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Home > A Model System: Energy Modeling

While the electric power industry rapidly changes, utilities and building owners will need to accurately model the engineering and economic operations of the power system to make informed decisions, so they require sophisticated modeling-software tools.

Power-system modeling primarily involves the representation of a power system or electric network in the form of an appropriate simulation model. According to Mandhir Sahni, head of department, power-system planning for DNV GL, the nature, level of detail and platform associated with power-system modeling will depend on the system itself, the phenomenon expected to be studied, and the drivers associated with the analysis to be performed.

“Power-system modeling is applied in a wide variety of analytical and engineering studies, ranging from power-grid reliability and planning studies, technology, feasibility and impact evaluations, and grid-integration evaluations, to power-system response analysis, and industrial and commercial power-system studies, to name a few,” Sahni said.

Power-system planning and design engineers and electrical-system operators use power-system modeling to analyze and evaluate system performance, design control strategies for protection and control equipment, identify abnormal conditions and possible design changes, and plan for power-system-capacity additions.

“Ideally, the power system would include sensors at every location to enable operators and engineers to continuously monitor the power system via direct measurements,” said Bob Uluski, vice president of distribution automation (DA) and distributed management systems (DMS) for Utility Integration Solutions Inc. (UISOL), Redmond, Wash. “However, installing sensors everywhere is not practical because of both the implementation cost and the burden it would place on the utility’s existing communication infrastructure. A more practical approach is to compute, rather than directly measure, the electric conditions at strategic feeder locations by using power-system modeling.”

The power system is generally divided into two categories: the transmission system (electricity generation and delivery on the bulk power system) and the distribution system (distributing power at lower voltages to commercial and residential loads).

“Power-system modeling examines important grid operations such as the balance of generation and load, line capacities, and voltages,” said James Cale, Ph.D., manager of the Distributed Energy System Integration group in the Power Systems Engineering Center of the National Renewable Energy Laboratory (NREL), Golden, Colo. “On the distribution system, modeling is used primarily to analyze line voltage and currents being supplied to end-user loads."

Models are built based on detailed information about the electrical characteristics of these grid assets, such as line impedances, transformer parameters, load, etc., that make up the power grid, along with information about how the assets are interconnected. They also include a small number of measurements from sensors located at the transmission lines terminals, the head-end of distribution circuits, and other strategic locations, Uluski said.

Power-system modeling can be used for a number of analytical approaches to answer electric-power-system questions from reliability and outage probabilities, to the effect of retiring coal plants or what price expectations might be under different conditions. According to Tanya Bodell, executive director of Energyzt Analytics LLC, Boston, market participants generally use two types of models to inform their investments.

"Market models provide pricing, dispatch and other information that help project generation, load, transmission and supply, and delivery capabilities and determine what generation capability is required to meet loads," Bodell said.

On the other hand, market participants use engineering models to provide a snapshot of the electric transmission system under certain conditions, including the new interconnection of renewable-energy systems to the grid.

The power-flow program, which computes the electrical conditions at any circuit location where no sensors exist, is the application that uses a power-system model the most. It is also used to compute key electrical parameters that are not easy, or even impossible, to measure directly, such as electrical losses.

"The power-flow program displays the results to the power-system operators and engineers to enable them to detect and rectify any problems at the earliest possible time," Uluski said.

Other examples of applications that use a model include, but are not limited to, the following:

- Contingency analysis, which identifies plausible contingencies (such as loss of a line or generator) that could have serious consequences and cascading effects; early warning of these situations may enable the utility to take actions that would mitigate the risk.

- Economic dispatch of centralized generation

- Volt/volt-ampere reactive optimization

- Predictive fault location

- Automatic service restoration

- Switching order management

"The power-system model and associated applications is essentially a power-system simulator, which enables the system engineer/operator to determine the dynamic and steady-state responses of generation and transmission facilities to power-system incidents, such as loss of a line, generator or other anomaly," Uluski said.

