Microgrids and Renewable Energy: Opportunities for Revolutionizing Electric Distribution Utilities

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The Microgrid Concept

The first electric power grids were designed for large factories and small urban centers; these initial power grids were direct current (DC), limiting their size and reach due to the significant losses associated with transmitting direct current over large distances [1]. Thomas Edison's original vision for the electrical grid included a local power generation plant in each neighbourhood, a concept that seems absurd compared to the interconnected electrical grid that we have become accustomed to, but perhaps not too far fetched given recent proliferation of renewable energy resources connected in cities today [2].

The current electric power grid consisting of large and centralized generation plants is a result of the efficiencies realized by economies of scale. Large coal, gas, and oil plants are built near existing fossil fuel reserves and major shipping corridors; hydroelectric dams are placed in mountainous regions, and nuclear plants are placed near large bodies of cooling water. These large centralized power plants then deliver power to major load centres via high capacity power transmission lines. The strategic placement of these large and centralized power generation plants has had a direct influence in shaping the topology of the current electrical grid as we know it.

The centralized, vertically integrated topology of the current power grid has made it particularly vulnerable to natural disasters, terrorist, cyber attacks, and cascading power failures. For example, the US-Canada blackout in 2003 that affected over 50 million people was simply triggered by drooping of over-loaded lines in the foliage in Ohio [3]. Driven by tighter requirements for system reliability and resiliency, researchers around the planet are exploring techniques to effectively decentralize the power grid. In this context, microgrids are considered a critical link toward smart decentralized networks [4].

> *'[A microgrid is] a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode."*
>
> *-- The U.S. Department of Energy's Microgrid Initiative [5]*

Small, decentralized power systems have existed for decades in remote communities such as island settlements, rural villages, and remote industrial sites. However, the concept of microgrid did not emerge until 2001 [6]. Due to their flexible and distributed architecture, microgrids have naturally emerged as an ideal platform for integrating and managing distributed energy resources such as diesel generators, battery energy storage systems, and renewable energy resources [7].

In recent years, microgrids have emerged as a significant disruptive force, enabling industrial and commercial institutions as well as residential participants to generate and provide electricity via renewable and distributed energy sources [8]. *Ernst & Young* has shown that by 2020, the microgrids will be able to save 64 to 171 BN USD in electricity cost for commercial companies in the 10 largest Organisation for Economic Co-operation and Development (OECD) and 10 largest non-OECD countries combined [9].

