Energy Storage

A power electronics system view

by Sudip K. Mazumder

At the 10th Future Power Processing Conference, I chaired the session "Energy Storage: A Power Electronics System View," which was held on 27 June 2019 in Tromsø, Norway. The two invited speakers were Dr. Isik C. Kizilyalli, the director of the Advanced Research Project Agency–Energy (ARPA-E) and Prof. Liuchen Chang of the University of New Brunswick, Canada. In addition, the session also included three invited panelists, Prof. Deepak Divan of the Georgia Institute of Technology, Atlanta; Prof. Pedro Rodriguez of Loyola University, Spain; and Prof. Ron Hui of Imperial College, United Kingdom, and the University of Hong Kong. Prof. Hui also served as notetaker for the session.

I initiated the session by highlighting the importance of energy-storage (ES) systems for broad power/power electronic applications including renewable energy, electric vehicles (EVs), and distributed energy resources (DERs) and their ability to address energy intermittency and load-operational variability. I pointed out that the ES market is expected to become a trillion-dollar business opportunity; by 2017, it reached US$194 billion and may increase to US$296 billion by 2024 (Figure 1). As such, ES deserves immediate attention in the IEEE Power Electronics Society (PELS).

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Dr. Kizilyalli's presentation, "Ongoing and Evolving Opportunities and Challenges Related to Storage at ARPA-E," indicated that, to make renewable energy dispatchable, there are two key requirements: an ES system with 1) tens of hours of duration and 2) low cost. During this talk, he introduced the Duration Addition to Electricity Storage program of ARPA-E, which supports 10 projects worth US$28 million and looks into various forms of long-term ES (powering up to hundreds of megawatts) including, but not limited to, flow batteries and some mechanical ES systems as an alternative to lithium-ion batteries with regard to number of hours and price. He illustrated his point by citing an example of a photovoltaic (PV) medium-voltage dc (MVDC) transmission system in which ES will play a significant role.

Prof. Chang presented "Distributed Energy Systems as Flexible Resources for Power System Operation." He argued that, as ES is still expensive, demand-side management of thermal loads (e.g., space heating and cooling), which occupy almost 80% of domestic loads, could be pursued as an alternative to traditional ES by dynamically shifting the capacity (Figure 2). For instance, shifting power by controlling domestic electric water heaters is a way of balancing supply and demand. With that view, he further pointed out that the grid-tied inverters would provide active power control for frequency regulation and reactive-power compensation for voltage control in the power grid. He showed an example of a pole-mounted distributed power inverter with a battery as a new means of reducing peak load.

Prof. Divan gave a brief talk, "Storage and the Future Grid—Grid as an Ecosystem" in which he summarized two driving needs for ES in electric mobility and grid applications. He stated that, for EVs, batteries are the answer today, and they are expected to move toward applications in hybrid electric aircrafts and locomotives. For the power grid, batteries continue to have shorter durations (up to 4 h), and pumped hydro is still needed for longer durations. With the coordination of many assets, such as an EV fleet, thermal loads, and renewable-energy-generation units, a dynamic balance of supply and demand can be achieved. He explained that a conservative voltage regulation is also a means to reducing power consumption, as 1% reduction in main voltages could lead to approximately 1.9% reduction in power consumption.

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Likewise, Prof. Rodriguez's panel presentation, "Hierarchical Control of Grid-Integrated Energy Storage Systems," outlined the hierarchical control of ES on three points. At the grid-connection level, grid services can be provided through inertia emulation, power-oscillation damping, primary voltage regulation, frequency regulation, and so on At the area level, it can provide flexibility, such as power-balance provision, power-curtailment management, and so on. Finally, at the power system level, it can offer flexibility services, including demand-response and backup management, generation schedule optimization, and so on.

Prof. Chang showed an example of a pole-mounted distributed power inverter with a battery as a new means of reducing peak load.

Finally, Prof. Hui's panel presentation, "Options for Energy Storage Sources," addressed the options for ES resources. He argued that if the energy density of a flow battery, with a high charge/discharge cycle close to 20,000, is increased 10-fold, as expected by some research groups in this area, its performance can outperform lithium-ion batteries that have charge/discharge cycles of up to only 4,000. The implication is that the flow batteries of EVs can be filled with liquid electrolytes within a few minutes, just like filling a gasoline tank in combustion-engine vehicle.

