Optimizing Renewable Energy Use with BluWave-ai Distributed Artificial Intelligence

Overview

The production, distribution, and consumption of energy, particularly electrical energy, is evolving from the traditional, one-way power delivery from large power plants via long transmission lines to end users to a new “energy internet” with a dynamic flow of data and energy between producers, consumers, and so called “prosumers”. As a result, technical complexities are emerging between multiple stakeholders. In particular, the electrical grid is evolving by a higher penetration of renewable energy from distributed sources such as solar and wind farms, storage systems, peer-to-peer microgrids, and residential generation. As the cost of solar, wind generation, and storage decreases, renewable energy resources have become an economic and sustainable solution to meet increasing energy demand worldwide.

Microgrids are considered a critical link in the evolution from vertically integrated bulk power systems to smart decentralized networks. A microgrid is defined as a group of distributed energy resources, for example: solar photovoltaics, micro turbines, thermal power sources, energy storage, and flexible loads. Microgrids should be able to operate in both grid-connected and islanded modes, with the ability to smoothly transit from one to another. Examples of microgrids facilitating the integration of renewable energy sources are as follows:

- *Commercial and Industrial microgrids* whose operators employ storage and solar generation to reduce energy costs and increase reliability and resiliency of operation, particularly in the case of a grid outage
- *Remote mining and forestry operations* in areas supplied by diesel engines, which are seeking to reduce costs and increase reliability of supply
- *Campus microgrids*, for example hospitals and universities, aiming for a lower carbon footprint and decreased overall energy costs
- *Military forward operating base microgrids* looking to maximize operational reliability and resiliency using renewables to reduce resupply frequency
- *Isolated remote microgrids* for communities in Northern Canada, sub-arctic regions, and developing countries that aim to use renewables to achieve self-sufficiency and lower costs
- *Net-zero communities* supplied by renewable resources to eliminate greenhouse gas emissions

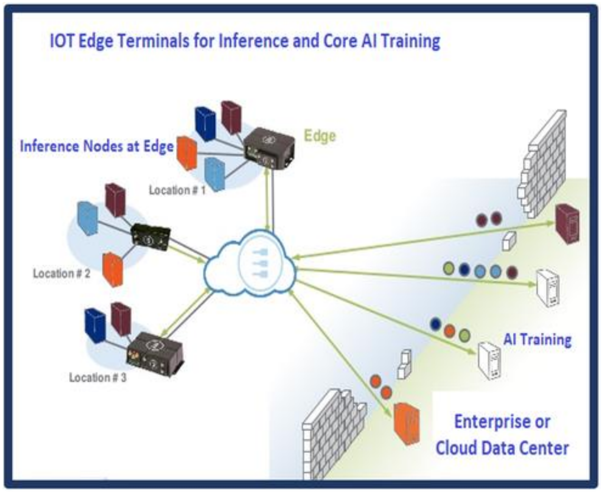
The performance of decentralized grids and microgrids and the intrinsic mathematical relationships between various system parameters are different than in conventional bulk power systems. Hence, intelligent and effective controls are needed to guarantee the system reliable and optimal operation. In this context, Utilities need to become energy integrators, managing the Smart Grid and providing value to all stakeholders. Integrating distributed energy resources, when properly aggregated, can create “virtual power plants”, giving the utilities the opportunity to become energy providers. As a result, new business models and opportunities can appear while simultaneously reducing demands on the distribution network, capital, and operating costs.

Conventional fossil-fuel-based generators are dispatchable, meaning their output power can be quickly adjusted, allowing the utilities to effectively react to peak loads and changes in demand. Renewable sources such as solar and wind are not dispatchable since their output depends on weather, and as result, peak generation may not match periods of peak demand. Traditional power systems depend primarily on rapidly deployable power sources, creating a centrally-managed grid with limited flexibility and control systems that are unable to optimize the use of renewables over fossil fuels. It follows that new analytical models, methods, control, and tools are needed to effectively increase the penetration of renewable energy resources.

