, enhancing the power grid's operational efficiency. In addition, communication networks found use in the remote support of automated circuit breakers known as *teleprotection systems*. More recently, grid communications enabled

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In This Issue

This issue focuses on emerging trends in communication networks for power systems operations. Communication networks have played a central role in power systems operation for decades for tasks ranging from communication within substations to providing system operators with visibility on the operating state of the grid. Modern power systems increasingly rely on secure access to data to support managing the grid, taking advantage of technological advances to allow the system to meet new challenges, such as supporting the increased penetration of inverter-based resources.

The writer of the "In My View" [A1] column provides a brief history of the application of communication technologies in power systems. The columnist discusses opportunities and challenges as the industry moves to Internet Protocol (IP) communication, with both wired and wireless networks. The author discusses approaches for creating resilient communication networks meeting the specific needs of the power industry and other critical infrastructures.

Toward that end, our guest editor has organized three articles in this issue that highlight the range of considerations for power systems communications needed to meet challenges for resilient operations in the coming years. These articles are supplemented by three additional articles submitted by authors for consideration in the magazine.

The article by L'Abbate [A2] makes the case for the use of private wireless broadband networks to meet the power industry's critical need for reliable high-capacity communication. The author discusses future communication requirements to support decarbonization and discusses options to meet the challenge, including the tradeoffs between using public or private networks. The author makes the case for the private long-term evolution wireless broadband and discusses the challenges and opportunities for deployment.

The article "Precise Time, All the Time" [A3] provides an overview of measuring time and the use of global navigation satellite systems for time references to associate with measurements. The authors discuss the applications of precise time in power systems, followed by a discussion of standards for distributing time reference signals. The authors discuss the vulnerabilities faced by satellite-based precise time systems, followed by a discussion of solutions to address these challenges.

The article by Stoupis et al. [A4] presents the application of distributed grid-edge computing to address the challenges of operating increasingly complex distribution systems. The distributed approach will rely on data from diverse sources fed to computing devices embedded in the distribution system to coordinate and optimize both utility and nonutility devices. The authors provide a general overview of edge computing, describe possible architectures, and provide experimental cases demonstrating the application-based deployment of programs to grid-edge computing devices. The article concludes by discussing near-term applications and suggesting a long-term hierarchical grid intelligence plan.

The authors of "Data Privacy for the Grid" [A5] talk about practices for data privacy and security. The authors provide an overview of concerns related to data privacy, followed by a review of current best practices. The authors point out the shortcomings of these approaches and propose approaches to overcome these shortcomings and position the industry to meet future needs. The authors provide example cases and conclude with suggestions for steps to move forward.

The article by Gutiérrez et al. [A6] is an unsolicited article that fits the theme of this issue. The authors provide an overview of IEC 61850-based digital substations but raise concerns with scalability when using conventional networking practices. The authors make the case for using software-defined networks to manage network complexity and security in digital substations. The authors point out that software-defined networks are beginning to see use in enterprise networks as well as in commercial products targeting operational technology networks. The authors propose using programmable data planes to fully support the software-defined network approach. The authors end the article by listing the challenges to fully implementing this approach.

The article "Synchro-Waveforms: A Window to the Future of Power Systems Data Analytics" [A7] highlights the emerging technology of time-synchronized waveform data. The authors contrast synchro-waveforms to synchrophasors and provide examples where synchro-waveform data provide useful information missed with phasor data. The article discusses possible data analytics approaches to extract information from the synchro-waveform data. The authors describe several applications for synchro-waveforms, including the analysis of responses of distributed inverter-based resources to system events, condition monitoring, and the location of sources for transient events. The article ends with a discussion of activities from IEEE technical committees related to synchro-waveforms and the need for standards development.

This issue has a letter to the editor [A8], the first we have received in almost a year.

—Brian K. Johnson

grid-edge technologies through the Internet of Things (IoT) and synchrophasor-based wide-area measurement systems (WAMSs).

