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KEN WACKS' PERSPECTIVES

Integrating Renewables into Smart Grids

By Ken Wacks

The traditional electric utility consists of a few generating stations supplying power to millions of customers through a radial (tree-like) grid of long-distance transmission and local distribution lines. In my summer 2013 article for *iHomes and Buildings*, I explained that the introduction of renewables (such as wind and solar) and storage may result in a very different energy system. Consumers may become prosumers as they produce energy and sell the excess to their neighbors and to a community microgrid. The future grid is likely to morph from a tree topology to a mesh with lots of power sources including the incumbent utility, which would no longer be the exclusive supplier.

The present electricity business is highly regulated with retail prices established as government-approved tariffs. The tariffs are set at levels that cover operating costs, a portion of capital investments, and a profit of about 12 percent. In those jurisdictions where prosumers are allowed to sell their excess, the only buyer is the local utility and the price is fixed. In the future environment, I described in the 2013 article, prosumers can sell into a microgrid using tools called Transactive Energy, which help consumers determine a market price and deliver the energy.

In this article, I introduce the concept of ascertaining costs in a distributed grid, which is a prerequisite for creating a market for distributed energy resources (DER). DER is a collective term for energy sources distributed throughout the grid that will initially supplement central fuel-based generators. DER may include:

- Renewable energy farms
- Prosumer-owed renewable generators
- Storage at fixed locations
- Mobile storage in electric vehicles

Market price for electricity

The factors that affect a competitive price for electricity include generation capacity, power quality, and the ability to deliver the power to the buyer. That is why Transactive Energy includes elements of a commodity-trading market tempered by the physical constraints and performance of the distribution network. To create a market for Transactive Energy, value must be assigned to the energy delivered based on costs for:

- Generating the power
- Converting the power to 60-Hz AC
- Connecting the power source to the grid
- Using the local distribution network
- Maintaining grid stability and minimizing losses

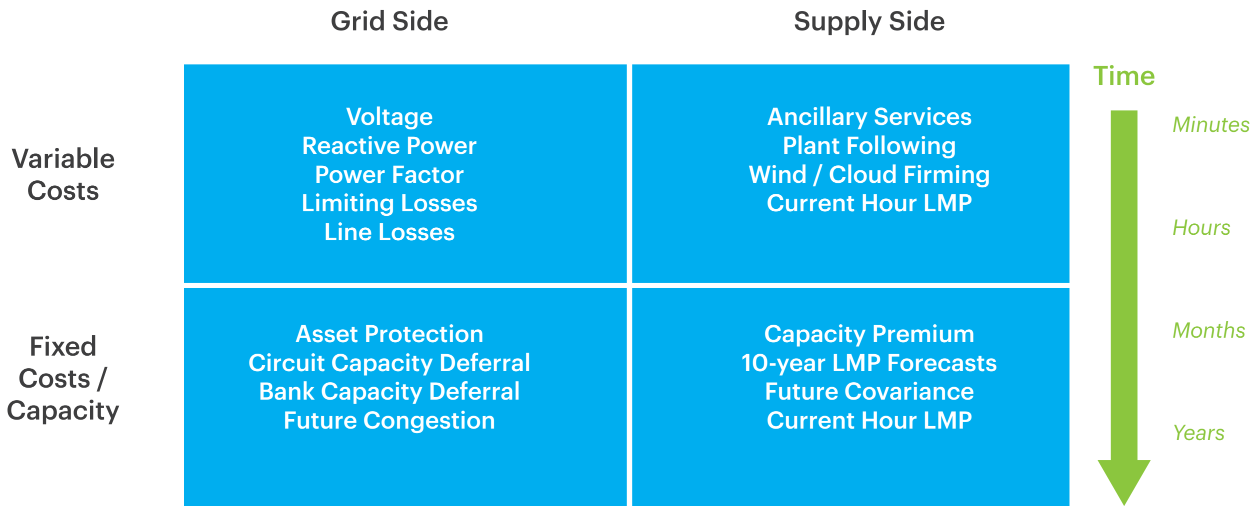
Distribution constraints are determined by the capacities of the power lines and transformers. Performance is determined by equipment that provides so-called ancillary services needed to maintain grid stability and to minimize power losses. Stability and loss minimization depend on synchronizing alternating current (AC) at 60 Hz (in North America), maintaining customer line voltages at 120 VAC, and minimizing the phase differences (called the power factor) between voltage and current.

Granular cost analysis

The introduction of DER implies that potentially significant grid resources are now being added at the edge of the grid. To accommodate and evaluate these new resources, utility cost-analysis must become more granular than traditional central plant analysis and regional load forecasts.

