WHITEPAPER

Microgrids:
How to use your Microgrid Controller to optimise and achieve maximum value from your microgrid

Abstract

Microgrids are being developed as a building block for future smart grid systems.

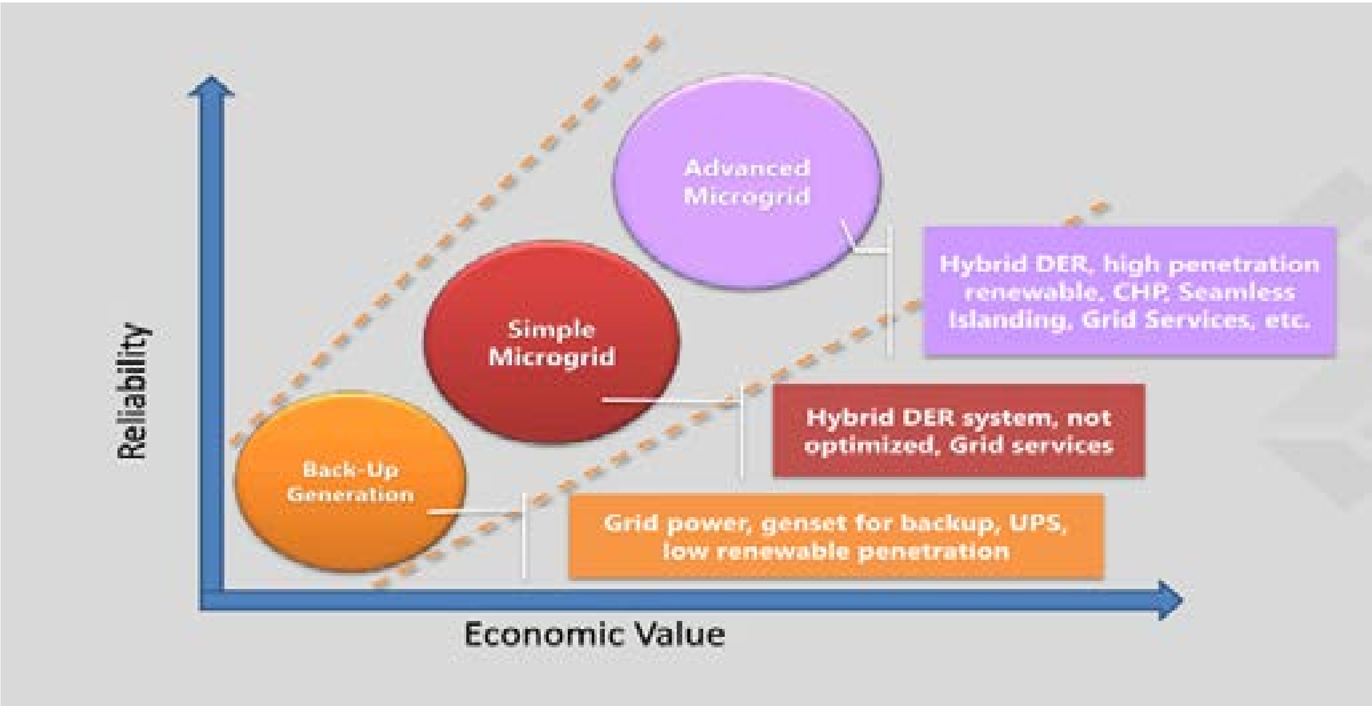
The selection of the combination of microgrid equipment is based on the key attribute that microgrids must have the ability to maintain a balance between available supply and desirable load demand through careful integration with intelligent control.

This paper focuses on microgrids that are characterised by their sophisticated use of advanced microgrid controllers. The controller orchestrates the microgrid's energy supply, which may come from several on-site energy sources, such as solar, wind, combined heat and power (CHP), energy storage and reciprocating engines, to achieve an optimised microgrid.