Energy storage has been demonstrated as a viable solution to handle the intermittent behaviour of renewable sources and minimize renewable energy curtailment. Recent improvements in battery energy storage system (BESS) technologies and other storage systems are significantly reducing the cost of deployment. If controlled properly, energy storage can significantly reduce the energy cost and increase reliability for utilities and microgrid operators. However, to date, many industrial battery energy storage and storage facilities are used only for local backup and reserve power. In fact, a study by the Rocky Mountain Institute (The Economics of Battery Energy Storage, October 2015) found such batteries may sit unused for 50 to 95% of their useful life. Hence, more intelligent supervisory techniques can better utilize existing energy storage assets, significantly increasing the energy produced by renewables while decreasing the overall energy cost.

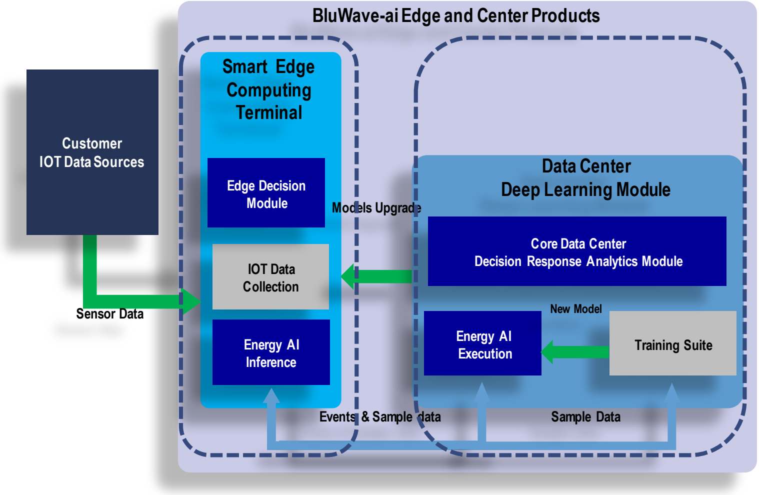
Artificial Intelligence for Optimizing Renewable Energy Integration

Conventional, static rule-based analytics cannot effectively handle the tremendous amount of data coming from a large, complex network of distributed consumers and producers, where constantly changing conditions jeopardize system operation reliability, security, and efficiency. On the other hand, Artificial intelligence (AI)-based techniques can utilize vast amounts of data to accurately model complex system behaviours, automatically learning to optimally respond in real-time and mitigate the negative impact of system uncertainties. Hence, by using AI, utilities and microgrid operators are able to properly utilize various assets in the system, yielding significantly reduced operation and investment costs as well as lower emissions.



BluWave-ai Artificial Intelligence

BluWave-ai provides a distributed AI-based solution to optimize the operation of smart grids and microgrids, in particular those with a high penetration of renewable sources. Components are combined at the Edge and core data Center. The Edge is at aggregation points of IoT sensors, meters, and other sources of data. These may reside in the field at edge computing nodes at, for example, a utility transformer, substation, or microgrid control facility, as well as in the private or public cloud data center, depending on where the IoT devices are terminated.



The BluWave-ai solution includes predictors for distributed loads and energy resources in the grid or microgrid. It uses real-time weather data, schedules, situational awareness, and device metering inputs from sensors at various assets. BluWave-ai analyses sensor signals in real-time, near real-time, or offline to optimally manage fluctuating outputs from renewable energy sources, which may be affected by weather and other factors. Bluwave-ai optimisers use real-time data, archived data, and forecasts from the predictors to send recommendations, signals, and actions to various resources to optimally meet desired goals, such as reducing use of non-renewable energy and energy cost.

BluWave-ai Center Deep Learning runs in the private or public cloud, ingesting data from Edge node to train BluWave-ai modules. It includes a Machine Learning (ML) suite with training models that discover patterns in data as well as perform predictive analysis and pattern detection in real time. All of this is accomplished with distributed computing resources between the cloud data center and edge computing points of presence, leveraging FPGA and GPU based accelerated computing.

A significant challenge in IOT data management is to identify useful data and storing it for post processing and subsequent ML training, aiming to enhance future inference. BluWave-ai provides scalable, optimized data storage that supports the volume and variety of IOT data at both the aggregation point edge computers as well as in the private and public cloud data center.