The alternatives to granular costing for energy are traditional utility rebates or incentives, which mask very high avoided-cost areas or opportunities. Because electricity has

Figure 1 – Four Categories of Distributed Marginal Costs
(Courtesy of Integral Analytics)



no or little buffer between supply and demand, price spikes are common and cause serious problems:

- Inequities as some users learn how to game the system with ad hoc substitutes for accurate cost signals.
- Continued operation of rooftop solar, energy storage systems, power-factor optimization equipment, demand-response and energy-efficiency programs, and other distributed-grid resources as separate silos with unknown risks.
- Sub-optimal management of the grid and grid investments.
- More regulatory hearings to increase rates or to introduce fixed charges as revenues from traditional generation shrink.
- Lobbying to slow DER.
- A decrease of investor confidence in the utility stock.

An objective of granular costing is to avoid these problems by improving energy management.

Distributed Marginal Price (DMP) metrics

Cost measurements are needed throughout the grid in order to determine prices for DER transactions. Distributed Marginal Price (DMP) metrics provide these cost measurements using DMP methods and software[1] that can predict node-by-node costs over a wide range of time scales and grid requirements in terms of both magnitude and timing. Placing all resources within a common cost-based analytical framework insures that all resources are evaluated on a level playing field.

The DMP software analysis tools deliver metrics to predict the performance and needs of the entire grid. Measurements are gathered from the transmission and distribution grid using supervisory control and data acquisition (SCADA) equipment, computer projections of power flows from radial power-flow models, data from billing systems and smart meters, and several other third party sources. The software creates a logical base map of the grid and operating parameters.

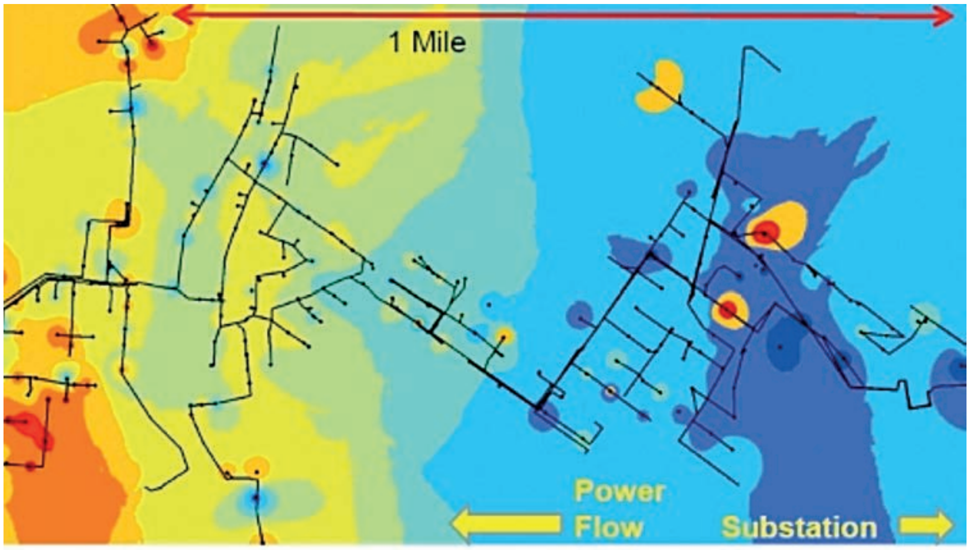
Changes to the grid are projected onto the base map using predicted developments in technologies, standards, demographics, and the introduction of customer programs such as Demand Response, storage, solar, Transactive Energy, and others. Placing all grid resources within a common cost-based analytical framework insures that all resources compete on a level playing field and that least-cost resource plans can be determined.

The development of DMP

DMP is an extension of Localized Marginal Price (LMP) used by some transmission operators who manage a competitive market among central-generation resources. LMP was introduced for transmission-grid operators to determine the cost of power at specific nodes on the grid in order to manage network congestion. LMP includes a

1 DMP methods and software were developed by Integral Analytics, Inc., http://integralanalytics.com
2 Michael C. Caramanis "It Is Time for Power Market Reform to Allow for Retail Customer Participation and Distribution Network Marginal Pricing?" Boston University Clean Energy and Environmental Sustainability Initiative, March 15, 2012.

Figure 2 – Grid Price Variations as Determined by DMP
(Courtesy of Integral Analytics)



Redder grid nodes have higher prices.
Bluer grid nodes have lower prices.

fixed element of grid costs and a variable component that reflects the incremental cost of any dispatch required to add or remove a generation resource in order to manage grid congestion. DMP also has fixed and variable components for both grid and supply.