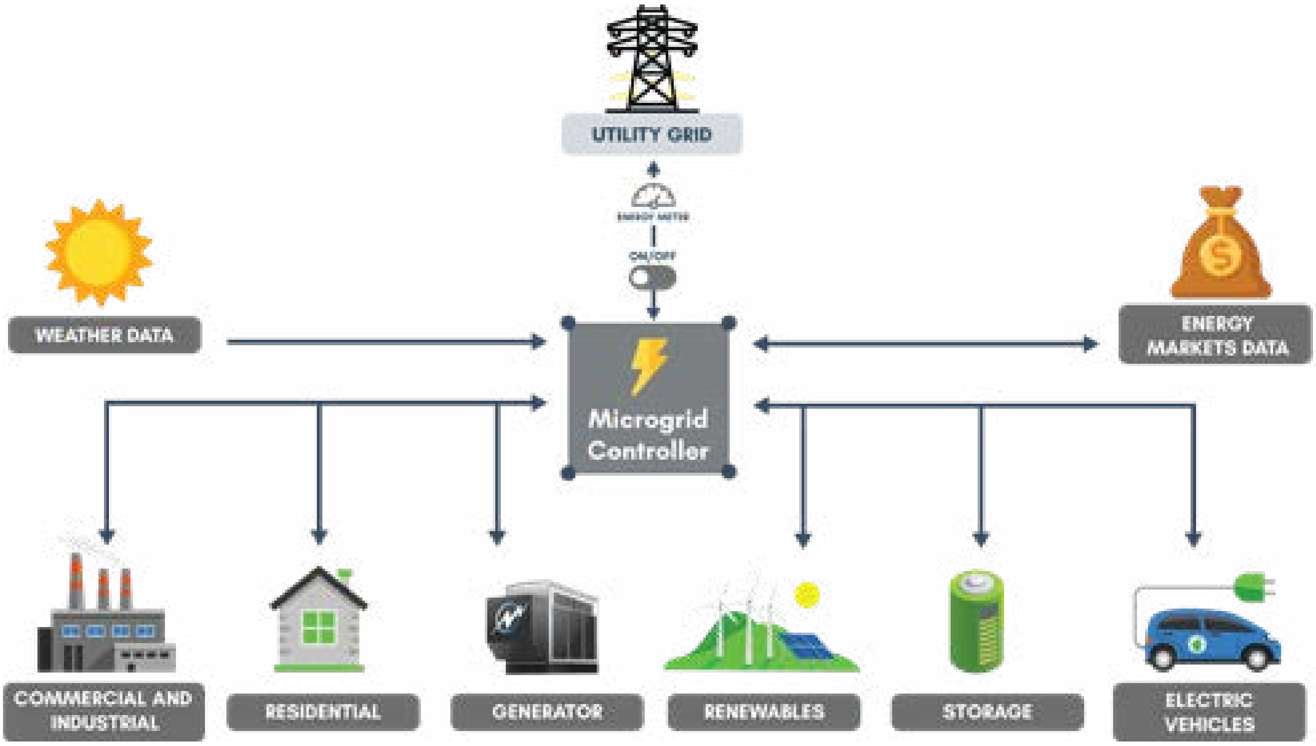
A simple versus optimised microgrid

To ensure the integration of generation sources with responsive energy balance; higher power quality, protection, reliability, increased resiliency, sustainability, scalability and availability, there is need for correct real-time operations and coordination through the use of intelligent control interfaces, gateways, networks, data information techniques, and wireless communications devices, protocols and platforms.

For easier energy management and operation, microgrid controls and other intelligent systems ensure grouping of these variable energy sources into smaller subsets, enabling islanded operation when there is a fault in the sub- transmission network. Effective controllers absorb the challenges during transients, making a quick recovery from faults.



Optimised load control



A microgrid must be able to supply energy to its connected loads, independent of the utility, so generation sources must exist within the microgrid. These sources could range from readily controlled to intermittent, to not controllable. This could be renewable (e.g., solar PV, wind, biomass; or solar thermal and hydro) or non-renewable (e.g., diesel, NG, combustion turbines, reciprocating engines, cogeneration, CHP, turbines, microturbines).

