Power Generation

DESIGNING MICROGRIDS FOR EFFICIENCY AND RESILIENCY

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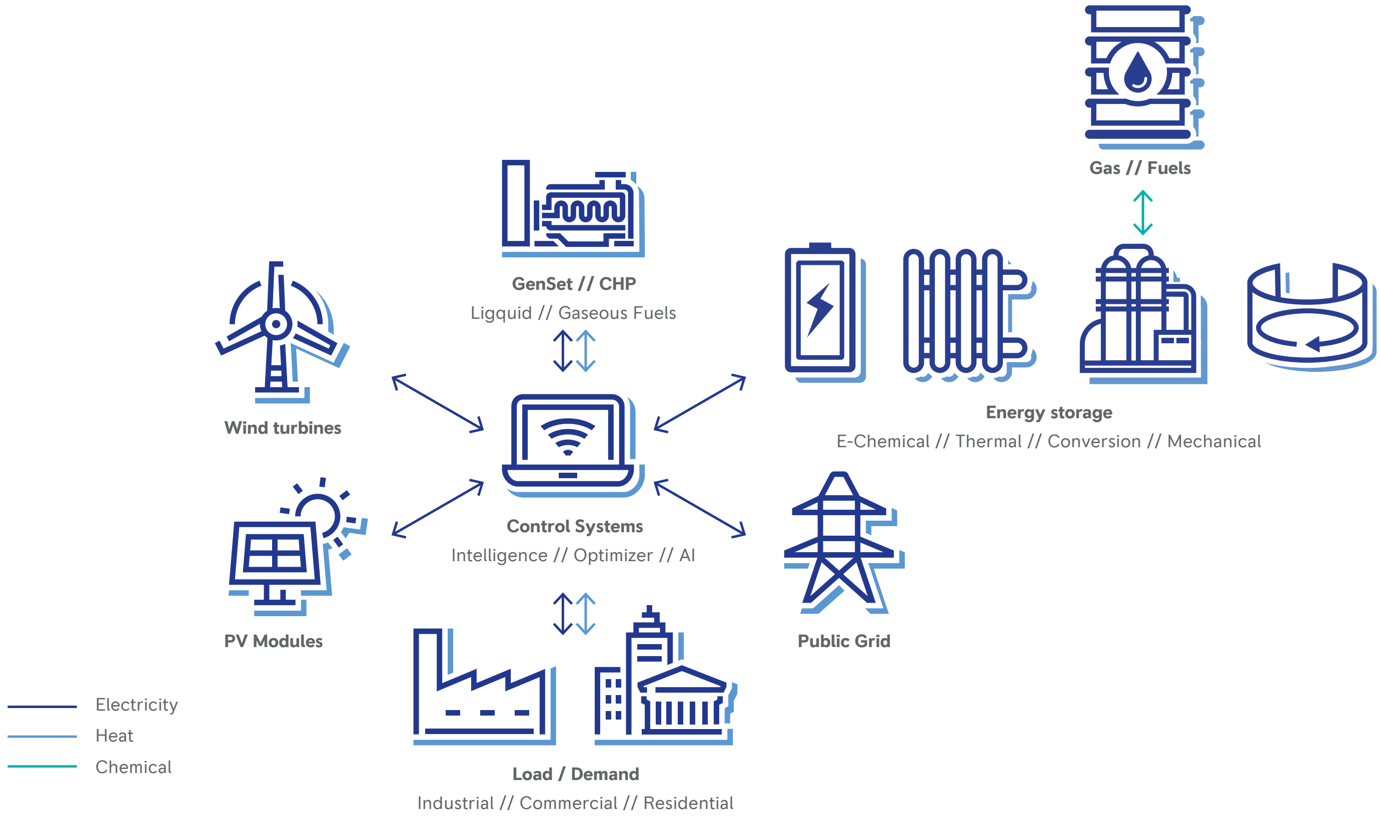
For decades, mission-critical facilities have depended on centralized power plants owned and operated by utilities. However, the traditional model is changing. Intelligent distributed generation systems, in the form of microgrids, are providing much-needed stability to an aging power grid.

A facility's energy demand is key to the design of a microgrid system. To ensure efficiency and resiliency, microgrids combine different components to meet a given demand, while optimizing costs.