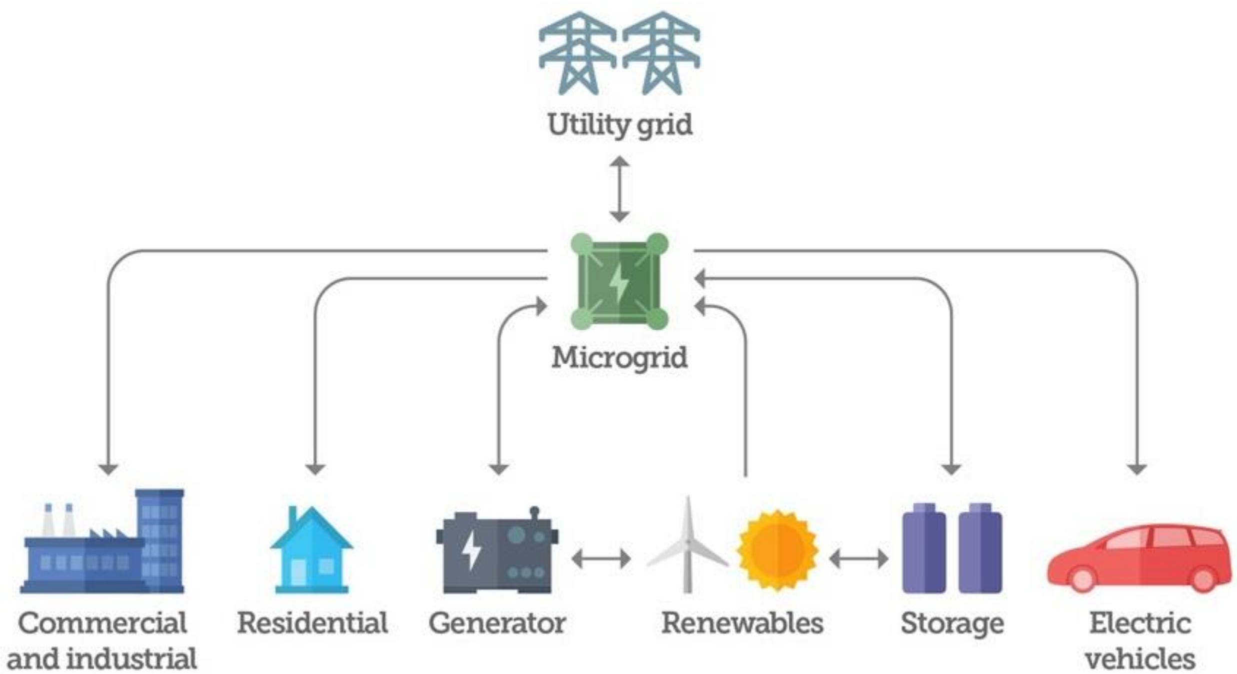

Figure 1 – Microgrids provide a flexible architecture for integrating renewable and energy storage assets closer to the end user. The microgrid also provides a point of common coupling to the main utility grid. Source: The Pew Charitable Trusts [10]

Renewable Energy and the Microgrid

Driven by environmental concerns and technological innovation, usage of renewable energy resources has proliferated over the past ten years. In contrast to conventional power plants, renewable energy resources can be decentralized and located along the edge of the grid, close to where the electricity is actually consumed, acting in aggregation as a virtual power plant. One example of decentralized renewable energy resources are rooftop solar panels.

Increased proliferation of renewable energy resources has introduced new technical challenge in the operation and control of electrical grids. Intermittent and volatile renewable resources such as wind and solar power increase the uncertainty of the power supply (illustrated below). In addition, the majority of these resources are electronically interfaced to the system, which decreases the overall system inertia (a measure of the system's ability to absorb shocks to the electrical supply and demand). Moreover, the conventional power grid is designed for unidirectional power flow, whereas distributed energy resources may result in reverse power flows, requiring revised control and protection schemes [10]. In this context, microgrids can facilitate the integration of distributed energy resources [7], by implementing local control and monitoring techniques [6]. From the perspective of the main grid, each microgrid, while containing several controllable and heterogenous agents, would appear to the distribution utility as a single entity that is either net-consuming or injecting power to the main grid [7].

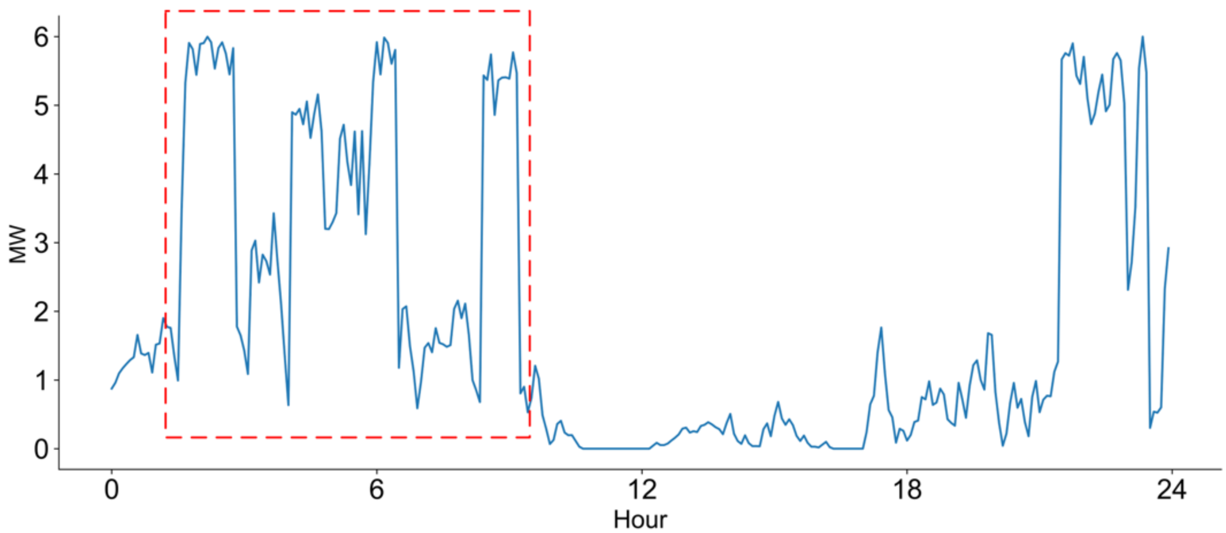

Figure 2 – The volatility in renewable energy output is illustrated in the wind output profile for a pair of 3-MW wind turbines. A period of sustained fluctuations in power generation is highlighted in the red box.