The selection of energy source needs to be adjusted to the demands on the microgrid, such as the desired generating capacity, required firmness level, ramp rate, renewable energy targets, and availability of fuel (and fuel storage requirements).

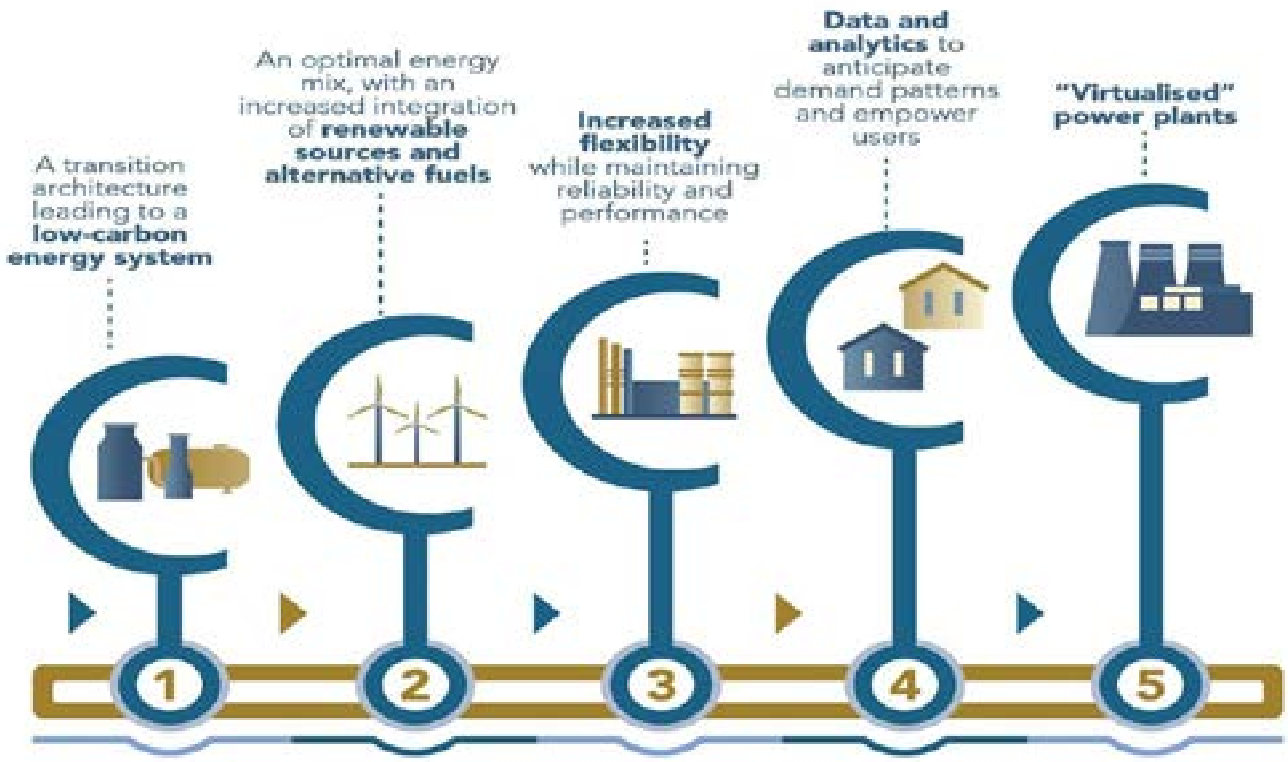
Brownfield microgrid setups often start with some form of existing generation already onsite, such as existing diesel generators, solar panels, or cogeneration facilities. The existing generation resources influence the additional distributed generation capacity required to be added for supporting the microgrid.

Microgrid energy loads range in controllability characteristics from critical loads, like data centres or hospital life support equipment at one end of the spectrum, to adjustable controllable loads, like air conditioning, lighting, or grid dispatch at the other end. This latter category of loads can be temporarily curtailed or adjusted in line with flexible user requirements, and most modern microgrids will have the capability to control these end uses to optimise the utilisation of generation and storage resources.