Key components

By combining different components, a microgrid can be tailored to every customer need, providing the ideal technical and economical solution. These systems are designed to satisfy an electrical and/or thermal energy demand that is traditionally supported by the natural gas or electric utility provider. A microgrid most commonly operates in island mode, but it also can be connected to the grid.

A Rolls-Royce
solution



Distributed energy resources

These include conventional resources, like natural gas or diesel generators, that convert fuel mechanically to make electricity and thermal energy as well as renewable systems, like solar and wind, that utilize natural resources.

Energy storage

Energy is held in reserve to be dispatched as needed to supplement other distributed assets. Systems include electrochemical (BESS), mechanical (flywheels), thermal (hot water) and energy conversion. This energy can come from the overproduction of renewables, or it can be stored/charged when energy is cheaper for use at times of peak cost.

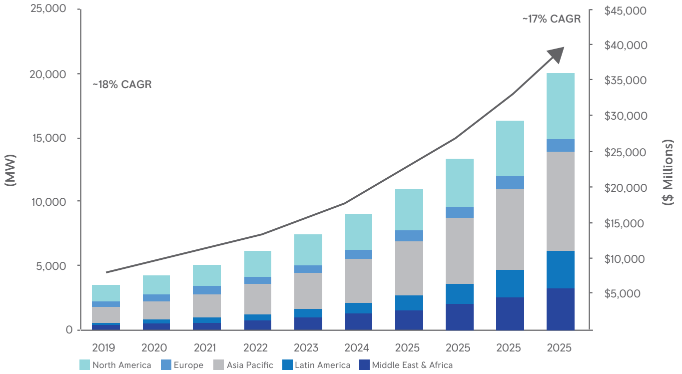
Control systems

Intelligent controls are used to optimize the available assets to provide the lowest cost of electricity by automatically dispatching supply to the most efficient resource. For example, shutting down one generator when two are running at the highest load factor to increase fuel efficiency. Control systems can operate with or without dynamic control (smart grids).

A successful microgrid solution provides modularity, scalability, energy dispatchability, power management and balancing of resources. Whether off-grid or on-grid, these powerful and reliable distributed energy generation systems can provide high performance under any site condition.

Global demand for new solutions

The energy world is undergoing a transformation. Various factors are driving growth in energy demand, and encouraging the development of flexible, sustainable, cost-effective energy solutions like microgrids. As a result, microgrid capacity and revenue continues to rise all over the world.



Source: Navigant Research

World Markets: 2019 - 2028

Benefits of microgrids and energy storage

By combining renewable power generation, power storage and conventional power generation to meet energy demands, microgrids can provide cost savings, reliability and sustainability.

Energy cost optimization
- Electricity cost reduction
- Fuel and O&M cost reductions
- Independence from electricity price development

Access to power
- Access to electricity in remote areas
- Increase of industrial load despite grid limitations
- EV charging in urban areas

Quality and security of supply
- Backup during power outages
- Voltage and frequency stabilization
- Reduction of fuel dependence

Positive environmental impact
- Increased energy use from PV & wind: reduced carbon footprint
- Incentives, tax benefits, fines avoidance
- Reputation

New revenue streams
- Revenues from grid services and energy markets
- Improved marketability of renewable energy

Implementation challenges

Every microgrid is different. To deliver the right energy mix for a facility's needs, several key parameters must be considered in the design stage.

Reliable and economical operation
- High penetration levels of intermittent generation in stand-alone mode of operation

Schedule and dispatch of units
- Supply and demand uncertainty and determination of appropriate levels of reserves

Demand Side Management (DSM)
- Design appropriate DSM schemes to allow customers to react to the grid needs and drives supply

Distribution Level Protection
- Re-engineering of DLP schemes to account for bidirectional power flows

Market/business models design
- New models to allow competitive participation of intermittent energy sources driven by fuel savings

Plug and play development
- Market and control mechanisms that exhibit P&P Feature to allow for seamless integration over time

Voltage/frequency control
- Development of control techniques to account for the increase in Power-Electronics-Interfaced DG

Grid code
- Addressing grid compliance issues for the grid connection of microgrids

Market conditions for distributed generation

Economic growth and population growth are increasing the demand for power. Increased pressure to decarbonize, and growing demand for more flexible, sustainable, cost-effective energy solutions are guiding governments and industry away from traditional energy sources like coal and gas, and toward renewable energies such as solar and wind power.