Following the presentations, there was an open discussion, when participants voiced several questions and remarks. One suggested that the choice of ES should be based on the nature of the applications. Others highlighted the need to explore existing/synthetic high-energy-density fuels for ES and, perhaps, assess their implications for power electronics-based ES system design encompassing stationary/mobile applications. It was further suggested that potential pathways for distributed and intelligent coordination and local adaptive response for optimal demand management and system resiliency should be explored, thereby reducing component-level ES needs.

Based on the presentations and the open discussions, the following R&D needs for the future of ES were collectively identified and suggested. First, power electronics researchers/engineers should watch the progress in flow batteries, decarbonization of synthetic fuels, and other promising nonelectrical energy-source technologies. Accordingly, R&D should be planned to discover solutions (in stationary/mobile energy spaces) that provide economically, temporally, and power-/voltage-scaling solutions tailored to application metrics that incorporate a holistic system overview and leverage advances in materials, devices, passive components, packaging, circuits, controls, and protection technologies. Additionally, to address the need for flexible resources in evolving power systems to dispatch power continuously, nonintrusively, resiliently, and flexibly, new distributed-energy-based technologies using intelligent, coordinated, dynamic-balancing, adaptive, and plug-and-play power electronics as an enabler must be developed to supplement conventional ES. Finally, the DER-based technologies complemented by and supplementing conventional ES should be explored to provide versatile, value-added services or programs to furnish the flexibility requirements of power systems so that they have a significant impact on the emerging smart grid.

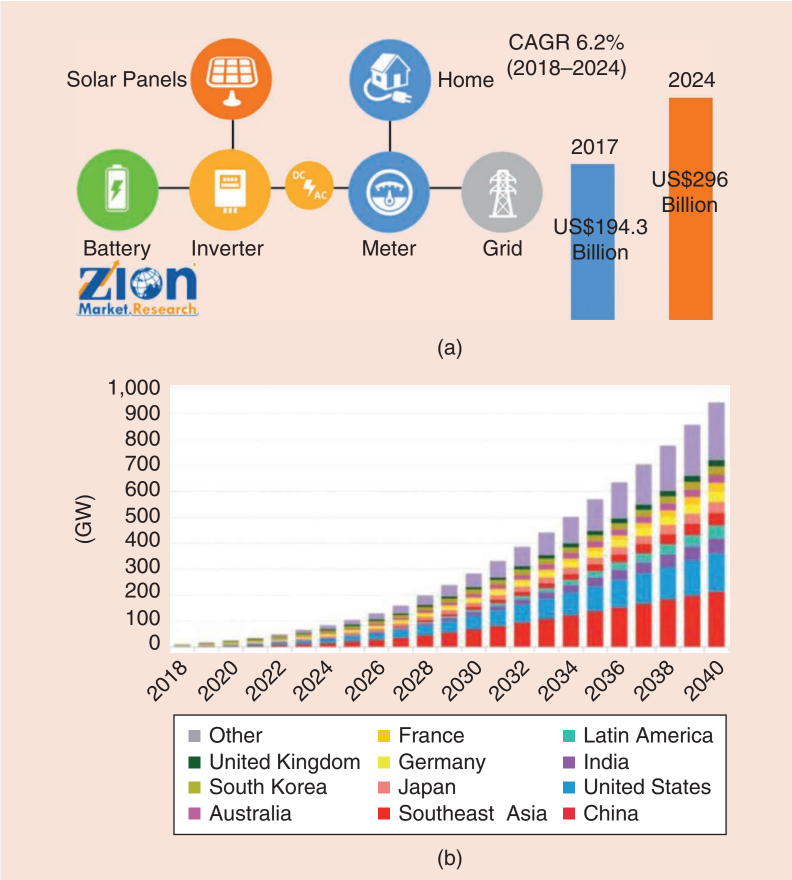

FIG 1 The global ES systems market. (Source: BloombergNEF.) (a) A diagram of the global ES market forecast analysis. (Source: https://www.zionmarketresearch.com/report/energy-storage-systems-market.) (b) The global cumulative storage deployments. GW: gigawatt; CAGR: compound annual growth rate. (Source: https://about.bnef.com/blog/energy-storage-620-billion-investment-opportunity-2040/.)