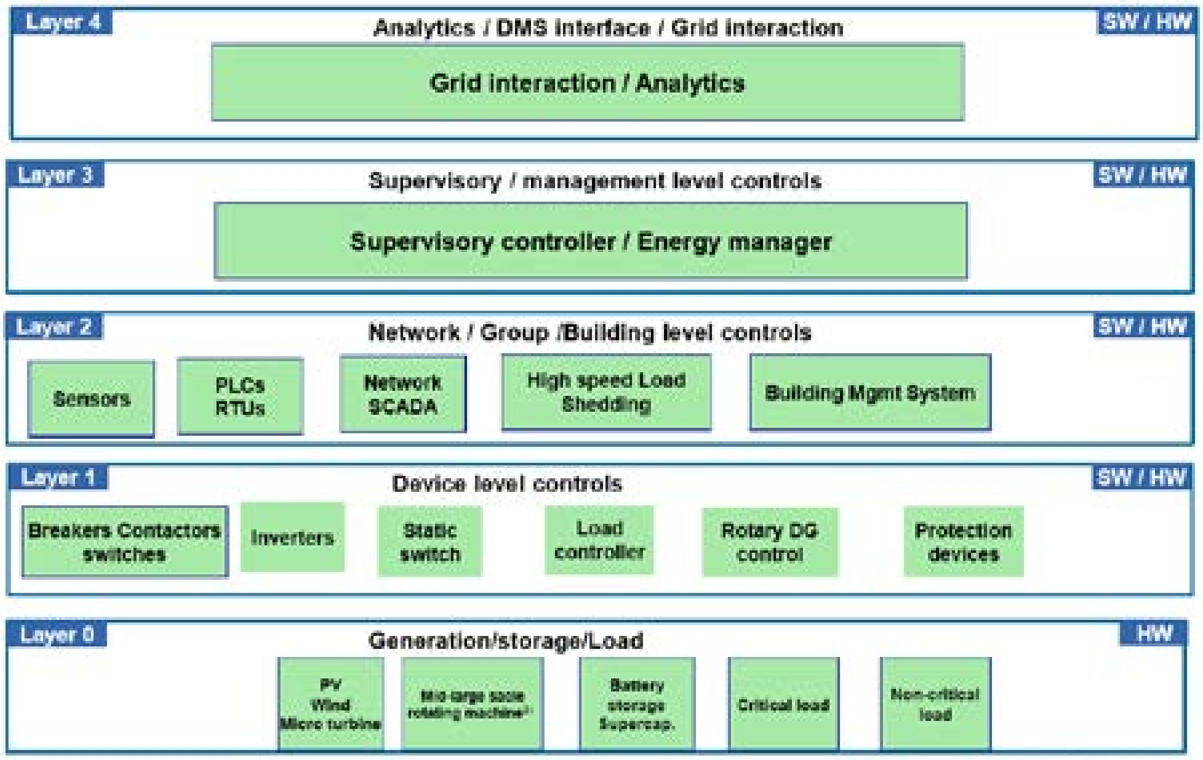
Components of an optimised microgrid

- Centralised and distributed control systems
- Coordinated protection systems
- Communications infrastructure
- Power quality and revenue metering
- Visualisation systems
- Engineering tools
- Economic optimisation system.

Five Pillars of Optimisation



Layered controller architecture - from DERs to grid interaction



Source EPRI Electric Power Research Institute

Microgrids open new possibilities in the realm of distributed resources (DR) as the control actions need not be limited to controllable flexible loads, but can extend to dispatchable on-site generators and storage, all of which can be harnessed in an integrated manner by the microgrid monitoring and control system. This would allow non-critical loads to be shut off or turned down, dispatchable generation to be activated, and storage to be harnessed, all concurrently, which would in turn allow for enhanced participation in distributed resource programs or arbitrage opportunities that may exist in regional power markets.

Thus, microgrids potentially present conducive conditions for advanced, price incentivised, unified responses to be leveraged across a wider range of assets through distributed resource schemes.