BluWave-ai can operate within a cloud infrastructure, for example AWS, Microsoft Azure, and Cloud Foundry, or in a private enterprise data center and equipment. It is designed to scale to support the large number of devices connected as well as vertically to address a variety of IoT solutions. With the host agnostic and partitioned design of the Center and Edge, BluWave-ai is equipped to support an array of possible operational configurations: Smart Data Centers and Smart Edge Terminals deployed in combination or standalone, pure public cloud, pure private cloud, or hybrid cloud.

The BluWave-ai platform is built on widely used, industry standard technologies, facilitating interoperability with existing enterprise applications and other IoT solutions. The openness of the BluWave-ai platform ensures easy integration with a variety of data sources and other vendors' existing or new solutions and applications. Data can be sent to the platform using widely accepted open protocols and data formats, for example JSON, XML, Text, CSV, XLS, and other binary formats. Data to be processed can also be pulled from proprietary systems using direct database access, invoking web services, and downloading files from file servers. After data is processed by the configurable processing pipeline, it can also be extracted using open standards.

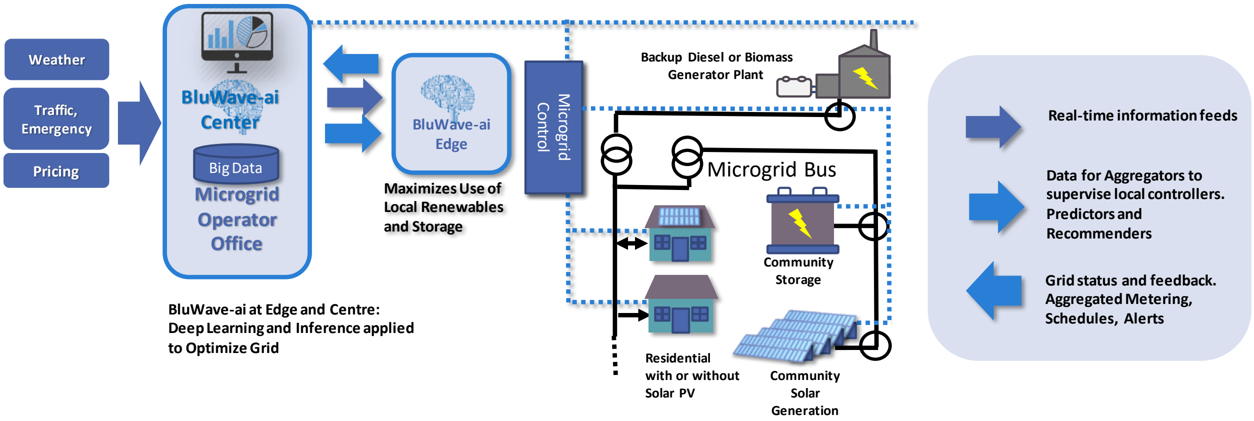
BluWave-ai offers an extensible API that conforms to REST standards. The RESTful API grants access to data stored within the platform, allowing for effortless integration with third-party solutions. The BluWave-ai platform provides an open RESTful API to interact with devices and gateways using various protocols and data formats as well as to ingest data in many ways. Open and widely adopted protocols and standards like MQTT, AMQP, HTTP, WebSockets, (S)FTP, and SCP are used to connect sensors, devices, and other resources to the platform. Processed data can be retrieved from the platform using the RESTful API, directly connecting to the underlying Cassandra database, or by exporting data in standard formats such as CSV or JSON.

