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Transforming the Grid from the Distribution System Out

The potential for dynamic distribution systems to create a new energy marketplace

Part of a continuing series on energy systems development by the Wisconsin Energy Institute

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Definitions of Key Terms

Centralized Generation: a power system architecture based on large-scale power plants (200 to 1000 MW) that are located centrally in radial utility networks and designed to deliver baseload power that changes very slowly.

Distributed Energy Resources: for discussion in this paper, distributed energy resources are power generation or storage systems that connect directly to the distribution network or connect on the customer side of the meter, including photovoltaics, internal combustion engines, gas turbines, storage, fuel cells, wind turbines, etc.

Distributed Generation: a power system architecture with small-capacity, non-conventional generation sources located close to load centers, often designed to provide both electricity and heat.

Microgrid: the CERTS microgrid protocol supports the seamless integration of additional distributed technologies, including generation, storage, controls and communications. The facility can "island" itself from the main utility grid as needed and independently generate and store energy.

Personal Power Plants: small generation systems that are owned by individuals, usually located within their homes. They include solar, wind, natural gas, bio-fuel systems, etc.

Smart Grid: an architecture for the overall control of the utility, distribution, and load power systems that is based on "Big Data" acquisition from large numbers of sensors throughout the grid and data processing by primarily large centralized computers and algorithms.

