

the future's energy mix

the journey to integration

IT'S HARD TO BELIEVE THAT IT'S been two years since the publication of the last issue of *IEEE Power & Energy Magazine* devoted to the integration of large wind and solar plants. A lot has happened during that time. What is most amazing is the breathtaking pace with which the composition of the generation mix is changing. When I look at the generator interconnection queues and see the increasing amount of wind, solar, and storage entering the queues and the near disappearance of nuclear and coal, it makes my head spin. We have passed a point of no return in this regard.

Wind and solar are mainstream now, and battery energy storage is not too far behind. In March 2018, the Utility Variable-Generation Integration Group changed its name to the Energy Systems Integration Group (ESIG). In the previous incarnations of ESIG (the Utility Variable-Generation Integration Group and the Utility Wind Integration Group before that), the commonly accepted thinking was that we needed to integrate wind and solar into the conventional energy system.

As newcomers to the system, wind and solar were often perceived as disrupting the status quo, with a lot of study effort spent on calculating integration costs and operating impacts. This changed as these resources became mainstream sources of our most inexpensive energy. With clean electricity expanding rapidly, we understood that the next big challenge is to use renewable energy from

the electric system to clean up our other energy systems as well—fuels that we use for heating, transportation, buildings, and industrial systems. By doing so, we soon realized that we could access many more sources of flexibility to help balance the system at the same time. Call it *energy systems integration*, as we do at ESIG, or call it *electrification*; we end up at the same place, a decarbonized energy supply.

There is an inexorable movement by society to decarbonize the energy supply. I see it every day when I read the electronic energy news. Another city, another county, another state, another company has made a commitment to clean energy, often committing to 80% clean energy by the end of the next decade and 100% clean energy by some future date (typically 2050 or sooner). For cities, counties, and states, there are myriad reasons, but the bottom line is that citizens and voters are demanding it. For companies, this is driven by the demands of shareholders, customers, and employees as well as the fact that it makes good business sense.

In the spring of 2018, the chief executive officer (CEO) of Xcel Energy, Ben Fowke, announced at the annual Edison Electric Institute meeting, that

Xcel would be shutting down two coal units at its Comanche plant in Colorado 10 years earlier than expected and replacing them with a mix of wind, solar, and storage. Amazingly, he said

that this would save the company and customers money, the air would be cleaner, and system reliability would improve.

“I will tell you, it’s not a matter of if we’re going to retire our coal fleet in this nation, it’s just a matter of when,” he said at the convention in San Diego, California. It knocked my socks off. Then, in December of 2018, Xcel made another announcement stating that it was committing to a 100% clean

energy supply across its eight-state territory by 2050, a first for the industry. The company had a pretty good idea of how to cut carbon emissions by 80% by 2030. It wasn’t quite sure how it was going to eliminate the last 20%, but it wasn’t going to let that stop it.

To make matters more interesting, Jim Robo, the CEO of NextEra Energy, made his own startling announcement on his earnings call in January 2019. He predicted that solar and wind plus storage will be cheaper than coal, oil, or nuclear power early in the next decade, this will be massively

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disruptive to the conventional fleet, and it will provide opportunities to developers well through the next decade. Here are the unsubsidized costs Robo anticipates early in the next decade:

- ✓ unsubsidized new wind at US\$0.02–0.025/kWh
- ✓ unsubsidized new solar at US\$0.025–0.03/kWh
- ✓ storage will add US\$0.005–0.01/kWh to the cost of solar
- ✓ the lowest average cost of a combined cycle gas plant will be roughly US\$0.04/kWh, which does not account for fuel cost uncertainty.

The funny thing is that these costs are already being achieved in many places today.

It's clear that renewable energy is the way of the future. The incentive to decarbonize is strong, the evidence to support the need is overwhelming, and it's

only a matter of time before it occurs. In the absence of federal leadership and with broad public support, state policy makers are leading the way, and forward-looking utilities are right there with them. Once society has spoken, our job as power system engineers is to design and operate systems that will achieve society's goals in the most economic and reliable way possible. The articles in this issue provide a status report from around the world on what is being done to help facilitate the transition to the new energy mix of the future. From grid-forming inverters, to new sources of flexibility, and the evolution of the electricity market

design, all of the things that we thought we knew are being called into question as we explore the path to the future.


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One of the interesting things about this path is that it follows a similar route in most of the countries around the world. Although it is true that some countries are at different stages of development, everyone considers a sustainable energy future as their

end goal. Some may rely on fossil assets longer than others, but the direction in which we are headed is undeniable. In the eight feature articles in this issue of *IEEE Power & Energy Magazine*, we are fortunate to have 80 authors from 11 countries share information and insights about what they have found on their respective journeys. There is certainly diversity in the approaches, and everyone has had slightly different experiences and lessons learned, but we find we have more commonalities than differences. We invite you to open the pages and compare your own experiences with those of the authors.