BluWave-ai Microgrid and Utility Grid Applications

In this paper, the following three BluWave-ai application use cases are examined for optimizing operation costs and increasing system reliability with a high penetration of renewable sources:

1) A remote, Northern Canadian community isolated microgrid. It relies on diesel power for its energy needs. The community adds a solar PV farm and a battery energy storage system (BESS) to reduce diesel consumption, lower energy costs, and provide better reliability of service independent of fuel delivery. The community also employs an electric vehicle fleet, which provides another energy storage resource.
2) A large industrial plant with critical production lines and a number of buildings, whose electricity is supplied by the local utility. To provide reliable supply for critical production lines, reduce energy costs, and decrease greenhouse gas emissions, the plant installs a solar PV array and battery energy storage. The system should be able to provide back-up in an event of grid outage; it should also reduce energy cost by shifting its demand from expensive peak to cheaper off-peak time intervals.
3) Residential community distributed solar generation and storage served by a local distribution company. Participants in the community opt to install rooftop solar PV panels and battery, creating a bi-directional, active distribution system: Energy can be shared amongst participants, allowing them to lower their electricity bills by reducing grid-supplied energy usage and selling back energy to the grid when needed. Furthermore, it can be treated as an aggregated resource by the utility in the context of a larger transactive energy system to create a virtual power plant.

Remote Community Isolated Microgrid



In the case of a remote microgrid, the goal for the community is to maximize the share of solar power generation, thus minimizing diesel consumption. This improves the community's independence, reduces energy costs, lowers carbon emissions, and environmental pollution. An critical constraint is that the energy must be supplied reliably and continuously, especially for critical facilities in the community.

Solar generation output varies significantly with weather, time of day, and particularly in the case of a Northern community, the season, where summer days and winter nights are considerably long. Peak energy demands of the community is not aligned with the peak solar irradiation. However, an optimally managed energy storage facility can store excess solar energy, for example during mid-day in the summer, and inject power when there is not enough solar production, for example during cloud cover or overnight. Optimal use of renewable energy and energy storage highly depends on accurate prediction of future generation and consumption profiles.

Forecasting the solar output requires predicting the weather and correlating it to the expected output. Forecasting the load for a community of a few hundred people with a mix of residential, commercial, and municipal buildings is a complex, multi-dimensional problem that may include, but not limited to the following factors:

- *Weather forecast* may affect the consumption for heating, lighting, air conditioning, and also modify community behaviour. For example, a severe storm may shift the routine power consumption profiles if businesses and schools decide to delay opening.
- *Seasonal, weekly, and time-of-day schedules and behaviours*, for example residents and building managers setting thermostat schedules. Other factors such as occupancy, events, holidays, etc. are also expected to alter behaviour.
- *Situational awareness* relates to actual demand and generation capacity for assets, including: BESS state-of-charge, diesel fuel reserves, planned refuelling and diesel generator ramp-up.
- *Historical records* of generation capacity and demand correlated with environmental conditions and schedule.

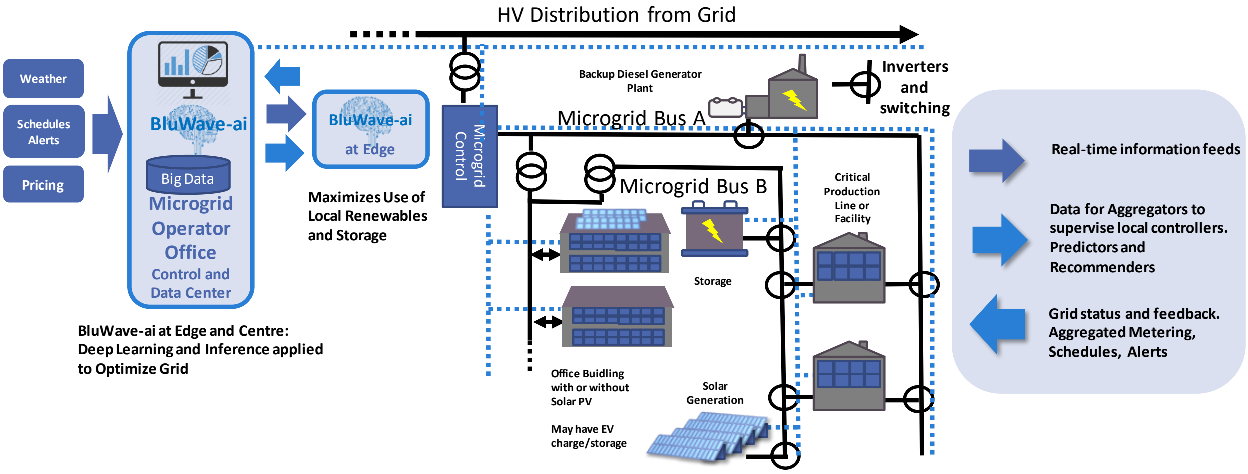
Adding extra distributed energy assets such as rooftop solar and electric vehicle charging stations further complicates the optimization problem. A fleet of electric vehicles in the community is a non-dispatchable, distributed energy storage resource as well as a variable load. While plugged-in, energy may be discharged from the car battery to the microgrid, considering constrains such as the minimum acceptable state-of-charge and user preferences. Satisfying such constraints requires an accurate estimate of the usage cycles and user behaviour.