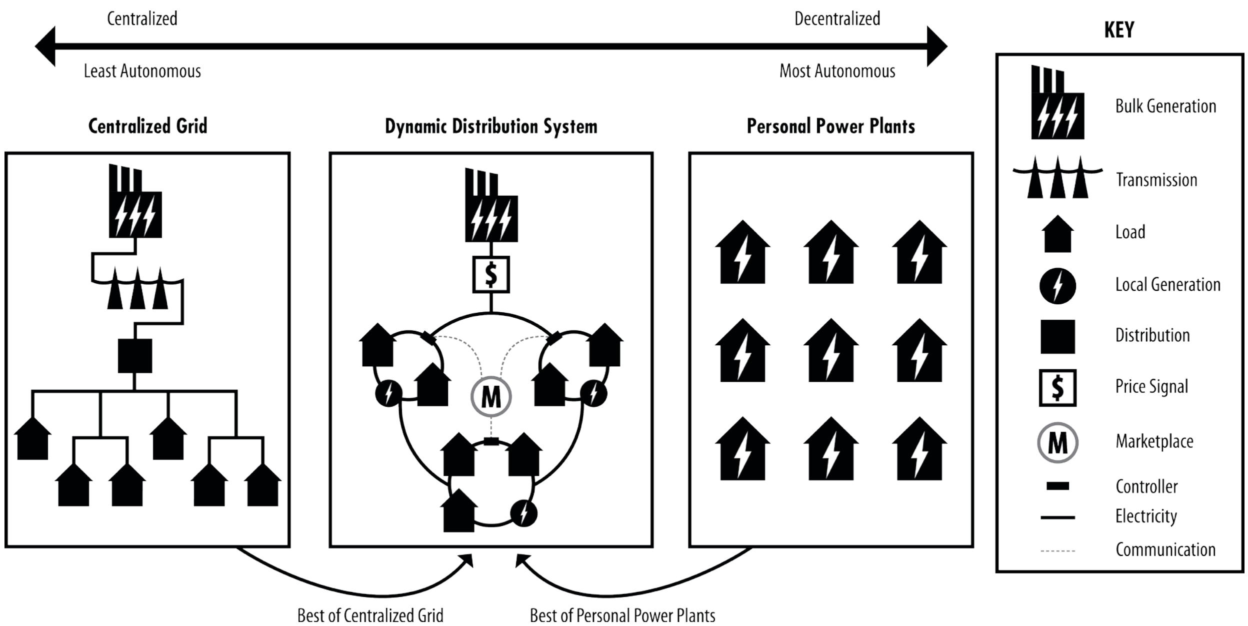
Summary

The prices of renewable and combined heat and power (CHP) generation systems are projected to continue their decline. According to an annual briefing prepared jointly by the Lawrence Berkeley National Laboratory and the National Renewable Energy Laboratory, the price of installed photovoltaic (PV) systems has fallen, on average, six to seven percent every year since 1998 (Feldman & Barbose, 2013). These declining prices, coupled with tax incentives, are driving increased use of distributed energy resources in the electrical utility system. For this reason, more power is being generated in homes, businesses, and commercial buildings and used locally. This jump in power production at the distribution level presents a challenge to the traditional electrical transmission and distribution system based on centralized power generation and control. The centralized system operated by utilities was not designed for the flexible load tracking required by renewables or the control of large numbers of distributed electrical energy resources.

An alternative approach that holds promise is a *dynamic distribution system* that would take over responsibility for tracking loads and smoothing intermittent renewable energy generation from the utilities. While significant new control technologies are needed to manage these energy flows, much of the requisite research, discussed herein, expands on the basic features of current microgrid technology developed through the Consortium for Electric Reliability Technology Solutions (CERTS) which enables the autonomous control of distributed generation and storage resources without the use of centralized information processing (Lasseter, 2011). The CERTS protocol can be extended to facilitate the incorporation and control of a large number of distributed energy resources in the dynamic distribution system.

The business models and regulatory policies that support distributed energy resources are at a precarious juncture. While creative approaches to expanding distributed energy resources (e.g., community or third-party ownership) are gaining interest, some utilities are simultaneously pursuing new rate structures that could devalue the return on these investments. Currently, the owners of PV and CHP generators either use their energy or sell it to the utility. In most regions of the U.S., there are very limited ways to buy or sell power except through the utility.

The dynamic distribution system could be the technological foundation of a new energy value proposition for consumer-owned, utility, or third-party energy providers. It could be the technology basis to create a new electrical energy marketplace in which electric power is generated and then bought, sold, and used, by multiple parties, all at the distribution level. This new dynamic distribution system would connect central and local electricity generation, storage, microgrids, and loads with a marketplace that enables energy transactions, such as payments passing between buyers and sellers of energy at the local distribution level. With this new system, distributed energy resources could, in some cases, deliver the same services at a better price, with decreased power losses, decreased emissions, and better reliability. The challenge is to further develop the dynamic disitribution system technology, including its distribution control, data informatics, cybersecurity, resiliency, and communications network, and address these issues to maximize its usefulness as the electricity capacity and distribution market evolves.



Balancing centralized generation systems with the increasingly popular "Personal Power Plants" model in a Dynamic Distribution System would create a win-win situation for utilities and end users by integrating what utilities do well (large-scale systems) with cost-effective DERs to provide for fluctuating (or dynamic) energy needs.

The Current Spectrum of Solutions

A wealth of solutions, including "Smart Grid" concepts and "Personal Power Plants" models, are being proposed to address potential threats to the existing electric utility business model. All of these solutions attempt to work within the existing power system, which has grown more complex with increased deregulation.