Microgrids provide an elegant solution for mission critical loads such as hospitals, military bases, data centers, and industrial facilities. These entities run mission critical or highly sensitive operations and cannot afford any interruption in the electricity supply. Traditionally, such facilities have relied on backup generation (typically diesel gensets) to minimize the risk of energy disruption. Microgrids would increase the reliability and resiliency of energy supply to these critical loads, while automating and increasing utilization of distributed energy resources. For example, during an upper grid failure, a microgrid would smoothly transit from the grid-connected to islanded mode of operation, without jeopardizing either grid's integrity [6].

Augmenting Microgrids with Artificial Intelligence

Widespread adoption of microgrids requires a holistic solution to the aforementioned obstacles and challenges, including complex end-to-end control strategies, intelligent demand response, and adaptive economic schemes [11]. In this context, AI-based solutions have been shown to deliver promising results [12]. In particular, two recent developments have provided an opportunity for artificial intelligence to augment microgrids:

1. **The increased deployment of smart meters at the distribution level generates large datasets in real time.** – Over 77 million residential smart meters were installed in the US in 2016, and another 20 million will be deployed by 2020 [13].
2. **Cloud computing is replacing the high-performance computing assets** – these would traditionally be installed on-site at the microgrids, but cloud computing facilitates remote AI training and inference, decreasing the hardware cost as well as the need for extensive IT infrastructure.

Cloud computing can ingest the high volume of data sets generated by smart meters to develop and train AI models, deploying them remotely in a distributed architecture. Pushing AI computation to the edge of the microgrid allows for data sampling rates much higher than the typical 15- to 60-minute used by many utilities in North America and Europe [14], providing a faster response time and therefore more accurate decisions.

Bluwave-ai has identified multiple use cases in which AI may be used to enhance microgrid functionality and operation, and increasing the value proposition for microgrid adoption:

1. **Energy Forecasting:** prediction of microgrid energy generation and consumption based on information such as historical generation and consumption, time of day, electric vehicle charging patterns, population density, weather, and commercial and industrial activity.
2. **Intelligent Optimal Dispatch:** Depending on the objective function, intelligent optimal dispatch models can achieve superior performance with a lower computation time compared to conventional models.
3. **Adaptive Control**: Self-learning and self-adaptive primary controls can yield higher system stability with less dependency on energy storage systems.
4. **Predictive Maintenance:** Compared to periodic maintenance, predictive maintenance techniques can decrease the operation and maintenance costs associated with system regular maintenance and unpredicted failures.

Bluwave-ai's solutions are based on a distributed AI architecture. This allows for high scalability which overcomes the issues pertaining to low bandwidth and limited communication connectivity typically encountered at the edge of the power grid. Our system leverages cloud computing located to train AI models (Bluwave-ai Center). The trained models are then deployed close to the end-user at the grid edge or where microgrid control resides and access to IoT sensor data (Bluwave-ai Edge).

BluWave-ai also is working with key industry partners to investigate the potential savings that its distributed AI architecture can help with in several use cases: a remote mine microgrid operator, AI-assisted energy optimisation for campus scale grid tied microgrids within a large North American utility's distribution network, and optimising renewable energy use and energy cost with integrated utilities deploying renewable power generation in Canada and overseas.

