Hugh Rudnick

natural disasters

their impact on electricity supply

THE SECURITY OF ENERGY SUPPLY has become a major concern worldwide, given modern society's strong dependence on its adequate delivery. Not only does the functioning of industry, transportation, and communication and computer systems depend on a continuous energy supply, but our complete style of living collapses when energy fails. Surges in fuel prices, political conflicts, wars, and natural disasters directly threaten energy supply, and important policy concerns are being implemented as countries look at ways to protect themselves.

Electricity is at the center of attention as today many essential services (water, gas, communications, and the Internet, for example) and infrastructures depend on its continuity for their smooth functioning. On the other hand, electricity power networks have developed to become large and highly complex technical systems, geographically extended, with differing degrees of connectivity, requiring complex operation in real time to balance supply and varying demand.

The occurrence of natural disasters and their impact on electric power system functioning has been of interest to countries worldwide, particularly in relation to earthquakes. Several countries such as Chile, China, Haiti, Indonesia, Italy, Japan, Mexico, the Philippines, Turkey, and the United States have experienced severe earthquakes that resulted in serious damage to their energy supply infrastructure and at times to their economic development, in addition to the loss of lives and property. But not only earthquakes and related tsunamis menace our electric infrastructure; havoc can also be caused by severe weather condition such as typhoons, hurricanes, tornados, floods and landslides, ice storms, volcanic eruptions, and even wildfires.

In response to this, studies and research in energy security and natural disasters have been conducted around the world. Research centers have been created; for example, the portal http://www.cbsnews.com/digitaldan/disaster/disasters.shtml lists many important links on the subject in the United States. Similar institutions are also in Asia, as listed in http://www.adrc.asia/link/index.html. Specific studies focusing on the impact on electricity supply systems may be found in some of these centers, but there is little published in IEEE periodicals on the matter, although conference publications have provided some information.

> Natural disasters and their impact on electric power system functioning has been of interest to countries worldwide.

The complexity of power system networks makes the task of maintaining a highly reliable operation a difficult one, even in normal conditions. Facing short unexpected interruptions has been a challenge for modern power system design and control, and much effort is placed on keeping the system in secure states rather than alert ones. Nevertheless, these efforts occasionally fail, and major blackouts have occurred even as a consequence of isolated faults. Thus, it would be impossible to keep normal interconnected power system operation when major natural disasters occur. Instead, the challenge is to curtail the impact of disasters on the power system and to carry out recovery actions so as to minimize social disruption. Thus, efforts center on power system resilience, with resilience defined as the ability of a power system to withstand a major disruption with limited degradation and to recover within a narrow time frame with constricted costs. The goals of resilience engineering are a reduced likelihood of damage to critical power systems and components, limited consequences of failures on society, and reduced time to supply recovery. There is no doubt that power system performance will be diminished when a major disaster strikes, but adequate countermeasures and response plans can help the system to return to its original functionality. Resilience not only depends on equipment, building codes, and technology but more so on the organization and standardized emergency preparedness of well-structured electricity companies.

Digital Object Identifier 10.1109/MPE.2010.939922
Date of publication: 23 February 2011

Often after a major disaster occurs, a proposal to take anticipatory strategies and invest more on security and n–2 or n–3 planning criteria is offered. However, this can waste significant investment against threats that may rarely or never occur, whereas resilience strategies can provide better protection with lower cost against uncertain events. That does not divert manufacturers and standards development organizations from designing and building power, communications, and computer equipment that can better cope with the impacts of those disasters in electrical networks.

This special issue attempts to look at specific disasters worldwide, quantifying their affects on the power systems they have impacted. We have asked experts and utility engineers to share the challenges faced and the lessons learned in different events, and this has resulted in five diverse articles of broadly different disasters.

In our first article, Qiang Xie and Ruiyuan Zhu review how Chinese power systems have coped with three types of natural disasters that have taken place in recent years: severe wind storms, ice and freezing rain, and earthquakes. The interruption of electric service caused by these natural disasters led to devastating economic losses in rapidly developing China. The lessons learned from these disasters and their consequences are described, as well as actions taken to reduce their impact in the future.

Hugh Rudnick, Sebastian Mocarquer, Eduardo Andrade, Esteban Vuchetich, and Pedro Miquel author the second article and provide a comprehensive report of the February 2010 earthquake, and related tsunami, that struck the central part of Chile. The authors assess how the earthquake impacted generation, transmission, distribution, and system operation and share challenges faced by electric companies, and their responses.

In the following presentation, Anshel Schiff, who has traveled worldwide to learn effects of earthquakes and draw lessons from them, reports on the 1994 Northridge earthquake. This event occurred in a densely populated area northwest of downtown Los Angeles, California. Based on his experience, he elaborates on how the Northridge earthquake and more recent ones in Chile and Mexico have influenced equipment design and testing, substation design, and utility practices.

Then Nicholas Abi-Samra and Wayne Henry report on the impact of floods on substations and how to protect against and recover from them and describe how a major U.S. utility handled floods in the midwestern United States.

The last article of this issue theme deals with the menaces of terrorism on infrastructure that, together with cyberattacks, is a growing worldwide concern. These potential man-made disasters often focus on the energy supply, a strong tool to better shock society and its foundations. Colombia has been a country historically hit by terrorism over the past two decades, and the transmission network has been a frequent terrorist objective. Pablo H. Corredor and María E. Ruiz describe attacks on the electrical infrastructure, resultant power failures, restoration procedures after a blackout, development of constrained transmission, cost impact and business recovery costs, and lessons learned from these emergency situations.

> We must learn how to make our systems more resilient and robust in the face of future uncertain and critical threats.

Finally, for the "In My View" column, we asked Eric Fujisaki and Jean-Bernard Dastous, chairs of two related IEEE committees (IEEE 693–Recommended Practice for Seismic Design of Substations and IEEE 1527–Recommended Practice for the Design of Flexible Buswork) to offer arguments on why they believe a much-needed and beneficial approach to prepare for natural disasters is the development of international standards.

Clearly, there is no single answer to protect our electricity infrastructure from major natural or man-made disasters. Given past events and learning from them, we must learn how to make our systems more resilient and robust in the face of future uncertain and critical threats, while developing new technologies and management features. As Fujisaki and Dastous say, "a reliable electric power supply following disasters is too important to be left to the same old approaches of the past." This issue will become more relevant in the future, as uncertainty increases, and with the possibility of global warming causing even more challenging weather-created disasters. p&e