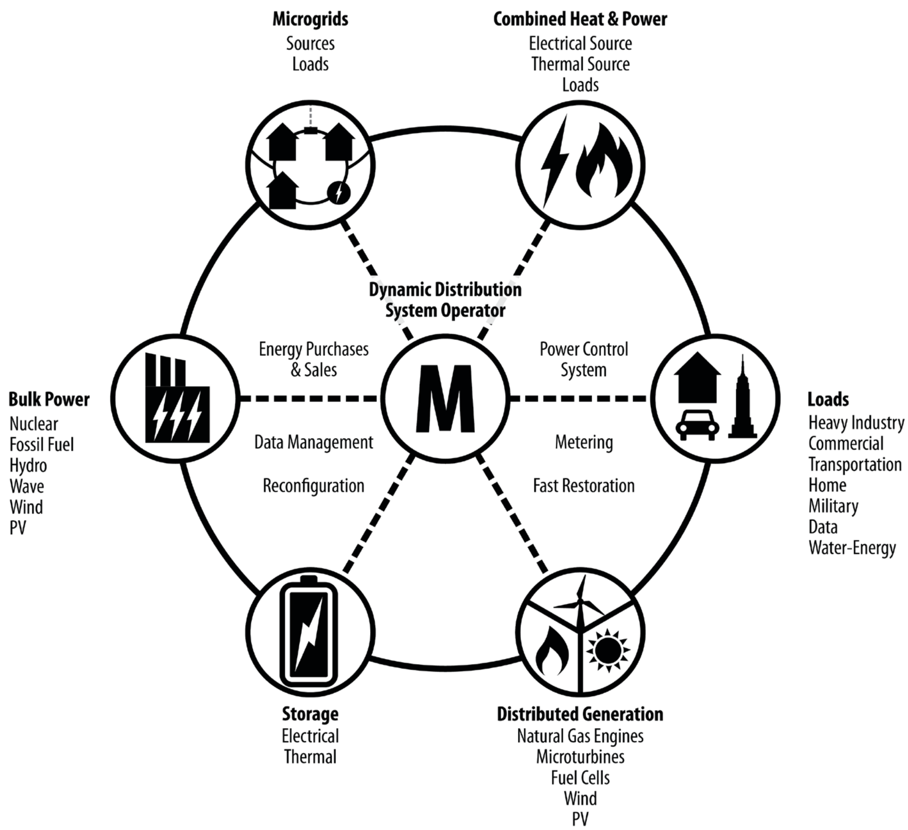
In the 1980s, providing electricity was a relatively simple affair. Utilities provided a constant supply of base-load power by building plants that ran on coal, nuclear energy, or hydropower. Natural gas-fired plants were easily and economically powered up and down to supplement load changes and meet peak demands. The vertically integrated utility in the centralized-model ran the base-load generators around the clock while the peaking units operated as needed to accommodate changing loads. Beginning in the 1990s, deregulation changed this ordered system, enabling power plants to produce electricity according to its marginal cost. This model resulted in a more complex power system with greater uncertainties. In addition, the advent of renewable energy further complicated the ability of utilities to adhere to the traditional system. Renewables have "grid priority" and the lowest marginal cost, meaning the grid is obligated to purchase their electricity first.

To more efficiently incorporate renewables into the system, engineers have proposed two types of solutions. In the "Smart Grid" model, a highly interconnected and interactive network of power systems combines with telecommunication and "big data" technologies to create a more flexible system. At the other extreme is the proposed "Personal Power Plant" model in which all buildings with distributed energy resources disconnect themselves from the grid. They could permanently operate as independent, self-sufficient microgrids either isolated from or as part of the distribution system.

The fact that the "Personal Power Plant" model is being seriously discussed and debated demonstrates the extent to which distributed energy resources are becoming a practical alternative to the centralized model (Farrell, 2012). Consider that CHP systems and solar PV have reached grid parity for commercial customers in many parts of the United States. Optimistic projections even indicate grid parity for millions of residential and commercial customers in New York and California within this decade (Creyts & Guccione, 2014).

Both of these solutions have benefits and liabilities. The "Smart Grid" model, while increasing flexibility, also creates complexity and can reduce customers' quality of power. The "Personal Power Plant" model, on the other hand, is becoming more and more economically feasible, while also providing high levels of power quality to each customer. However, a generator in every home may not be the preferred solution for many energy end users.

Dynamic Distribution System



Dynamic Energy Marketplace

- Wholesale bulk power
- Distributed generation power
- Renewables
- Storage
- CHP
- Microgrids
- Small and large customers

Resilient Systems

- Coupled microgrids
- Network reconfiguration
- Robust fuel sources
- Fast restoration
- Graceful degradation

Simultaneous Control

- Energy conversion
- Renewable energy harvesting
- Power flow
- Load demands
- Heat recovery
- Energy storage
- Carbon minimization

A Dynamic Distribution System creates the technical solutions for an adaptive electric energy marketplace and provides a new basis for analyzing the policy and regulatory issues that surround the energy utility transition.