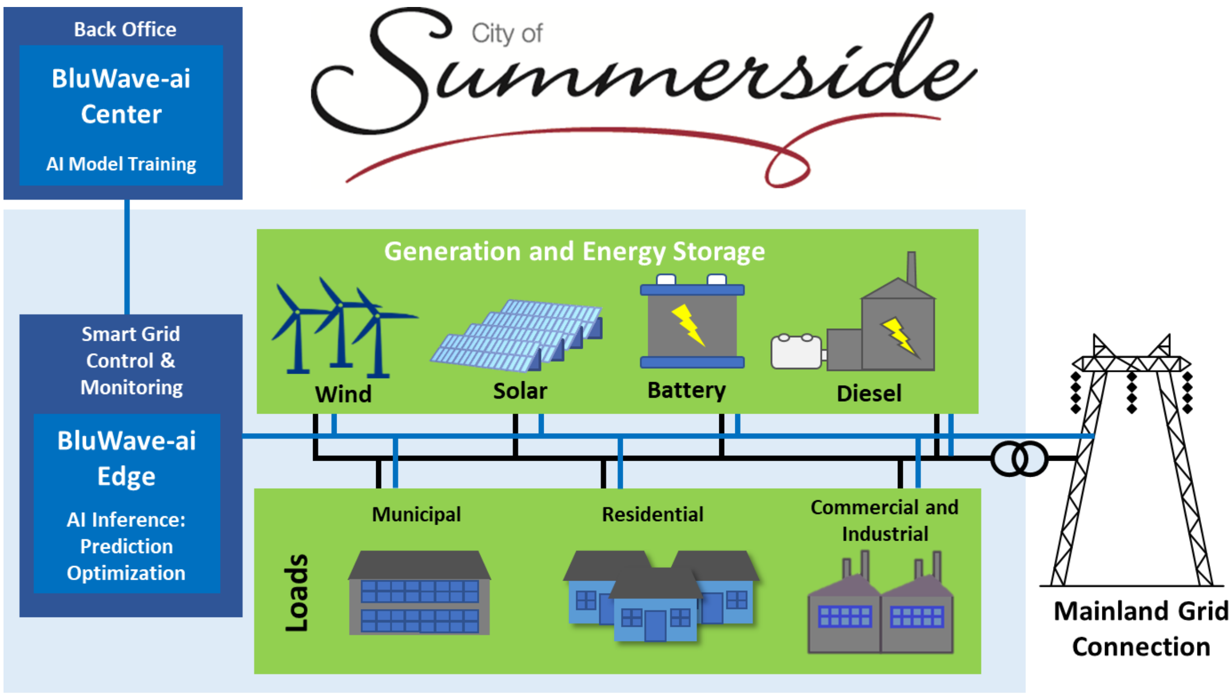

Figure 3 – Illustrating a small microgrid consisting of renewable and energy storage assets, running Bluwave-ai edge and center AI-enabled solutions. Bluwave-ai has partnered with the City of Summerside, PEI in order to improve the efficiency and economics of the energy supply.

Opportunities for Electric Distribution Utilities

Electric distribution companies are ideally positioned become the pioneers in reshaping the electrical grid to enable AI-enhanced microgrids by leveraging their experience in field operations, asset management, regulatory compliance, grid operation and control, and consumer billing [15]. In Canada and the United States, utilities are also often regulated at the provincial and state level, giving them exclusive rights to manage grids in the areas that they serve [15]. Third party developers, on the other hand, would require extensive effort to secure the rights and permits pertaining to the microgrid development and operation.

Microgrids provides tremendous opportunities for electric distribution companies and grid operators, from both a technical and operational perspective. Some benefits include:

1. **Facilitating grid modernization** and integration of new smart grid technologies [5].
2. **Enabling a local control** and management of critical loads and distributed energy resources, thus enhancing the system controllability and reliability [5].
3. **Enabling more effective peak-shaving and energy shifting schemes**, as a result of higher controllability, addressing issues such as losses in the system [10] and saving the investment costs pertaining to new feeders and corresponding operational expenditures
4. **Achieving a higher resiliency and reliability** due to the ability of microgrids to operate in islanded mode [6].
5. **Reducing transmission costs** associated with transporting electricity along far distances. In a microgrid scheme, generation assets are located in close proximity to the electrical end-user.

Operating microgrids can also serve as an alternative source of revenue for electric distribution companies. Instead of treating microgrids as a competitor, some utilities are investing in microgrids, implementing them for customers such as those with critical loads [16]. These services are not a part of the utility company's regulated product offering, and therefore can be priced as a value-add or premium service. In addition, microgrid deployment can disrupt the utility company's conventional business, shifting their focus from distributing energy and maintaining infrastructure to managing a grid of microgrids in the distribution level. Hospitals, schools, small manufacturers, and campuses that already have generation infrastructure have been identified as ideal microgrid costumers [15].

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