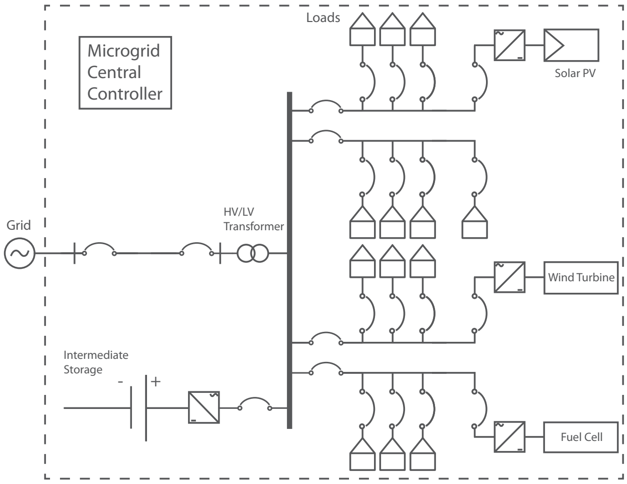
Microgrid: A solution to the aging grid infrastructure

The business community and consumers are continually expressing their concern regarding climate change, energy security and the increasing price of electricity. Within these scenarios, renewable energy technologies increasingly present themselves as viable alternatives. With the increased penetration of renewable generation sources on the electricity network, the aging grid infrastructure can struggle to cope with the operational challenges presented by these new technologies, such as intermittency, voltage rise and oversupply. A solution being employed to deal with these challenges is a relatively new grid structure known as a Microgrid.



What is a microgrid?

A microgrid is a combination of interconnected distributed energy (DE) generators, energy storage units and loads (see image). A microgrid is connected to the main grid at the point of common coupling (PCC) and can provide energy during peak demand as well as ensure good power quality for the main grid. Microgrids should not be confused with minigrids, which are electrically independent of the main grid.

Microgrids can operate in grid-connected mode, where the microgrid can draw energy from or supply energy to the main grid depending on the load requirements and generation output, or in island mode, where the microgrid disconnects from the main grid and operates independently. Island mode is usually initiated by abnormal conditions in the main grid or the inability to connect to the main grid and is often more difficult to manage without the main grid backup (Pedrasa & Spooner, 2006).

Energy storage may be required to maintain the balance between supply and demand of the microgrid and the main grid. Microgrid energy storage is usually a combination of battery banks, supercapacitors or flywheels. Electric vehicle batteries can also serve as this energy storage. In island mode, microgrids often have no inertia or spinning reserves; that is, they are unable to provide for the instantaneous loss of renewable generation. Energy storage can make up for this lack of inertia by providing the necessary energy until another source can provide the required energy.

Monitoring and Control Systems

Microgrids require complex monitoring and control systems to maintain grid stability and to ensure that demand is met. These systems must be able to monitor all generation sources and loads, as well as other factors such as weather, battery state of charge (if present) and main grid demand.

To ensure that the system modelling and data collection is suitable for operation in both grid-connected mode and island mode, locally available information should be used (Lasseter, 2001). If in island mode, a microgrid should also be able to establish and regulate the main grid voltage and frequency as well as the acceptable power quality.

There are several different rationales that can be used for microgrids in island mode which are affected by power quality and stability, installed storage capacity, types of generation units and microgrid ownership. For all possible rationales for the above factors, the power output of each individual DE generator must be controlled. PQ control can be used to control the output of a DE generator so that its real and reactive power is constant. Droop control can be implemented to ensure that any variation of frequency or voltage from nominal values is fixed. This variation is usually caused by variation of DE generation output and load profiles. (Engler & Soultanis, 2005)

'Pure droop control' is one technique that can be used for the interconnectivity of DE generators and energy storage units. When the microgrid islands, all available DE generators and energy storage units switch to droop control mode and then work together to control the voltage and frequency, ensuring it remains within acceptable limits. (Pedrasa & Spooner, 2006). Further approaches and more details are proposed by Pedrasa & Spooner.

Case Study – Wildpoldsried, Germany

In the town of Wildpoldsried, Germany, residents utilise microgrid, renewable energy and battery storage technologies and produce up to 500% more energy than they require. Wildpoldsried incorporates approximately 6MWp of solar PV, 1MW of biogas and 12MW of wind as well as hydro, biomass heating, solar thermal and geothermal heating.

The Integration of Regenerative Energy and Electric Mobility (IRENE) project was set up by a number of organisations to attempt to automate the stabilization of the microgrid. Some of the challenges recognised by IRENE was the integration of variable renewable electricity, bidirectional power flows, power asymmetries and harmonics and electric vehicle (EV) charging integration. These were overcome by implementing a closed loop control system, voltage regulated transformers, installing Li-Ion battery storage and controlling PV inverters and EV charging.

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The IREN2 project was then set up further on from IRENE. IREN2 intends to investigate how improvements can be made to energy systems with distributed energy generation, energy storage and other additional components, using Wildpoldsried's existing infrastructure. IREN2 also intends to further test microgrid technologies over a period of 3 years in an attempt to qualify the system to become a topological power plant (TPP) for the main power grid. Ensuring safe re-synchronization with the main grid, proving grid stability, testing ancillary services provision and proving blackstart capability are also targets for this project. This will be achieved through technological improvements as well as modifications such as improved control and automation systems and adjustment of energy storage. (Becker, 2015).

These projects can assist in finding the most efficient and cost-effective options for distributed energy generation integration.

The future of micro-grids in Australia

The success story of Wildpoldsried should inform the Australian energy sector that the challenges of integrating distributed energy are being solved.

With an excellent solar and wind resource, Australia could develop the commercial and technical opportunities of the future microgrid market. A combination of improvements in solar PV technology and the introduction of generous feed-in tariffs has seen the solar PV industry in Australia grow significantly; Australia currently has ~4.2MW of solar PV installed (APVI, 2015). This provides a strong foundation for microgrid implementation. As battery storage technologies continue to improve and prices continue to fall, the previous major barrier to the market expansion of energy storage is being removed. The combination of Australia's suitability to use distributed energy generation and the improvement of battery storage will see the implementation of microgrids in Australia within the next decade.

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