A Dynamic Distribution System and Marketplace

A solution proposed by the authors of this paper is the creation of a dynamic distribution system and marketplace. The system moves dynamic control functionality down to the distribution level. It also connects energy sources, loads, storage, bulk power providers, CHP systems, and microgrids with an energy marketplace, where energy transactions occur between buyers and sellers. These distribution-level markets promote optimization of all systems (large-scale, customer-owned, and third-party solutions). Benefits of a dynamic distribution system can include improved reliability, lower power losses, increased use of renewable energy sources, and lower total cost-per-kWh. They can also improve the efficiency of electricity supply through the use of distributed CHP systems that utilize the heat generated from power production. The highly flexible and scalable architecture allows the easy integration of new energy technologies and the addition of new power sources incrementally as needed.

This proposed dynamic distribution system addresses the technical challenges facing both centralized generation and distributed generation. Centralized systems are ill equipped to manage local sources of energy generation. Their large base-load generators are not economically designed to track load swings or cope with the intermittency of renewable energy generation. Distributed generation is uniquely equipped to address these shortcomings. On the other hand, central generation such as large wind, concentrating solar power, and combined-cycle power plants, can provide bulk power as a clean, cost-effective energy source for the dynamic distribution system.

The system integrates the best of central utilities and the best of distributed energy resources. Central utilities are effective at financing large-scale projects and can provide cost-effective bulk power as part of this system. Distributed energy resources can provide cost-effective power generation to meet individual customers' fluctuating energy needs.

A New Energy Architecture

The dynamic distribution system creates the opportunity for any distributed resource investor to provide reliable, resilient, safe, and clean power at competitive prices. To create this new value paradigm, the microgrid concept must be extended to accommodate and support a dynamic distribution system (Lasseter, 2011). The system builds upon the strong points of the microgrid building block, next-generation DERs, and distribution equipment. Dynamic market theory adds intrinsic optimization and market intelligence to the already resilient fundamental microgrid core. In doing so, it can provide the foundation of the future electrical energy marketplace, and provide new products and services within the energy system.

A new energy distribution system that combines the best of plug-and-play distributed generation, microgrids, and advanced power distribution and control equipment would provide business opportunities to existing utilities and third-party energy stakeholders alike. This new architecture enables an equitable marketplace for any investor, such that electric utility, third parties, and power users can equally access and profit from a network of distributed energy resources, including greater clean energy generation options, demand response, and energy storage, as well as other technologies. In fact, this option may enable a better use of combined energy transmission resources by allowing for measures such as: targeted customer services of improved reliability; clean energy generation; campus reconfiguration and ongoing upgrades; preventative maintenance; and lower overall system operating costs. The increased deployment of microgrids and the creation of a new distribution system could enable a re-purposing of the electric utility that extracts more return from its associated investments. In this new distribution marketplace, businesses operating at the distribution level can increase technology innovation, advance greater efficiencies, and lower costs. In some cases, DERs could provide less-expensive power with greater reliability and efficiency than centralized generation.

New, flexible utility business models are needed that allow utilities to form new lines of business or companies that can compete at the distribution level with third-party energy providers. New regulatory policies are also needed. In fact, some regulatory initiatives are emerging, including one from the New York State Public Service Commission, to utilize a new network framework based on distributed generation that can address the deficits of centralized generation. Currently utilities are fragmented by diversity in ownership models, regulatory models, market segments, fuels used and power generation technologies, so many variations in new network frameworks may be needed.

