

Advanced Microgrids—the State-of-the-Practice and Research Needs

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Advanced microgrid technologies are an exciting topic for innovation and impact related to energy and environmental priorities for the nation and the planet. They can be instrumental in decarbonizing energy generation and usage, protecting critical infrastructures, lowering costs for both utilities and consumers, and improving energy security.

Our objective in participating in the Energy CPS workshop is twofold: We seek to make the research community more aware of the state-of-the-art in commercial microgrids and to highlight priority needs for future research in the area.

Commercial Microgrid Case Studies

Microgrid technologies have made substantial progress in just the last few years, with deployed applications and in-progress projects. We discuss two notable examples.

The FDA campus in White Oak, Maryland. This facility has had an operational microgrid for over a year. The microgrid includes natural gas, diesel, and renewable generation; electric and thermal energy storage; flexible loads; and an islanding mode. 30% energy reduction from a baseline and millions of dollars in demand savings have been achieved. On average, the campus has supplied more power to the utility than it has received. On several occasions, based on adverse weather forecasts and other factors, the campus has been automatically islanded. The facility and its energy assets are being substantially expanded and the microgrid is being scaled up as well.

Hospital complex in Netherlands. Another microgrid we discuss is implemented in a hospital facility in the Netherlands. The emphasis here is on economically optimized operation, with dynamic price communication of electricity and gas from the utility driving decisions about electrical and thermal generators and loads. A sophisticated forecasting engine with adaptive algorithms is included in the solution. A mixed-integer program is formulated and solved. A screenshot of the operator dashboard with additional insets is shown in Fig. 1. The microgrid (VERA, for Versatile Energy Resource Allocation) has been operating for several years with year-over-year reduction in energy costs.

We believe the research community is insufficiently aware of developments such as these microgrid implementations, which in some respects achieve what are considered futuristic research objectives (e.g., automatic islanding, price-responsive optimization). At the same time, however, current projects have limitations that point to priority research needs. Loads, generation, and storage assets are categorized and parametrized to enable their automatic, dynamic operation under various external factors. Customizations are required and, for the most part, manually undertaken. The time and cost associated with configuring and commissioning microgrids is significant. In addition, the fixed operating logic for many installed microgrids limits their flexibility and performance.

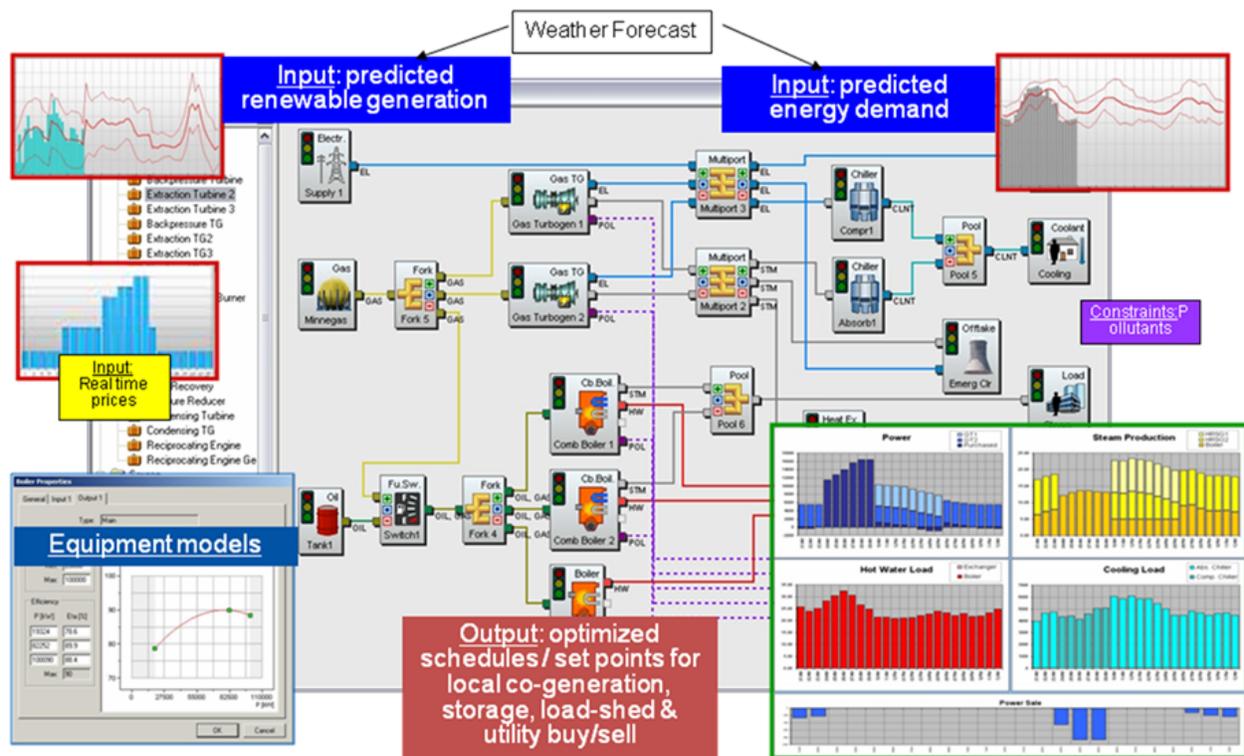


Fig. 1. VERA microgrid implementation

Research Needs in Microgrids

In addition to describing deployed microgrids we would like to identify key research needs that can enable microgrids to be more widely and more readily deployed and to operate more effectively. Priority topics for research include the following:

Decentralized and cybersecure microgrid architectures. Decentralization is an effective strategy for resilience, but it often requires sacrificing optimality. This compromise can be effected in various ways that will usually be application-specific. The development of higher-performance and more-robust distributed optimization, monitoring, and control algorithms can complement the architectural research.

Semantic models for energy assets. A framework is needed that can be used for the information modeling of the variety of energy assets in microgrids. Some major steps have recently been taken that are relevant to this goal, such as Building Information Modeling (BIM). Semantic models are not an end in themselves; they are required, for example, for open, nonproprietary configuration and simulation tools.

Mathematical models and optimization formulations. Nonlinearities, hybrid (switching and continuous-time) dynamics, stochasticity and uncertainty, scale, constraints . . . these are some of the challenges facing the realization of truly optimal microgrids. These complexities arise from diverse sources, as illustrated in Fig. 2.

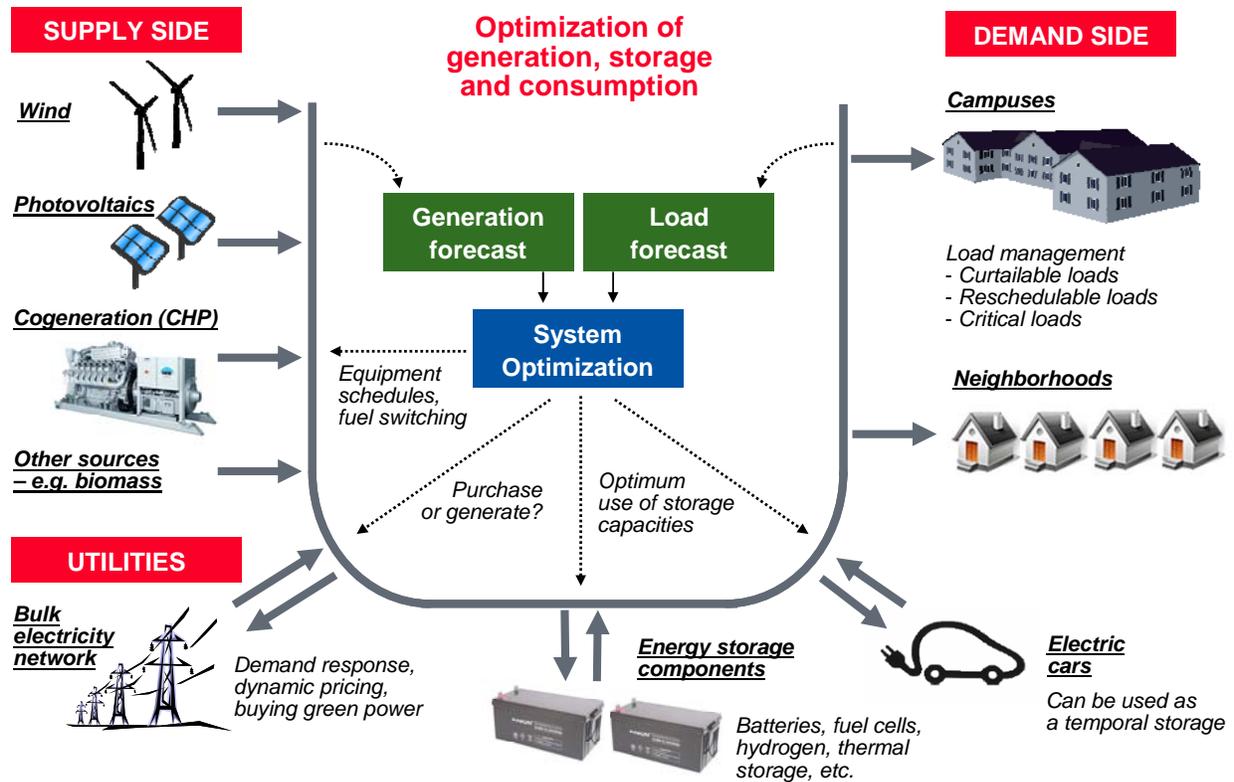


Fig. 2. Microgrid optimization: opportunities and complexities

Interoperability and standards. Microgrid assets—both physical devices and automation algorithms and systems—will come from different vendors. Without industry-standard interfaces and protocols for interoperability, the benefits of a diverse ecosystem of innovators cannot be fully availed of. This is especially the case for academic research, the technology transfer of which would be substantially expedited with progress in this area.