Distributed Energy Resources: Issues and Challenges

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Distributed energy resources (DER) constitute a relatively new paradigm in the electric power industry. The concept is gaining popularity because of the inherent modularity of DERs. They can be regarded as more flexible power sources, albeit with limited capacity, than centralized power units. DERs are power generation or storage units that are connected directly to the distribution network or connected to the network on the customer side of the meter. These energy sources can include microturbines, fuel cells, wind power, solar power, and several forms of energy storage.

If barriers can be removed, DERs can be valuable resources to the power generation and distribution industry. They have the potential to improve reliability, power quality, and environmental pollution while deferring transmission and distribution (T&D) capital expenditures. However, careful studies are required to prove their true potential.

In this special issue devoted to "Distributed Energy Resources—Potentials for the Electric Power Industry," eight high-quality papers out of the nineteen papers received were selected for publication. Each paper was reviewed externally by at least two leading researchers in the field. The topics addressed by the papers include a wide array of issues faced by the power industry as it readies itself for a possible influx of distributed resources in the near future. These are as follows:

- DER modeling;
- Storage aspects of DER;
- Microgrids;
- Economic and operational aspects of DER;
- Impact on power quality and reliability; and
- Interconnection standards.

Although different circles define distributed generation (DG) in somewhat different perspectives, the most widely accepted version defines it as being a generation source located in proximity to load centers and having a generating capacity of anywhere from 10 kW to 50 megawatts. Often, such generating sources use nonconventional fuels, and many of the units are designed to produce both electricity and heat, in applications simply known as combined heat and power (CHP). This represents a departure from the current industry practice of locating very large fossil-fired generating sources at remote locations, closer to the fuel source and transmitting the generated power over high-voltage transmission lines to load centers.

Many of the DER technologies, such as those that depend on solar power, wind power, and biomass, are inherently renewable in nature. Since solar and wind power outputs depend on an intermittent resource, predicting the amount of power that will be available at certain times of the day often becomes difficult. With large amounts of intermittent generation, operating the renewable DER within an existing electric utility's system can bring about some uncertainties in both the generating source behavior and the network behavior. Studies have shown that at certain penetration levels, one may start to see problems with interconnection. Some suggest this level to be 15%, whereas some suggest 30%. However, whatever the penetration level is, it is clear that the resource variability will most likely have an impact on system operations, including voltage and frequency and, in general, power quality. Therefore, many advocate using distributed energy storage in the system to overcome the variability in the power output from the renewable DERs. Storage also helps provide the needed regulation capacity when load demands change from minute to minute. Batteries, ultracapacitors, flywheels, and so on, can provide this storage capacity.

Since distributed energy resources are installed near loads, they are likely to be installed on low-voltage (below 25 kilovolts) distribution systems. The distribution systems also account for the higher percentage of system losses compared with the higher voltage transmission systems. Therefore, installing DGs at the distribution levels has the added benefit of improving the overall efficiency of the system. However, certain locations on the distribution system offer better choices from the losses perspective. In this issue, Tong and Miu discuss the need for a distributed slack bus model in the power flow model to assign loss contributions to each and for benefit payments to individual DGs on the system.

Radial distribution systems are currently the norm for distribution systems. DGs will make these systems more like the loop system, thereby providing higher reliability of service from the perspective that a specific load can be served from alternative sources in case of a system fault. Multiple sources of generation and alternative routes for power transfer also enable a distribution systems to function as independent self-contained power systems, called *microgrids*. In traditional power grids, large synchronous generators with well-equipped excitation systems provide the necessary voltage and frequency control that are part of the mandatory reliability standards. Illindala et al. discuss the use of multiple DG sources in a microgrid environment for rural electrification. They advocate the use of droop-based active and reactive power controllers in each DG for frequency and voltage control to counter the effects of load variations. They illustrate their proposed strategy with a laboratory-based experiment.

Lasseter further discusses the microgrid concept from the perspective of both parallel and islanded operation of the subsystem that includes distributed generation and loads. The subsystem is able to disconnect from the main grid by using a fast static switch during an event that leads to poor overall power quality. In the islanded mode, the DGs are able to provide their own voltage and frequency control to maintain the proper power quality of the subsystem. The author also provides an experimental validation of the microgrid operating concept.

In their paper, King and Morgan use an engineering-economic model to evaluate the economics of microgrids that may include combined heat and power. Their model estimates the maximum cost-savings that a given customer will enjoy by being served from a microgrid. The authors discuss the sensitivity of their economic model to variations in the microgrid application model, location of the microgrid, demand characteristics, and fuel and electricity rates. In all, the authors evaluate the cost-effectiveness of 36 cases involving six microgrid applications in six different locations in the United States. They argue that microgrids will be most economically attractive where customers have a higher value for electric reliability or a willingness to pay for backup capacity.

It is hard to tell how many electric utilities are currently allowing DG to be interconnected to their systems, but the number is on the rise. Various regulatory and operational issues are involved in allowing customers or even a third party to generate and sell power back to the utility company. It is becoming somewhat easier because of international standards bodies like the IEEE have developed new standards or modified existing ones to standardize the interconnection of DG. Many of these recommended codes deal with safety and reliability issues, as well as interface procedures, allowable voltages and currents, certification, testing, and monitoring issues. However, the interconnection issue remains a difficult problem to solve because of the uncertainties involved with the new forms of DG technologies. Radibratovic et al. take a close look at the current interconnection standards. They discuss a screening process to help utility companies sort out the interconnection approval process. This automated process will result in an approval/disapproval status, sizing and siting of the DG, and the modifications required in the current feeder protection to handle the power from the new DGs.

Because DERs are often connected to weak distribution networks in rural areas, especially where wind power penetration could be significant, Milano et al. investigate potential voltage disruption problems attributable to lack of appropriate reactive power resources. The authors propose several remedial actions that use different control devices to provide voltage support. Since the control devices are not free, the authors use a case study of a 40-bus distribution network to discuss the economic implications of different control schemes.

Two papers focus on technoeconomic aspects of DER technologies. As wind power penetration increases around the world, it is extremely important to have a better understanding of its profitability, which is a major consideration for market entry. The profitability relies on an accurate wind power forecast. Inaccurate forecasts can also result in disruption of unit commitment decisions, with additional costs to recommit and redispatch generating units. Therefore, an accurate wind power forecast model is very much needed. Durán et al. propose a state-of-the art model that uses auto regression with exogenous variables to better predict wind power. Siddiqui et al. consider the adoption of new distributed generation technologies, typically CHP systems, in commercial customers. A methodology applying mixed-integer linear programming is used to minimize the overall energy cost with different scenarios of CHP connection. Bill savings of DER with heat storage system is demonstrated for customers.

We hope that these eight papers covering a variety of topics in this relative new paradigm of DER can spur new research on the array of important problems arising in this fast-changing industry.