Policy Steps can Ease Electric Utility Transition

A California Public Utility Commission white paper states that an easy way to encourage collaboration between electrical utilities and distributed energy providers is to create a policy that places tailored combinations of distributed energy resources, microgrids, and distribution automation in locations that benefit the existing electrical grid. This would motivate developers to collaborate with utilities to identify areas that are experiencing congestion, power quality, capacity or grid-balancing issues. This targeted siting strategy might allow for costs to be built into a utility rate structure or attached to the physical assets' tax equity instead of requiring developers or specific customers to shoulder the full installation costs. One advantage of microgrids is their ability to be placed at locations that will benefit from having CHP onsite without requiring major grid infrastructure upgrades. Microgrids also provide customers with resiliency and the ability to function as islands. Microgrids can be strategically located to provide power to critical urban infrastructure sites such as hospitals, police and fire departments, as well as sites such as public schools and university campus areas that are used as safe havens for the general public in the event of emergencies (Villareal et al., 2014).

The development of new business and regulatory models will be key to the successful transition to a dynamic distribution system. While the centralized generation model may remain resistant to change, regulatory flexibility will be critical during the transition. Can regulators, for example, develop fair models that enable utilities to derive substantial revenues from distribution services? This new income is needed to offset the income losses from progressively lower sales and revenue from traditional energy generation sources and the costs of off-loading aging coal plants. New state laws will be needed to give existing utilities the ability to create lines of business separate from the traditional electricity rate-making structure and, at the same time, allow other competitors in that market space. State regulators must find innovative approaches for utilities to invest in or partner with distributed resource owners. Innovative public utility commissions could experiment by creating new market demonstration sites based on greater utilization of distributed energy resources.

Another possible business model that would allow for U.S. electric utilities and third-party energy providers to coexist is performance-based ratemaking, in which energy-provider profits are decoupled from costs and tied directly to performance standards. For example, third-party energy providers, in whole energy markets, could be rewarded for achieving energy efficiency goals and deploying more CHP systems. Performance-based ratemaking is not new, but may need further refinement to address emerging energy sector issues. In addition, policies should assist utilities to transition away from high-carbon

Dynamic Distribution System Benefits

- High level of grid resilience.
- Greatly improved efficiency.
- Decreased power losses.
- Lower total cost per kilowatt hour (kWh).
- Highly scalable architecture.
- Ability to easily integrate new energy technologies.
- Lower upgrade costs.
- Increased grid flexibility.
- Improved economics for renewable energy systems.

energy generation sources to clean energy sources. A bottom-up approach that empowers producers/consumers and third parties, in conjunction with a broad, accelerated program of competition and innovation provides a viable future for the electricity sector.

Conclusion

The authors propose a new dynamic distribution system that has the responsibility of tracking load fluctuations, firming intermittent renewables and providing a distribution-level marketplace. Off-loading these fluctuations allows for more efficient operation and planning for the centralized generation system. This enables integration of larger amounts of renewable energy, including biomass power, geothermal, solar and wind, while easing the path for an effective evolution of the central grid to other low-carbon energy conversion technologies. This system combines the best of both the centralized generation system and distributed energy resources and could be the technological foundation for a new energy value proposition in which both utilities and third-party power providers prosper.

This new system re-envisions the modern electrical power distribution system. Its successful implementation will necessitate new control technologies, business models, and regulatory policies. First, a new distribution system architecture composed of distributed renewables, CHP, microgrids, advanced power control and conversion subsystems, and a dynamic marketplace is required. In addition, new business models and regulatory policies are needed that provide business opportunities and revenue for market participants. Federal policy can help guide this transformation of the electrical utility system. Federal energy policy, research, and guidance could greatly assist in the development of a dynamic distribution system. While energy regulations primarily occur at the regional, state, and local jurisdictional level, access to the new energy markets should be more consistently administered. Further market constraints will occur with 50 different definitions of distributed generation or microgrids, for example, and many existing interconnection standards and rules about access to right-of-ways and transmission lines can effectively kill marketplace competition. A robust national conversation needs to occur, and that could start with a vision of what this new dynamic distribution system marketplace should look like. The development of a dynamic distribution system has the potential to create a superior ecosystem for utilities, third parties, and users without turning off the lights.

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