Managing the efficient use of these assets necessitates real-time decision making that takes into consideration factors such as weather, demand profile, community schedules, warnings, emergency notifications, and situational awareness such as availability of fuel. Considering all these parameters creates a highly stochastic and complex optimization problem which needs a computationally efficient solution to make real-time decisions. Bluwave-ai address these needs, ensuring optimal and reliable system operation.

BluWave-ai Edge components at the microgrid control center continuously monitor the situation and provide control and dispatch signals to the microgrid components. Information feeds such as weather warnings and storm alerts, demand profile, and user specified or predicted behaviors are used by BluWave-ai Edge to take actions that optimize system operational reliability and efficiency. By providing enhanced forecasts and reaction to shorter term and real-time events, BluWave-ai delivers superior performance compared to existing rule-based platforms, maximizing use of renewable resources and prolonging the life of energy storage assets.

At the microgrid control center or optionally at a remote microgrid operator's site, BluWave-ai Center deep learning and reinforcement learning modules continuously consume data to improve control and optimization performance, significantly enhancing the system operational metrics as the system continues to operate.

Industrial Plant Microgrid

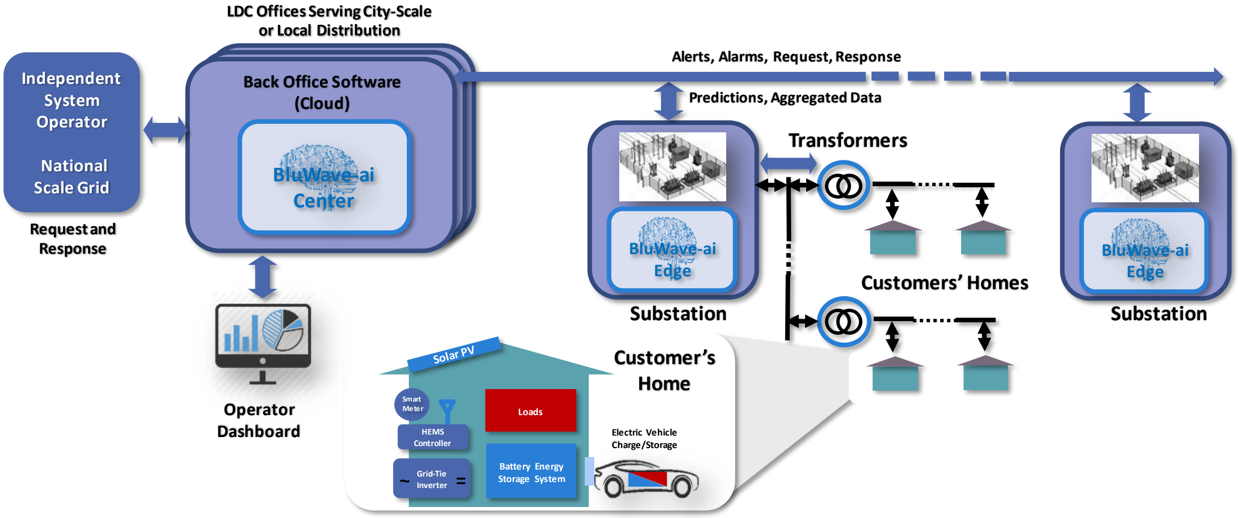


Fundamentally, a large industrial microgrid shares the same goals mentioned previously for a remote isolated microgrid. In this case, the plant has a number of production facilities, and some are critical to the plant’s operation and must run 24/7 uninterrupted. For a large plant, electricity costs are a significant portion of the operating cost. Implementing a solar PV array and energy storage allows the plant to both reduce operating costs and provide backup in case of grid supply interruption, minimizing the use of backup diesel generators. In addition, the plant operator can benefit from carbon credit schemes while running a cleaner manufacturing environment.