For many readers, communication networks are only an expedient tool to support the grid operations and wide-area protection, control, and situational awareness functionalities enabled by the IoT and WAMSs. Conversely, practitioners in communication networking look at the power grid as just another enterprise that can be supported using the traditional and proven network architecture and design for network service providers and enterprise data networks. However, public telecommunications networks are simply not adequate when applied to critical infrastructure such as smart grid communication networks, serving a product that can't afford any delay or time uncertainties in its delivery to the consumer. Making things worse, the context of the power grid has evolved fast recently, with increasing dynamic and stochastic responses resulting from intermittency, uncertainty, and the reduced inertias of inverter-based renewables. The need for ancillary services and power grid control on ever faster time scales shouldered by distributed sources has picked up momentum accordingly. In parallel, cybersecurity threats through communications channels have increased in number and severity from rogue countries and underground criminal associations (https://en.wikipedia.org/wiki/Category:Cyberattacks_on_energy_sector).

Power grid evolution toward decarbonization has made more stringent the need for faster and more secure grid data communications supporting enhanced wide-area control and situational awareness tools and platforms. Indeed, an effective way to contain uncertainties inherent in the modern renewable-driven power grid is through faster, preferably real-time, decision support tools and platforms, i.e., using information updated continuously based on actual measurements. By contrast, most existing operational rules are determined offline, considering the worst-case scenarios, and therefore, they may lack preventive/corrective measures to mitigate unforeseen (new) types of operational risks. Having richer and contemporaneous data can enable proven capabilities of artificial intelligence (AI) in decision making/support under highly complex situations. Like other industries, such as aviation, where the human factor may compromise system performances in emergency conditions, many experts have stressed the need for more closed loops to mitigate uncertainties and remove humans from the loop when possible. Fast sampling rates allow controls to use simplified models (as feedback compensates for inaccuracies) and to react quickly to uncertainties.

Given the large scale of the grid and the growing number of objects connected to it (Figure 1), fast data communications require reinforcement and modernization of the communication networks. Many integrated utilities operate their own private communication networks, which may be as large as those of some national telecom operators (https://www.hydroquebec.com/data/centre-donnees/pdf/2020g326-telecom-acc-v6-secure.pdf). These specially tailored telecommunications can meet the stringent requirements for network protection and wide-area control and dynamic situational awareness without any cybersecurity concerns. To put this performance in context, we performed an experiment to assess whether the communication network at a utility was suited for wide-area closed-loop inter-area power oscillations damping control. Theoretical investigations had shown hitherto that, for a stable operation of such wide-area controllers without performance impairment, the total delay incurred by the input and output signals together must be less than three cycles of the fundamental frequency. The measured average roundtrip telecom delay was 16 ms over a 400-km area. This delay was mainly due to the modems, so it dropped to fewer than 5 ms with an Internet Protocol Multi-Protocol Label Switching (IP-MPLS) solution.

As for the other performances, the average jitter was 0.04 ms, under a constant bandwidth of 1.5 Mb/s, achieved without any packet loss. Clearly, the utility communication network was capable of wide-area damping control, especially under the more advanced private MPLS scheme, leaving ample margin for other sources of latencies inherent in the synchrophasor units. But that hefty performance didn't come cheap as the IP-MPLS network, with a quality-of-service warranty, was more expensive compared to the Synchronous Optical Network (SONET)-based conventional solution.

By contrast, we recently came across the performances of a major worldwide communication network operator (http://www.verizonenterprise.com/about/network/latency/#latency). In April 2023, the packet delivery rate for North America was 99.997%, which is satisfactory in most cases, although we would conservatively prefer a "nine" in place of the "seven." The intra-North America

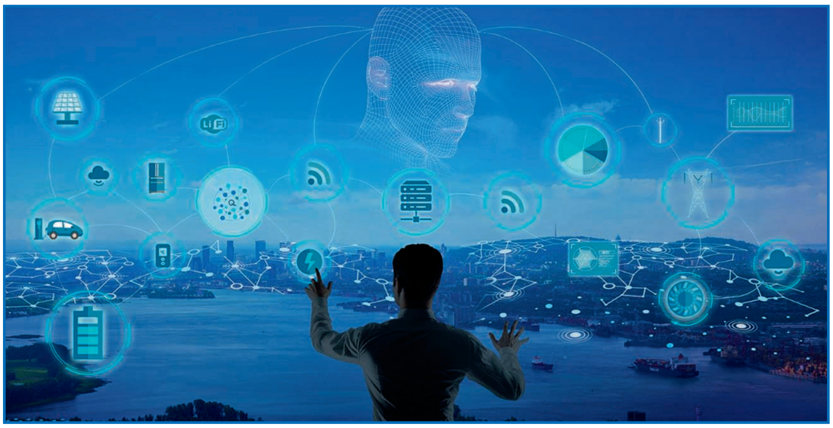

figure 1. Communication-intensive smart grids enable sustainable digital communities

latency was 25.346 ms in the same month, while the specifications are 45 ms or less for regional roundtrips within North America and 30 ms or less within Europe. The average jitter was 15 ms in the United States, Canada, and Mexico. These are not acceptable numbers for wide-area control, and because of the "enterprise" nature of the network, we will further need firewalls at every step, which will add to the jitter and latencies.