With the ability to analyze "what if" scenarios, the engineer could, for example, determine whether generator controls would become unstable during a nearby short circuit, causing the generator to trip and go offline.

Why model?

In general, power-system modeling is essential for utilities and system operators to ensure that the power-system network is reliably planned in advance.

"Power-system modeling enables utilities and system operators to evaluate the impact of future growth patterns on the reliable operations of the power-system network," Sahni said.

In addition, power modeling allows utilities and system operators to identify transmission-system issues and bottlenecks in advance and plan for mitigation measures that ensure smooth and uninterrupted functioning of the power-system network.

The sheer size and complexity of the electric-power grid makes it challenging, if not impossible, to continuously monitor and track possibly millions of data points per minute. Therefore, power-system modeling is vital for condensing the volume of data down to a manageable number of analytics that focus on important issues that require operator attention.

Practically speaking, utilities use power-system modeling for planning and design calculations.

"Utilities use models for analyses, such as planning for growth in load and to make decisions concerning capital equipment and future upgrades," Cale said.

Protection engineering is another practical component of power-system modeling.

"For example, utility engineers can examine the timing and sequences of breakers, relays and switches to plan for and better isolate faults and reduce outage times," he said.

Models, and the analytical data generated by them, are also important in both capacity planning and creating integrated resource plans.

"Capacity planning is how utilities, independent system operators and regional transmission organizations try to discern how much new generation capacity is required to meet reserve margins," Bodell said.

Integrated resource plans are multiyear projections on which infrastructure investments will be required in the power system to meet changing conditions. These plans help utilities incorporate resources such as demand response and energy efficiency.

The challenges associated with power-system modeling primarily involve obtaining the appropriate and correct data required to accurately and adequately represent the network

“With solar photovoltaic [PV], battery storage and other emerging technologies, some of the challenges lie in developing models that appropriately integrate them with the power--system grid model,” Sahni said.

Why should an EC care?

According to Sahni, power-system modeling is important to electrical contractors (ECs) because they can use the data to perform specific power studies and evaluate the impact of the building under construction on the power-system network.

“Alternatively, the contractor can hire third-party expertise to perform those power studies to better understand the technical and economic impacts the facility will have on the power system or vice versa,” he said.

Some contractors working on new facilities may be called on to supply information that must be included in a utility’s power-system model. The biggest issue for the contractor, then, would be to supply information pertaining to the steady-state and dynamic characteristics of a facility’s solar PV, wind power or energy-storage resources. These resource technologies will certainly include the newer “smart” inverters, and that information will be vital to utilities as part of their control strategy for intermittent renewables.

According to Cale, ECs that are familiar with power-system modeling can work with utilities to perform design calculations for both the bulk-transmission system as well as the distribution system to determine design specifications, such as transformer ratings, conductor sizes and relay timing.

“One caveat is that contractors that perform power-system (modeling) should ensure that they have a detailed enough model, or use a software package that does, to accurately represent the system’s underlying physics,” he said.

Another reason to be familiar with power-system modeling, Bodell said, is the increasing need for contractors to understand electricity market prices and how demand-response operations can interact with those wholesale markets.

“Electrical contractors who understand these models will be able to respond to evolving market demands and be more involved in choosing and implementing the controls and other smart-building systems that take better advantage of the interaction between retail and wholesale electricity markets,” he said.

As the country moves toward a next-generation electric grid that integrates more renewable and other distributed generation technologies, there will be an increased emphasis on power-system modeling and its ability to evaluate the impact of such technologies on the grid and on ensuring that they are integrated reliably. Adoption of renewable-energy technologies are also starting to blur the lines between the transmission and distribution sides of the industry, leading to the development of combined transmission- and distribution-system models.

"With the growing deployment of renewable-energy generators on the distribution system, it will eventually be impossible for utilities or contractors to examine the transmission system without considering generation occurring on the distribution system," Cale said.

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