At present, there are many types of equipment in microgrids, including DERs, monitoring devices, and protection devices with different information interfaces and communication protocols. Influenced by some uncertain factors such as complicated operation scheduling, and intermittent fluctuations in renewable energy power, this equipment may be put into operation or shut down frequently. If a large amount of equipment is put into operation with multiple protocols, supervisory control and data acquisition systems (SCADAs)/energy management systems (EMSs) cannot automatically identify the device characteristics, or adjust operation strategies to adapt to new system states.

Therefore, microgrids need a "plug-and-play" function to reduce the time of system configuration during the equipment integration to improve the system integration efficiency. On the other hand, microgrids may convert their operation modes, such as conversion from the autonomous mode to the grid-connected mode and vice versa according to the operation requirements, and need fast and reliable control of the diverse equipment during the conversion to ensure the stable operation of the microgrid.

The Microgrid Control System (MGCS) architecture in a layered representation.

The Microgrid Control System (MGCS) architecture in a layered representation.
Layer 1 through Layer 4 are referred to together as the MGCS. The primary purpose of Layer 1 through Layer 3 is to improve grid resiliency. Layer 4 is the only level devoted to non-resiliency MGCS functions.

Layer 0 contains the equipment within the microgrid, such as circuit breakers, transformers, transmission lines, cables, motors, traditional generation, renewable resources, and the like. The equipment at Layer 1 has hardwired connections to monitor and control this equipment, such as current transformers (CT), potential transformers (PT), and digital status and controls.

Layer 1 includes multifunction protective relays, remote I/O modules, and meters. Layer 1 devices provide all of the I/O, data collection, metering, protection, and physical control of Layer 0 devices. All of the protection and some of the controls are programmed in these Layer 1 devices. Typical controls in Layer 1 include islanding detection, decoupling, and resynchronisation. The microprocessors in the Layer 2 equipment provide a robust distributed control and protection system that mirrors the well-proven designs of the utility power system.

Controller requirements to achieve optimisation

Connectivity and interoperability

Communicates with any type of DER and intelligent electronic device using IEC 61850 standards (also IEC 60870-5 and Modbus). Interacts by retrieving weather forecast information, historical DER energy data, day-ahead electricity tariff rates to dynamically control microgrid DERs and optimise facilities performance.

Intelligent

Performs dynamic electrical topology computations and measurements in real-time to overcome challenges in the microgrid's changing electrical topology. Manages microgrid DERs' (energy sources, controllable loads and energy storage systems) operational priorities based on customer strategies and needs.
Sheds non-critical loads when the microgrid power production is lower than the demand.

Power reliability and protection

Adjusts protection relays and the grounding/earthing system settings to the current microgrid mode (grid-connected or islanded).

Resilience and high performance

Advanced energy management functionalities like load sharing, load shedding, black start, load restoration and battery energy storage system.

Cybersecurity

Advanced cybersecurity features help to comply with standards: NERC-CIP, IEC 62351-8 RBAC, IEC 62443-2-4, BDEW, ANSII, IEEE 1686, etc.:

- Individual Role-Based Access Control Active directory synchronisation
- System security logs recording
- Encrypted communication to SCADA/EMS
- Malware protection and OS/application hardening

Continuity and stability

Constantly monitors the grid and automatically switches the operation mode of the microgrid (grid-connected or islanded mode) in case of abnormal electrical conditions.