From the early 2010s to now, we have witnessed a lot of writings and discussions on the new end-to-end electric energy system applied to the generation, transmission, distribution, and distributed energy resource (DER) domains, including the associated control centers (Figure 2). The concept of the smart grid promotes bidirectional, interactive, unpredictable, and fluctuating flows of information between all the domains instead of the unidirectional traditional model "from generation to the customer." At the core of such a vision, there is a power grid communication infrastructure seamlessly integrated with the electricity network and working synergistically with it. Grid communications will remain a supporting technology driven by the needs of the power grid, with its development seeking a cost optimum between data quality and network latency and bandwidth. It will enable concepts and technologies such as situational awareness, AI, the IoT, digital twins, centralized protection and control, and dynamic state estimators, which are now sufficiently mature to be considered realistically, as in the smart grid orientations and visions that the industry is looking for.

The present issue of the magazine was designed with the goal of providing some elements of power systems needs to networking practitioners and to provide some elements of networking to power systems practitioners tasked with implementing smart grid visions. In reference to Figure 2, we have an article dealing with the comprehensive design of a wireless private utility-grade network to enable communication-intensive functionalities inherent to a smart grid [A2]. Another article provides an update on substation digitization based on the International Electrotechnical Commission (IEC) 61850 standard and the grid communication implications of applying it (see the left end of Figure 2) [A6]. Privacy and trustworthy data issues under the high penetration of consumer-owned DERs are tackled in another article, with innovative solutions investigated [A5]. The orchestration of all connected devices over a