Four trends are transforming the energy world, triggering demand for new solutions:

Globalization
- Increased mobility and energy needs
- Higher level of price competition
- Urbanization

Decarbonization
- Decentralization
- Energy transition
- Increase of fluctuating renewable sources
- Environmental awareness

Electrification
- Rising electricity demand
- Increasing power need
- Environmental awareness
- Sector coupling

Digitalization
- New business models
- Increased computing performance
- High data volume and energy need for services

Costly consequences

Systems must be in place to ensure power to communities in extreme conditions. An outdated and overstressed grid has made the network more susceptible to outages. For example, in July 2019, with only 45 minutes of notice, Con Edison had to shut down power to New York City residents when a section of its system reached a maximum capacity of 12,063 MW. In Northern California, PG&E has been proactively shutting down power through rolling blackouts to avoid the risk of fire during high-risk times of the year.

In 2019, a weather/climate event caused more than $1 billion in damages 14 different times. Total costs for that year was $45 billion. In 2020, wildfires in California and the Pacific Northwest have destroyed power transmission infrastructures, disrupted public services and caused massive financial losses. Also in 2020, a storm in Iowa cut power to more than 400,000 people. Estimated damages due to lost crops are $3.7 billion, along with $82 million in home damages. For data centers, it costs nearly $9,000 every minute an outage occurs. And healthcare facilities can average nearly $700,000 per outage.

New solutions are needed

The increase in non-dispatchable renewable generation in the form of grid-scale wind and solar has added to the overall instability of the grid. Solar power, wind power and other renewable energy sources offer key benefits, but there are some drawbacks as they are dependent on weather and time-of-day, can suffer output fluctuations, and often require major capital investment. A smart microgrid uses storage and/or complementary generation technologies to optimize the use of renewables.

Upgrades to the grid are becoming more and more important due to the overall age of the transmission and distribution network. The U.S. Department of Energy (DOE) reports that 70% of power transformers are 25 years of age or older, 60% of circuit breakers are 30 years or older, and 70% of transmission lines are 25 years or older. The average age of the country's 40,000 miles of transmission lines is 52 years. The need for reliable, independent access to power has never been greater.

Customers, key benefits and configurations

Power
Examples: grid system operators, utilities, independent power producers
Key benefits: new revenue streams, energy cost optimization
Typical configuration:

Commercial
Examples: offices, retail, warehouses, data centers, infrastructure, transport, hotels, restaurants
Key benefits: energy cost optimization, secure and reliable power supply, access to power
Typical configuration:

Industry
Examples: agriculture, manufacturing, mining, commodities
Key benefits: energy cost optimization, CO2 avoidance
Typical configuration:

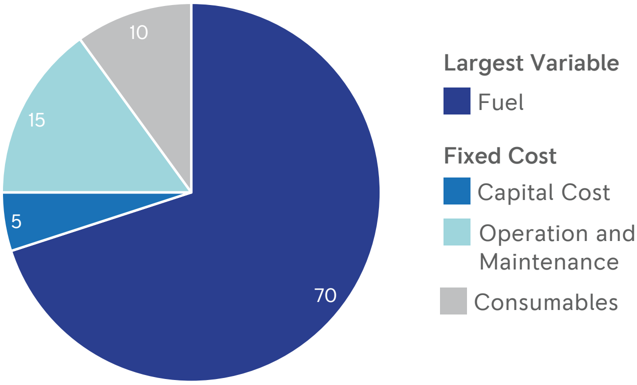
Communities
Examples: remote communities, urban district/town solutions
Key benefits: energy cost optimization, access to power, CO2 avoidance
Typical configuration:

Public
Examples: military base, healthcare, institutional, education
Key benefits: energy cost optimization, quality and service of supply
Typical configuration:

Design factors for efficiency and resiliency

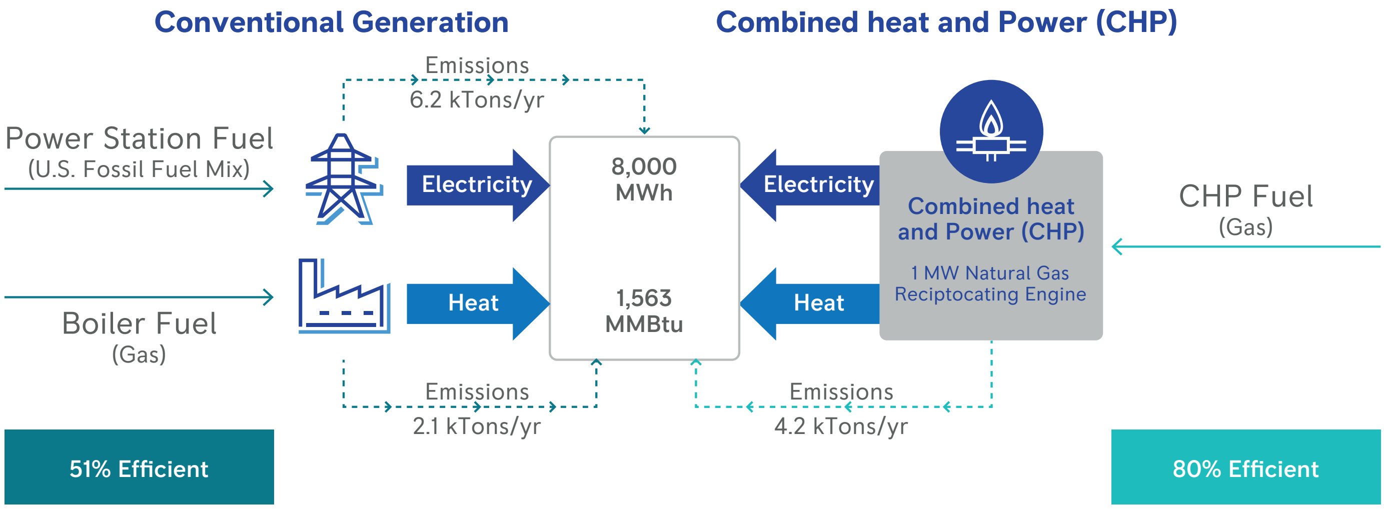
In a true microgrid application, the load or energy demand is key to the design of the energy system. Designing to efficiency and resiliency means balancing these assets with the cost of operation, space available, fuel resources, and government regulations.

Lifecycle costs for distributed generation system



A power generation project is a large investment. However, upfront and other fixed costs are just a small part of the total lifecycle costs. Fuel accounts for up to 70 percent of lifecycle costs. By utilizing renewable energy sources and battery storage, a microgrid can lower fuel consumption, reducing overall operating costs while ensuring the availability of reserve power.

Distributed generation systems generally lower operating costs compared to conventional power generation techniques. Properly deploying distributed generation systems requires an analysis of the existing thermal and electrical systems, ensuing the selection of building systems that are critical to continuous operation.



Secondary fuel costs

Many microgrids use a combined heat and power (CHP) module, which can produce both electric energy and heat energy from the same fuel, thereby nearly doubling overall efficiency. Higher operating efficiencies enable CHP systems to consume less fuel while generating the same amount of power and useful thermal energy as separate heat and power systems. Compared to conventional electricity and heat generation, CHP modules reduce carbon emissions by approximately 50 percent.

The challenge in maximizing the efficiency of a cogeneration application is matching the demand for the heat byproduct with the demand for electricity. If demand for electricity is greater than demand for the heat product, then excess heat must be exhausted to a radiator or water-cooling tower, thus efficiency suffers. If demand for heat exceeds generator output (light electrical demand or high heat demand), then it will need to be scaled back to match the heat output of the generator or the process, augmented with heat from a boiler.

The perfect balance

When designing a microgrid system for any application, it is important to choose the right combination of components to balance resiliency with efficiency.

Fuel availability and emissions regulations

With a widespread distribution network, natural gas is often used for North American microgrid systems. In Latin America, where pipeline natural gas might not be available, other options are often considered. Emissions rules can limit fuel types. For example, diesel may only be used in some areas for standby and with a limited run time of 100 hours or less annually.

