Scalable Microgrids for Enhancing System Resiliency and Efficiency

The concept of microgrid is not new. For instance, a CHP-based microgrid on UCONN's Storrs Campus has been in operation for five years serving most of the electricity load of the campus. As most of us still remember, the two severe blackouts caused by the August and October 2011 storms affected nearly 880,000 customers and led to enormous economic and social upheaval in the State of Connecticut. Thanks to the microgrid, UCONN Storrs Campus never lost its power during the two storms. Later, the Storrs Campus survived the blackout caused by Hurricane Sandy, again, because of the availability of UCONN's microgrid. It is believed that microgrid, if properly designed, could be a potent option to prevent, mitigate, and recover power outages because of its compatibility to the grid, substantially immune to tree damages, and inherent stability when operating autonomously.

In general, microgrids can provide a variety of benefits to stakeholders and electricity users. One of the potential benefits is the capability of providing ancillary services. The participation in local ancillary service market could open up new opportunities for microgrids to meet system obligations and achieve business proliferation. When grid-connected, microgrids can provide various services, e.g. frequency control support, voltage support, congestion management, reduction of grid losses, and power quality improvement, to help maintain the integrity of transmission and distribution system. In particular, as renewable energy and electric vehicle penetration rises, transmission or distribution operators will soon find themselves closer to the technical limits of their system and under pressure to find ways to cost-effectively increase those limits. Accommodating high levels of renewable energy and electric vehicles penetration locally through multi-microgrids is of importance for reducing stresses in both the distribution and transmission systems. If the utility grid has emergencies, microgrids could offer black start capabilities to pick up local loads as well as provide frequency and voltage support to accelerate the restoration of utility grid. Moreover, microgrids could contribute to the reduction of peak load and network losses if appropriately located and managed. Microgrids could also provide a flexible platform for demand side management with market incentives and smart control on the load side.

Currently, a few microgrid pilot programs are being developed to test and validate the benefits, efficiency, performance, and operation under community and critical infrastructure conditions. Among them are CT's first-in-the-nation statewide microgrid program and DOEsupported New Jersey Transit System Microgrid.

In spite of the potential benefits, implementation of microgrids suffers from a few challenges and potential disadvantages, as follows.

- High costs of building and operating microgrids

  Building microgrids often involves high costs of distributed energy resources, energy storage, and utility grid upgrades for accommodating fault current contribution and mitigating reliability impact from microgrid.. A joint study between UCONN and Northeast Utilities entitled 'Reliability Evaluation of Selective Hardening Options' has summarized the quantitative reliability benefits of emergency generation, undergrounding circuits as well as microgrids for critical infrastructures within selected CT towns under different weather conditions (normal weather, major storm, tropical storm, Category 1, Category 2 and Category 3 storms). The results show that traditional microgrids can be a high cost option for hardening critical infrastructures. Also, there is a lack of coordinated control, reliability enhancement and optimization technologies to ensure long-term economic performance of microgrids. Further, there is a lack of economic and highly reliable communication infrastructure to enable the resilient and efficient operation of microgrids.

  The solutions to the challenges lie in the extensive education and R&D efforts for microgrid protection, control and management, especially for the coordinated control, reliability enhancement and optimization technologies such as optimal power flow. Recently, research communities including UCONN have focused on methods to develop cost-effective, fast-speed and fault tolerant communication and control, to build advanced microgrid energy management systems, and to reduce the costs of renewable energy, CHP units and energy storage. Our UCONN team is actively developing a 'plug and play' non-synchronous microgrid technology that isolate the voltage, frequency and phase angle of microgrids from that of the utility grid while complying with utility requirements. This technology will largely eliminate the impact of microgrids on power quality and reliability and help increase the penetration of microgrids in smart grid.

- Need of market environment and regulatory support

  It should be emphasized that market environment and regulatory settings have a significant impact over whether or not a commercial microgrid would be able to survive and thrive. Public policy support, therefore, will be one of the key enabler that helps recognize the locational value of microgrids, popularize demand responses through microgrid, encourage technological innovations leading to further cost reduction and create local markets for ancillary services.

Therefore, with the collaborative efforts of our society and the consistent and significant investment in the R&D, we could be able to turn the barriers into enablers that make microgrids one of the powerful and viable approaches to enhancing energy infrastructure resilience and efficiency for our nation.