Forecasting the solar generation and demand profiles for an industrial plant is a complex task involving several factors. For example, various office and production lines will have different demand profiles affected by day, time, weather, and planned production schedules and shifts. In addition, reserves should be accurately considered to guarantee a continuous and uninterrupted supply for critical facilities, which adds to the overall complexity of the system.

In this case, BluWave-ai uses historical and real-time data to predict demand, forecast generation, and consequently recommend optimal actions. For example, to effectively reduce the energy cost, which is a primary objective in industrial microgrids, the energy storage can be charged during off-peak cheap time intervals and discharged during more expensive peak intervals. Accordingly, pricing schedules and signals from the grid and market are used by BluWave-ai to reduce energy cost. Thus, plant operators achieve a higher rate of return for their investment in solar and storage equipment by lowering their operating costs.

Residential Community Distributed Solar and Storage



In the case of a community with distributed solar and energy storage resources on a local utility grid, the goal is to optimize the use of the resources while satisfying operational constraints such as feeder limits and reducing losses. This allows consumers to reduce their energy costs and also provides many cost and operational benefits to the utility. BluWave-ai's distributed architecture is designed to address the complex hierarchal control framework of a distributed network with high connectivity among various nodes. BluWave-ai Edge aggregation points are located at substations or transformers and receive and predict various data including the load profile and availability of stored energy and solar generation. Based on the current and forecasted data, BluWave-ai sends signals to various hierarchy levels, ensuring highly optimized operation that otherwise is not tractable by conventional supervisory techniques.

BluWave-ai also handles the large amount of data pouring in from the numerous meters and sensors, extracting relevant data and sending it the BluWave-ai Center at the utility's back office. ML techniques are applied to continuously optimize the performance of the Edge models. Using pricing signals from the electrical system operator as well as grid data, weather data, and schedules, BluWave-ai optimizes the operation of the whole system. The local utility is able to aggregate the distributed energy resources into virtual power plants to meet local grid demand or sell excess energy to other utilities. BluWave-ai also enables a transactive energy system so the utility can manage the exchange of energy between all distribution grid participants.

Home consumer participants can be paid for selling excess energy from their solar panel and stored energy to the grid, reducing their energy bill. For the utility, benefits include decreasing the need for investment in capital equipment upgrade, as increasing and changing demand can be met locally by the community's energy resources.

Summary

BluWave-ai incorporates best-of-breed technologies in messaging, service bus, relational database, non-relational database, distributed computing, and AI engines within a flexible, scalable, and purpose-built platform that is tailored for the operation of smart grids and microgrids.

Bluwave-ai Edge and Center modules are trained to extract the most relevant information from complex data patterns, and take optimal decisions for highly complex distributed and decentralized smart grids and microgrids, ensuring maximum efficiency and reliability. Bluwave-ai is easily deployed in a microgrid or utility grid to receive and process data from SCADA, IoT devices, and external data sources such as weather feeds, usual and unusual events, market pricing, market availability, and system performance objectives.

Bluwave-ai easily integrates with microgrid and utility grid control as well as SCADA software to provide the data and signals needed by operators for optimized planning and operation. Depending on the desired level of autonomy, Bluwave-ai can be directly interfaced to microgrid and smart grid controls at various levels to ensure stable, reliable and economical operation with minimal human interaction.

Optimize Your Grid with BluWave-ai

To understand more about BluWave-ai and how AI can improve the efficiency of your microgrid or smart grid project, contact us. BluWave-ai's team of AI specialists, data analysts, and smart grid scientists is available to assess your particular project or existing system and determine the appropriate AI-based control and optimization solution to maximize economic benefits and operational reliability.

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Artificial Intelligence for Clean Energy