Wind

Strength: No fuel requirement

Solar

Strength: No fuel requirement

Gas (CHP)

Strength: Opportunity to use biogas
Weaknesses: Gas pipeline or storage required, emissions controls required in certain areas

Diesel

Weaknesses: Fuel transport/storage, high CO2 emissions, high NOx emissions, limited run hours

Energy storage

Strength: Enables integration of renewables, increase flexibility of genset

Grid connection and permitting

Each individual utility creates a set of rules that govern the process and costs of operating in parallel with its transmission and distribution system. Even when electricity is kept behind the meter, the costs and time needed to properly operate in grid parallel add additional unforeseen costs to projects. Exporting excess energy is even more costly and difficult. Analysis must be performed on how any distributed energy system will affect a relationship with the utility provider.

Wind

Strengths: No carbon emissions, federal and local incentives
Weaknesses: Not dispatchable, visual and noise pollution, capital cost

Solar

Strengths: No carbon emissions, federal and local incentives
Weakness: Large space required (greenfield sites)

Gas (CHP)

Strengths: Opportunity to use biogas, dispatchable

Diesel

Strength: Dispatchable
Weaknesses: High CO2 emissions, high NOx emissions, limited run hours

Energy storage

Strength: Federal and local incentives

Ambient conditions and plant operations

Facility load or demand will drive the size and shape of the microgrid. It is important to analyze each site individually even if the loads and designs are similar, as location affects local regulations. In addition, ambient conditions, such as high altitude and high temperature, will affect how the distributed energy resources will perform. Local codes and standards are one of the main early drivers for the design of a microgrid.

Wind

Weakness: Dependent on weather conditions

Solar

Strengths: Retrofittable, e.g. on buildings
Weakness: Dependent on weather conditions and time of day

Gas (CHP)

Strengths: Power heat and cooling, efficient, economic continuous operation

Diesel

Strength: Fast start time (<20 seconds)
Weaknesses: High operating and maintenance costs

Energy storage

Strengths: Flexible use for various applications, low operation and maintenance cost
Weakness: Battery capacity degrades over time

Applications

Example #1: Industrial Facility – Southeast USA

Site details

- Industrial demand response project
- Industrial process with high peak electrical loads

Challenges

- Control peak demand to reach goal of $100,000 monthly reduction in energy bill
- Microgrid controller to optimize all distributed generation assets

Solutions

- 3 x 16V4000 natural gas generators (6MW)
- 3 x 2MW/2MWh – 6MWh ***mtu*** Energy Pack
- 18.7 MW of PV
- Projected $1 million annual savings

Example #2: Granjas Carroll de Mexico – Puebla, Mexico

Site details

- New pork processing facility for one of the leading producers in Mexico
- Continuous power project

Challenges

- Complete independent off-grid solution
- Customized automation system for plant control and remote operation
- Accommodate extension for heat recovery and use of biogas in future

Solutions

- 4 x 20V4000 natural gas generators
- 1 x 16V4000 diesel generator
- 9.7 MWel power output
- The first off-grid solution of its kind for Rolls-Royce Power Systems in the Americas

Microgrid Validation Center

Every microgrid is unique. Modeling real-world applications can ensure a microgrid and its control system is designed optimally. ***mtu*** Microgrid Validation Centers offer highly flexible simulation and testing capability. Equipped with diesel and co-generation standby generator sets, solar panels, ***mtu*** EnergyPack battery storage and integrated ***mtu*** automation system, the self-sustaining Validation Centers can simulate a wide range of conditions, including off-grid operation. Located in Aiken, South Carolina and Friedrichshafen, Germany, they are effective proving grounds for customers to apply a software model to just about any real-world installation.

Conclusion

Power security for mission critical facilities has traditionally been limited to a coal-fired central power plant that supplies electricity through a transmission and distribution system with on-site standby generators for selected loads, but trends are changing.

End users are paying more attention to how they design and purchase their power systems. Intelligent distributed generation systems in the forms of microgrids increase security and efficiency by offering a wide selection of power generation and storage sources, providing maximum control for facility managers, and reducing reliance on utilities.

Rolls-Royce provides world-class power solutions and complete lifecycle support under our product and solution brand ***mtu***. Through digitalization and electrification, we strive to develop drive and power generation solutions that are even cleaner and smarter and thus provide answers to the challenges posed by the rapidly growing societal demands for energy and mobility. We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems. These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.