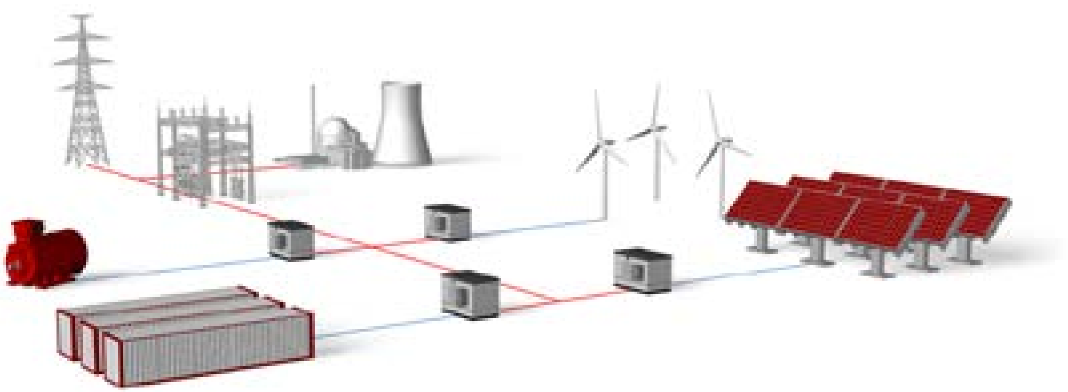
Synchronises load voltage and frequency to preserve microgrid power supply continuity and stability when disconnecting and reconnecting to the grid.

Using the microgrid controller to increase revenue

A microgrid uses software intelligence to coordinate its energy supply and demand in a way that extracts maximum value and performance from its resources. An advanced microgrid does so with an eye toward the microgrid's internal economics and the outside market. So, the level of value the microgrid secures is location dependent; it is influenced by rules, regulations and market conditions that vary by states and regions.

Some ways the controller derives value include:

- Integration and optimisation of renewable energy (solar photovoltaics and wind) and battery energy storage systems
- Utilising thermal energy from CHP
- Participating in utility-run demand response programs
- Managing controllable loads via Building Automation Systems
- Forecasting weather and managing load and generation accordingly
- Optimising economic dispatch and unit commitment
- Automating operations and control, reducing the need for on-site operators
- Providing energy resiliency/averting power outages.



The microgrid controller configures and dispatches the most reliable and economic mix of resources for use at any given time. This might mean integrating on-site renewable energy with other generation resources to overcome the 'variability' of solar and wind—the problem of non-production by these resources when the sun doesn't shine or wind doesn't blow.

To make up for any lag in energy production from renewables, the controller can tap into battery storage, reciprocating engines, central grid power (if it is connected to the utility grid) or some other resource. The microgrid can even plan ahead in making these decisions by tracking weather forecasts.

The controller also derives value by tracking market prices for power, to determine when it's most advantageous for the microgrid to use its own generation versus buying power from the grid. In some instances, the microgrid may even supply power to the grid, as well as ancillary services, such as frequency control. The utility or grid operator pays the microgrid for these services, which creates a revenue stream for the microgrid.

The controller also works with Building Automation Systems to analyse energy use in buildings served by the microgrid, and to determine where and what time of day it can 'shave' energy use without affecting the comfort of occupants.

During high cost energy periods in summer afternoons, for example, the Building Automation System may increase the temperature by one or two degrees to reduce load per the microgrid controller instruction. Meanwhile, the microgrid might rely on CHP for continuous operation to serve its base load requirements — the minimum electrical needs of the microgrid host over a 24-hour period.

CHP will also offer value by way of thermal energy. CHP uses wasted heat produced in power production for heating buildings, warming and chilling water, producing steam or some other use valuable to the customer. This distinguishes CHP from conventional power plants, which let the heat waft, unused, into the air or water. A microgrid controller optimises CHP systems by ramping up or down capacity to match the forecasted load as well as to maximise economics of the system in relation to utility rates. It is important to note that the advanced microgrid controller handles all of this coordination — forecasting, dispatch, interaction with the central grid — automatically. No human intervention is required.

External factors that hinder the MGCS optimisation

Several external factors influence the ability to fully use microgrid software management control, and optimisation capabilities.

Some of these locational factors include:

- Utility electric rates
- Natural gas prices
- Grid operator rules and markets for ancillary services
- Availability of demand response programs
- Local rules for net metering
- Renewable energy credits and other financial incentives.