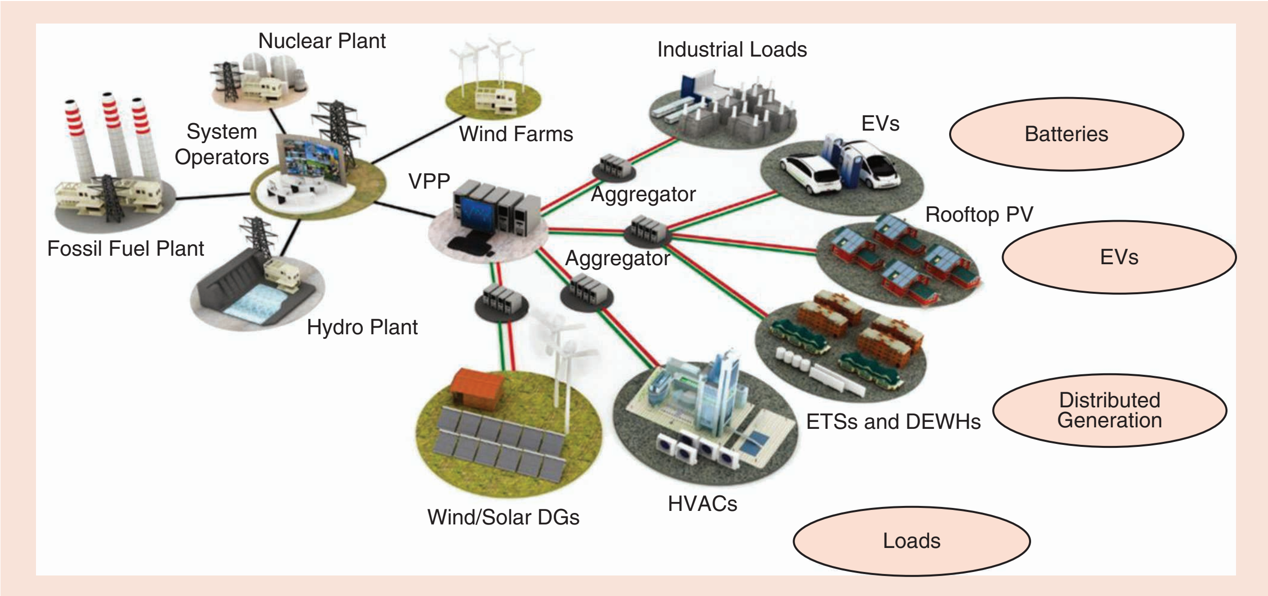

FIG 2 The demand-side management of thermal loads as part of the DERs portfolio. DG: distributed generator; HVAC: heating, ventilation, and air-conditioning; VPP: virtual power plant; ETS: electrical thermal storage; DEWH: domestic electrical water heater. (Source: Prof. Liuchen Chang; used with permission.)

About the Author

Sudip K. Mazumder (mazumder@uic.edu) received his B.E. degree from the Delhi College of Engineering, University of Delhi, in 1989, his M.S. degree from Rensselaer Polytechnic Institute, New York, in 1993, and his Ph.D. degree from Virginia Tech in 2001. He is a professor in the Department of Electrical and Computer Engineering at the University of Illinois, Chicago. He is an IEEE Power Electronics Society (PELS) Distinguished Lecturer, the IEEE PELS Technical Committee (TC5) chair on sustainable energy systems, and an editor-at-large of *IEEE Transactions on Power Electronics*. He is a Fellow of the IEEE.

Challenges Facing Emerging Megawatt Applications

New technology and solutions needed for high-power applications

by Jin Wang

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Standards exist for voltage levels, but there are no industry or IEEE standards to define power levels. Typical perceptions of high power can range from hundreds of watts to hundreds of megawatts. At this year's IEEE Future of Electronic Power Processing and Conversion workshop, the high-power session focused primarily on megawatt applications.

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