DMP extends LMP to the distribution grid with near real-time and/or long-run data analysis focused on marginal-cost-based metrics. Technological advances in data acquisition, database management, data analysis, and communications enable DMP. DMP complements costs with additional data such as:

- Power flow analysis between the substation and the customer, including distance from the substation, resulting efficiency losses, and power quality impacts due to DER.
- The value of providing reactive power to improve the power factor, voltage support, and other such technical ancillary services at different points on the grid.
- Capacity and limiting factors along the circuit and at the substation.

According to a study from Boston University[2], LMP for a transmission system addresses high-voltage transmission operational costs including maintenance, fuel, congestion, and reserves. These represent about 65 percent of the total delivered cost of electricity consumed in the United States. DMP measures costs within the low-voltage side of the grid, but importantly includes LMP costs such that 100 percent (vs. 65 percent) of the total cost to serve is addressed. Some of the enhancements offered by DMP over LMP include measurements of power factor, line-losses, distributed generation, and storage availability.

DMP applications

The range of quantitative data types offered by DMP is summarized in Figure 1. The four categories of Distributed Marginal Costs shown in this figure provide data for granular avoided-cost calculations and for planning. Actual prices that result from calculating DMP are illustrated in Figure 2.

DMP is a signal of cost, importance, and urgency. DMP may be directly reported as a price for power, may simply be a cost estimate on which to base decisions, or may serve as an ancillary-service cost trigger, or a DSO-initiated cost trigger for use in dispatching (adding or removing) flexible demand or storage.

Utilities that use DMP metrics can develop a business plan incorporating DER plus central power generation as revenue sources. DMP facilitates distribution planning by offering a top-down plus a bottoms-up impact forecast of load shapes over a planning horizon. DMP enables an optimum grid as DER proliferates. Such a grid is synchronous with micro resources balanced in near real time, rather than a series of independent microgrids. DMP complements the free-market aspects of Transactive Energy by facilitating reliability while minimizing inefficiency and overspending, as well as informing future DSO operators of potential price gaming by third-party manipulation of demands.

Benefits of granular cost data for DER

The challenges facing utility managers are unprecedented because of fundamental technological and business changes. Utilities are poised to lose revenue from traditional power generation to solar, wind, and storage. Granular cost data from DMP enables utilities to evaluate and quantify the benefits of investments in the distribution grid to accommodate the inevitable growth of DER, to improve grid resiliency, and to propose new cost-based business models to regulators.

A smart distribution grid with price incentives could automatically manage the load on transformers, thereby extending the life of this equipment. Some distribution grids may include temporary storage to absorb excess generation or may interact with storage facilities at customer premises. A pricing scheme enabled by DMP to encourage supplying or depleting these reserves may prove useful and efficient.

Granular costing data combined with the DMP analytic tool offer the following key capabilities for power systems:

- Target the bulk of avoided costs by adding intelligence about the grid, particularly on the lower-voltage grid beyond the substations.
- Provide quantitative data to calculate how much grid-edge resources such as DER could save in power plants not being built, or feeder lines, transformers, and substations not requiring upgrades or replacements.
- Offer a platform for monitoring and orchestrating a multitude of distribution grid assets and demand-side resources to create an optimal least-cost portfolio.
- Determine which combination of technologies and strategies could provide services with minimum costs and maximum benefits for utilities and customers.

In summary, DER can be valued and thereby integrated into the business and operation of smart grids by using granular data that:

- Reflect real costs useful for market tenders (offers to buy and sell).
- Measure relative importance of events, which are useful for operations and planning.
- Accommodate new grid resources being added at the edge of the grid, some by consumers. ●

Dr. Kenneth Wacks has been a pioneer in establishing the home systems industry. He advises manufacturers and utilities worldwide on business opportunities, network alternatives, and product development in home and building systems. In 2008, the United States Department of Energy appointed him to the GridWise Architecture Council. For further information, please contact Dr. Wacks at 781.662.6211; kenn@alum.mit.edu; www.kenwacks.com.

INDUSTRY TRENDS

Building Internet of Things

Overall connectivity penetration rates across all building systems are currently only around 16 per cent. This connectivity penetration rate will rise steadily over the coming years, and with it the market potential for the Internet of Things in Buildings (BIoT). Memoori projects that the global market for the BIoT will increase from approximately $23 billion in 2014 to over $85 billion in 2020.

Wireless sensor networks

Wireless sensor network (WSN) chipset shipments will approach half a billion in 2015 due to due to plummeting component costs, open source software, developer platform advancements and growing demand for Internet of Things (IoT) technologies, according to global technology research firm ON World.