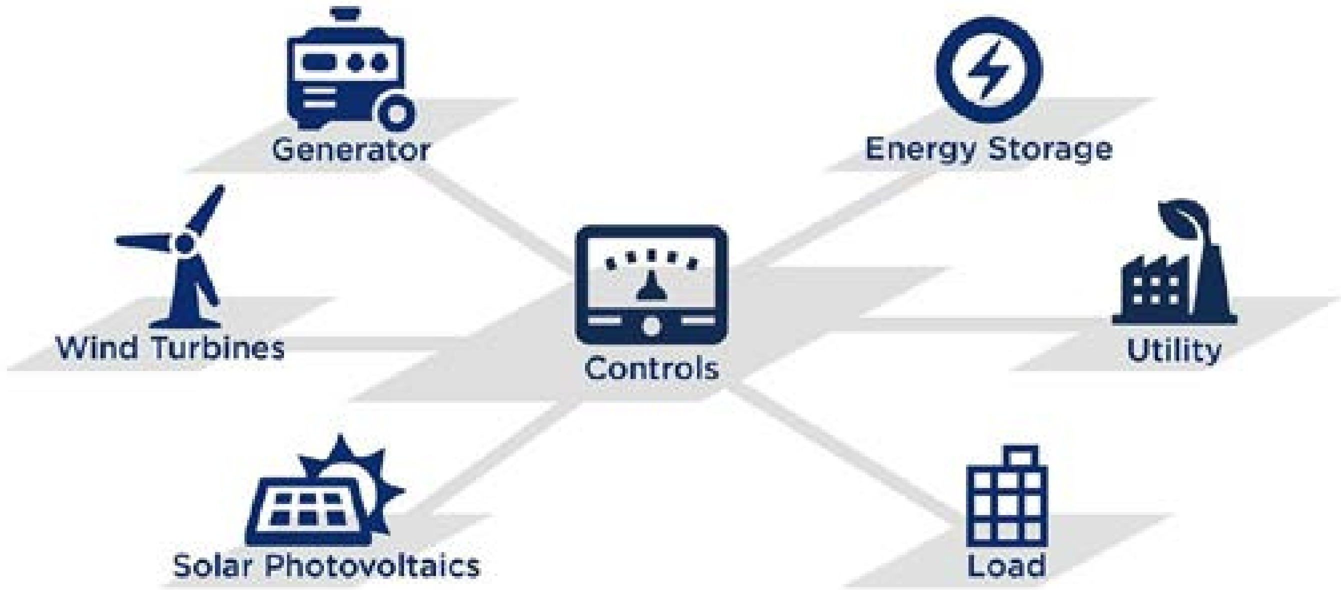
Local utility rates are one of the most important influences on microgrid value. Like most distributed energy, microgrids tend to pencil out best in regions where utility rates are high. If utility rates increase over time, as they have historically, the microgrid may be able to show a widening of savings over its lifespan. This is particularly true if at least part of the generation used by the microgrid has fixed, or even zero fuel costs, as does wind or solar energy.

Some of the parameters influencing the microgrid's ability to fully optimise include:

- Current electricity and gas contract costs
- Hourly electricity prices
- The value of fuel cost savings the microgrid can derive from CHP at any given time
- The availability of controllable loads, which can shift
- The influence of load shifting on utility charges
- How load profiles change over time
- How energy contract prices change over time
- The size of the generation resource; how it might change over time
- The variability/output of renewables and how energy storage is used
- The value of resiliency
- Generator efficiency and ramping ability
- Diesel fuel costs.

Conclusion

The bottom line is that an advanced microgrid or distributed energy project has many resources at its disposal. When an advanced controller is used to manage the resources, it can derive value unavailable to simple generation-only projects. A facility that uses CHP alone, or solar plus storage, without this advanced optimisation and control, offers less flexibility and fewer pathways to maximum efficiency and best pricing.



Case Studies and News

Energy management control system to bolster remote solar

https://www.sageautomation.com/our-work-energy-stories/energy-management-control-systems-to-bolster-remote-solar

SAGE and Enerven to help SA Water turn solar into savings

https://www.sageautomation.com/news/pages/sage-and-enerven-to-help-sa-water-turn-solar-into-savings

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