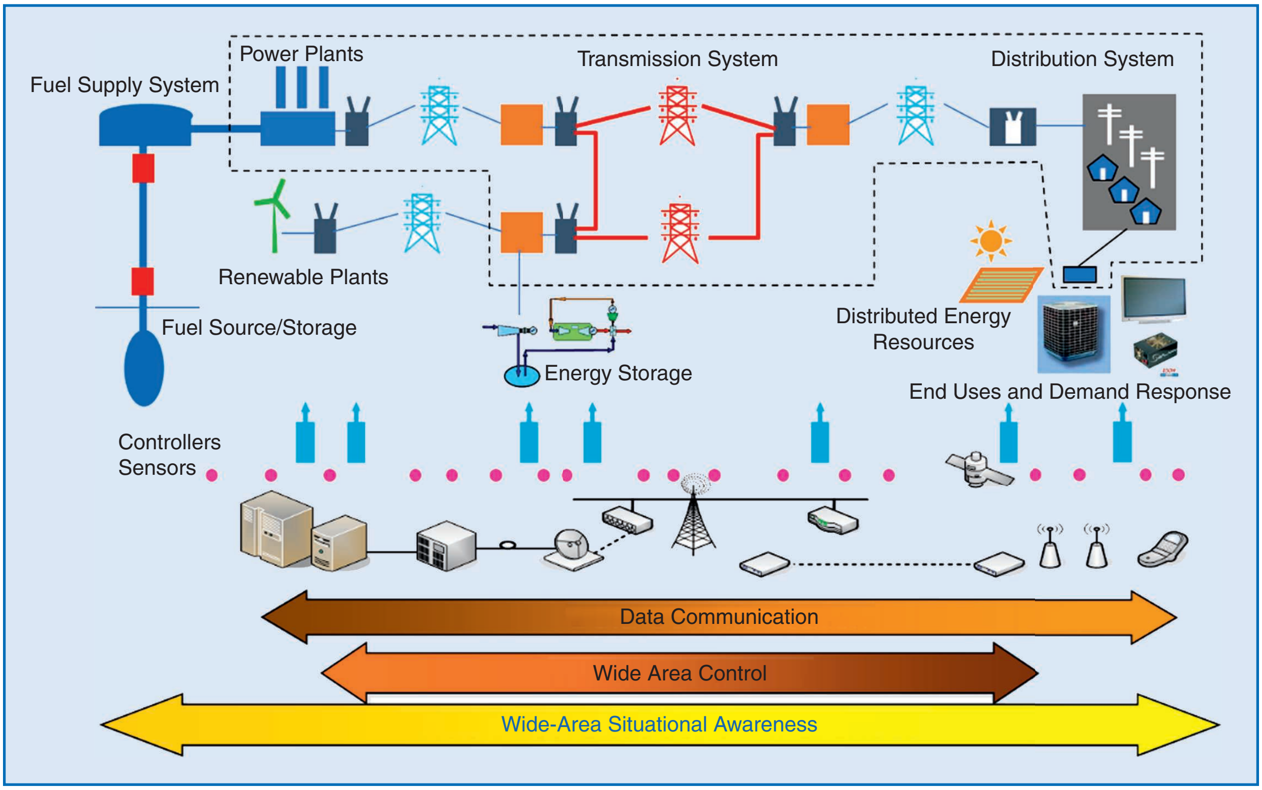

figure 2. End-to-end power delivery operation relies on fast and secure data communication.

Call for IEEE Power & Energy Magazine History Articles

The History column of the IEEE Power & Energy Magazine has been a mainstay since the inception of the magazine in 2003. Technologies and the inventors are featured in this column every issue. The fascinating power engineering world is comprised of a limitless number of innovations and the people who made them work. This historical perspective is presented with space allocated in every issue of Power & Energy Magazine. It is a feature that provides a perspective of the great accomplishments of the past from which we can fuse a bridge to the future.

This call for papers encourages authors to prepare and submit articles covering key aspects of electrical power and energy history, including local, regional, and global advancements.

Some target characteristics of your submission include:

- ✔ Target approximately 4000 words
- ✔ Prepare up to 8 figures (photo's, diagrams)
  - • Authors should verify copyright status or obtain permissions
- ✔ Identify up to 6 For Further Readings to point the readers to broader reading
- ✔ The magazine format does not allow equations
- ✔ The magazine format does not allow citations such as in a journal paper

The optimal schedule is as follows:

- ✔ On or about 6-Months out – Draft to Associate Editor, History (some flexibility in this date)
- ✔ On or about 4-Months out – Near Final version to Associate Editor, History
- ✔ On or about 3-Months out – Associate Editor to submit manuscript for publication to the IEEE P&E Magazine Editorial Staff
- ✔ On or about 2-Months out – Final Galley Proof for author review (quick turn-around usually requested – less than 1 week)

Each article also features a short introduction to the topic by the Associate Editor, History, including a brief author bio and affiliation.

Please submit your ideas and manuscripts to:

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wide area using data communications infrastructure requires a common time reference. The concepts, standards, and technologies required for that purpose are the topics of another article [A3]. After the 2003 Northeastern American blackout, the fault recorder oscillograms from different substations were hard to reconcile because, back then, submicrosecond data synchronization using, for example, GPS clocks or IEEE Standard 1588 on precise time synchronizing, was not prevalent.

The two last articles deal with communication-dependent applications in distribution grid modernization, areas where most of the action is taking place nowadays [A4], [A7]. The first article highlights the use of IoT-based technologies for classifying different faults and detecting anomalies in the grid, including potential cyberattacks [A4]. The next one introduces a new device, the synchrowaveform measurement unit, which uses a higher sampling rate for transmitted data than current synchrophasor measurement units, to unlock new frontiers in system dynamics tracking, incipient fault detection and identification, and asset condition monitoring in inverter-based resource-dominated grids [A7].

Leader's Corner

IEEE Power & Energy Society (PES) Treasurer Juan Carlos Montero is our guest leader in this issue [A9]. A non-U.S. IEEE volunteer working in the utility industry, Juan Carlos is well placed to pinpoint the benefits brought to IEEE members worldwide by conferences. Together with top-of-the-line publications, conferences allow PES to maintain a healthy bottom line while offering members with worldwide opportunities to network. As an example, the recent launch of the Grid-Edge Technology Conference, to be held in non-T&D conference years, was an amazing financial and technical success according to Juan Carlos.

News from the Magazine Desktop

We are pleased to announce that the themes of the magazine for the next year (from 2024 to 2025) are now posted on the magazine website (see Upcoming Issue Themes on https://ieee-pes.org/publication-item/power-energy-magazine/). In case you are interested in getting involved in any of the special issues, you must directly contact the guest editors for that issue.