The first article, "Secrets of Successful Integration: Operating Experience With High Levels of Variable, Inverter-Based Generation," is led by Debra Lew, an independent consultant. It is truly amazing to see what is already being achieved as well as the plans for the future.

In the second article, "Transformation of the Grid: The Impact of Distributed Energy Resources on Bulk Power Systems," a team of authors headed by Ryan Quint of the North American Electric Reliability Corporation examines the necessary steps for ensuring bulk power system reliability. It is clear that the power system of the future will have significant amounts of generation and storage connected to the distribution system, and the impacts are already being felt on the transmission system today.



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Sue Haupt of the National Center for Atmospheric Research leads an international team for the third article, “The Use of Probabilistic Forecasts: Applying Them in Theory and Practice.” This topic assumes an ever-increasing importance, with renewable energy occupying a larger portion of the energy mix.

The Electric Power Research Institute’s Erik Ela and his team explore the fascinating world of market design in the fourth article, “Future Electricity Markets: Designing for Massive Amounts of Zero-Variable-Cost Renewable Resources.” Making the transition from a world in which markets were designed assuming the importance of nuclear, fossil, and hydro resources to one dominated by renewable

energy goes to show you never can tell.

The fifth article, “Flexibility From Energy Systems Integration: Supporting Synergies Among Sectors,” is led by Antje Orths of Energinet, the Danish transmission system operator. The need for additional sources of flexibility from the integration of energy systems to manage the power system of the future is laid out in a clear fashion.

In the sixth article, a team by Jason MacDowell of General Electric reveals the extent of cooperation on international standards in their article “A Journey Through Energy Systems Integration:

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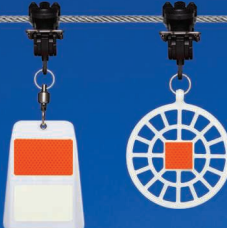
Trending Grid Codes, Standards, and IEC Collaboration.” It is amazing to see that, with the differences in the operation of individual power systems, a common approach to standards that cover the design

of the related equipment and systems still applies.

Julia Matevosyan of The Electric Reliability Council of Texas leads a diverse team for the seventh article, “Grid-Forming Inverters: Are They the Key for High Renewable Penetration?” This article offers a fascinating tour through the different perspectives of original equipment manufacturers, system operators,

making life visibly safer

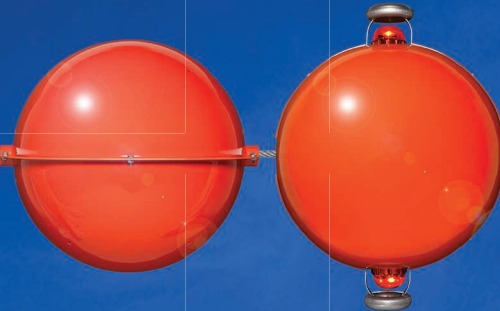
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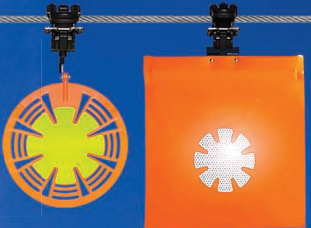
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and the research community on the transition to a low-inertia grid.

In their article “Variable-Generation Integration in China: An Update,” Liping Jiang and Caixia Wang of the State Grid Energy Research Institute in China and their coauthors provide new information about wind and solar integration in China. The rapid rise of renewable energy in China, the associated policy environment, and the transition from rapid growth to quality development are documented in a very thorough fashion.

Putting together this issue of *IEEE Power & Energy Magazine* was a significant undertaking. In addition to the numerous contributing authors, I would like to acknowledge a few of the many people who helped make it happen. First are the eight lead authors, five of whom are female colleagues, who

did a great job in coordinating across cultures and time zones to pull it all together. My co-guest editor, Charlton Clark, recently of the U.S. Department of Energy, provided enthusiastic and tireless support. Next is Mike Henderson of ISO-New England and the editor-in-chief of *IEEE Power & Energy Magazine*, whose patience, understanding, and support were instrumental in making this issue a reality. Going back to the beginning, there is the vision of Mel Olken, the previous editor-in-chief of *IEEE Power & Energy Magazine*, whose idea it was many years ago to embark on this path. And, of course, the fantastic staff at the IEEE for their steadfast dedication—many thanks.



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