Energy Insecurity

Antonio J. Conejo and Federico Milano

As the power industry moves from a capacity-limited to an energy-constrained generation mix, diverse situations impact energy security. Environmental considerations may prevent the deployment of components that increase the energy security level, e.g., nuclear or thermal units, or may require the retirement of such components. Limited transmission capacity, outdated operational procedures, and/or limited storage availability may also significantly decrease the operational security level. The interaction of different energy systems is yet another emerging issue. For example, natural-gas unavailability due to issues about natural-gas sources or pipelines affects the operational capability of power systems with a significant share of renewable generation.

There exist, of course, new technologies and tools that, if properly harnessed, may help maintain or even increase energy security. In this vein, demand flexibility has great potential. The redesign of operational procedures involving a comprehensive use of data processing, forecasting, and optimization also appears as a viable and effective solution. Models that accurately represent the physical laws (AC power flow equations) are increasingly important to make informed operational decisions.

This issue provides an overview of energy security problems and remedial actions in power systems in different regions of the world.

This issue contains seven articles and a column. The first two articles address energy security issues in the "electrical island" of Texas and in California where wind production and solar production, respectively, are most relevant. The following three articles describe energy security approaches in Europe, including the very distinct cases of Ireland, Denmark, and Switzerland. The last two articles pertain to Japan and Australia where insularity and a continental-wide service area, respectively, call for tailored approaches. The issue concludes with the "In My View" column, which provides an insightful formal analysis of energy security by Göran Andersson.

In the first article, Julia Matevosyan and her co-authors provide a comprehensive description of the operational security framework at the Electric Reliability Council of Texas. It includes background, a review of issues about high inverter-based resource penetration, market-based solutions comprising an array of ancillary services, improved forecasting, and different situational awareness tools to ensure security from day-ahead to energy delivery.

In the second article, Guillermo Bautista introduces the California power system. He analyzes energy insecurity due to the coupling of the natural gas and power systems as a result of the significant electricity production with combined cycle gas turbines and the high penetration of weather-dependent renewable sources. The article focuses on issues in southern California from the Aliso Canyon natural gas storage leak in 2015. Remedial and preventive actions to ensure electric energy supply security are described. These actions are mostly related to the coordination of the operation of natural gas and power systems.

In the third article, Ivan Dudurych presents the all-island Irish power system and focuses on the impact of a high share of wind generation on the transient, voltage, and frequency stability of the grid. The article provides a set of definitions and best practices adopted by the transmission system operator, EirGrid Group, to cope with the peculiar features of the Irish grid. On one hand, to reduce emissions, the operators allow up to 65% of instantaneous wind generation. On the other hand, the system is islanded and connected asynchronously to the British system. This interconnection can supply up to 10% of the Irish peak demand but can trip unexpectedly and very quickly in case of fast and large variations of frequency. The article concludes with a discussion of the relevance for the monitoring of the system security of metrics, such as the rate of change of frequency, system inertia, and system non-synchronous penetration level.

In the fourth article, Jacob Østergaard and his co-authors provide a comprehensive overview of the Danish power system and the ambitious targets of the Danish government regarding decarbonization. The article explains how such targets can be achieved through renewable generation and load flexibility. The latter appears as the most promising way to keep an acceptable level of system security in a scenario where a large quota of the generation mix is based on weather-dependent sources. A review of ongoing Danish research projects suggests that there are many challenges but also many possible solutions. Key to the process toward secure decarbonization is the role of distribution system operators, a multilayered landscape of energy markets and services, and the emerging concept of energy communities.

In the fifth article, Marek Zima and his co-authors give a comprehensive overview of the Swiss power system emphasizing the characteristics that make it unique in the context of energy security. As opposed to the other systems discussed in this issue, the transmission network of Switzerland is strongly meshed and highly interconnected to the grids of neighboring countries. A variety of real-world events, spanning from generation shortages to the consequences of the lockdown caused by the COVID-19 pandemic, illustrates the need for flexible and adaptive mechanisms to guarantee the security of the system. The article outlines a new operational paradigm to address energy security.

In the sixth article, Makoto Tanaka and his co-authors describe the transmission bottleneck management in the two-frequency power system of Japan. They describe in detail the fundamentals of a new methodology (N-1 inter-trip scheme) being implemented to minimize congestion issues exacerbated by the integration of weather-dependent renewable sources. Such a methodology involves instantaneous curtailing of generating units in case of a fault by using an advanced protection system.

In the seventh and last article, Pierluigi Mancarella and Farhad Billimoria illustrate the well-known energy trilemma (affordability-sustainability-reliability) through the unique perspective of the Australian system. The long radial Australian transmission system with high penetration of renewables appears as an emblematic example of system brittleness where even futuristic solutions, such as the world's largest battery energy storage system installed at Hornsdale (South Australia), are both the solution and a source of grid security issues. The article concludes with an in-depth discussion on why the economic implications of the system fragility are the most compelling challenges that demand a new approach, possibly even more than the technical challenges.

The issue concludes with an "In My View" column by Göran Andersson. Physical and cyber insecurities are analyzed using stability concepts known to power engineers. Such concepts are expanded and adapted to reflect an energy-constrained production mix. Building on these stability concepts, the analysis provides several relevant observations to boost robustness and resilience in current and future electric energy systems.

Our goal in putting together this issue is to spur a much-needed conversation on energy security as the power industry shifts worldwide from a power-limited to an energy-constrained paradigm. Such a conversation will hopefully involve regulators, operators, producers, consumers, researchers, and the academic community. We hope that this will generate innovative ideas that will contribute to ensuring a secure, efficient, and environmentally friendly supply of electrical energy.

We are most grateful to Mike Henderson for suggesting writing this issue and for nurturing its initial steps.