According to IEEE publication policies, we want to acknowledge an incremental rotation of the Editorial Board membership, under the recommendations of the Nominations Committee chaired by MacKay Miller, to whom I extend my appreciation. A sincere thank you for all the hard work by our outgoing board member Ning Lu, a past associate editor. We welcome two new Editorial Board members, Caixia Wang, from China, and Marianna Vaiman, from the United States.

IEEE is committed to diversity and equity in the technical professions. The new additions, selected by the Nominations Committee for both their technical and communication skills, come from different industry segments and different PES technical committees. They are a testimony of the PES leadership's commitment to diversity and regional representation.

In Memoriam

We are sad to report the recent passing of Dr. Mo-Shing Chen, an emeritus professor at the University of Texas at Arlington, where he started his long career in 1962. Among other achievements, this IEEE Fellow was known for his annual two-week course, "Modeling and Analysis of Modern Power Systems," which I attended at the beginning of my career as a power systems scientist for a utility. Dr. Chen's obituary is included in this issue [A10].

Wrap Up

I want to thank the editors and their team of authors for their massive work in making this issue happen despite their heavy professional commitment. James Ogle and Antonio Conejo deserve a lot of praise for their patience in smoothing the large uncertainties that were faced unexpectedly when implementing the original publication plan. Several articles were missing for various reasons. But fortunately, we were able to find timely contributions that not only fit well within the original scope but that also complemented the initial slate of authors nicely in terms of both topical and geographical diversities. The magazine is planning to build on this grid communications foundation to sponsor a special issue next year dealing with WAMS and its related applications to control, protection, and situational awareness.

I conclude my introduction to this issue by stressing, once again, that I am always looking for new ideas in spontaneous articles that are solicited for any special issue, giving anyone who is interested in this magazine an equal opportunity to have their views published. Feel free please to forward any concerns or questions to me at innocent.kamwa@gel.ulaval.ca.

For Further Reading

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Appendix: Related Articles

[A1] J. D. Taft, “Utility communications: Unlocking the value of digital networks,” *IEEE Power Energy Mag.*, vol. 21, no. 5, p. 84, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288597.

[A2] C. L’Abbate, “A modern communications platform to enable the modern grid: A utility-grade wireless broadband network,” *IEEE Power Energy Mag.*, vol. 21, no. 5, pp. 18–26, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288589.

[A3] P. Robertson, K. Fodero, C. Huntley, M. Elshafi, and D. Williams, “Precise time, all the time,” *IEEE Power Energy Mag.*, vol. 21, no. 5, pp. 27–37, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288593.

[A4] J. Stoupis, R. Rodrigues, M. Razeghi-Jahromi, A. Melese, and J. I. Xavier, “Hierarchical distribution grid intelligence: Using edge compute, communications, and IoT technologies,” *IEEE Power Energy Mag.*, vol. 21, no. 5, pp. 38–47, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288596.

[A5] R. Currie, S. Peisert, A. Scaglione, A. Shumavon, and N. Ravi, “Data privacy for the grid: Toward a data privacy standard for inverter-based and distributed energy resources,” *IEEE Power Energy Mag.*, vol. 21, no. 5, pp. 48–57, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288595.

[A6] S. A. Gutiérrez, J. F. Botero, N. G. Gómez, L. A. Fletscher, and A. Leal, “Next-generation power substation communication networks: IEC 61850 meets programmable networks,” *IEEE Power Energy Mag.*, vol. 21, no. 5, pp. 58–67, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288579.

[A7] H. Mohsenian-Rad and W. Xu, “Synchro-waveforms: A window to the future of power systems data analytics,” *IEEE Power Energy Mag.*, vol. 21, no. 5, pp. 68–77, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288583.

[A8] D. Wilson, “Share your thoughts,” *IEEE Power Energy Mag.*, vol. 21, no. 5, p. 78, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288581.

[A9] J. C. Montero, “PES supporting our members worldwide,” *IEEE Power Energy Mag.*, vol. 21, no. 5, p. 14, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288586.

[A10] M.-S. Chen, “In memoriam,” *IEEE Power Energy Mag.*, vol. 21, no. 5, p. 79, Sep./Oct. 2023, doi: 10.1109/MPE.2023.3288575.

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