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BEHIND THE METER ENERGY OPTIMIZATION: AN OVERVIEW

White Paper by:

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Abstract

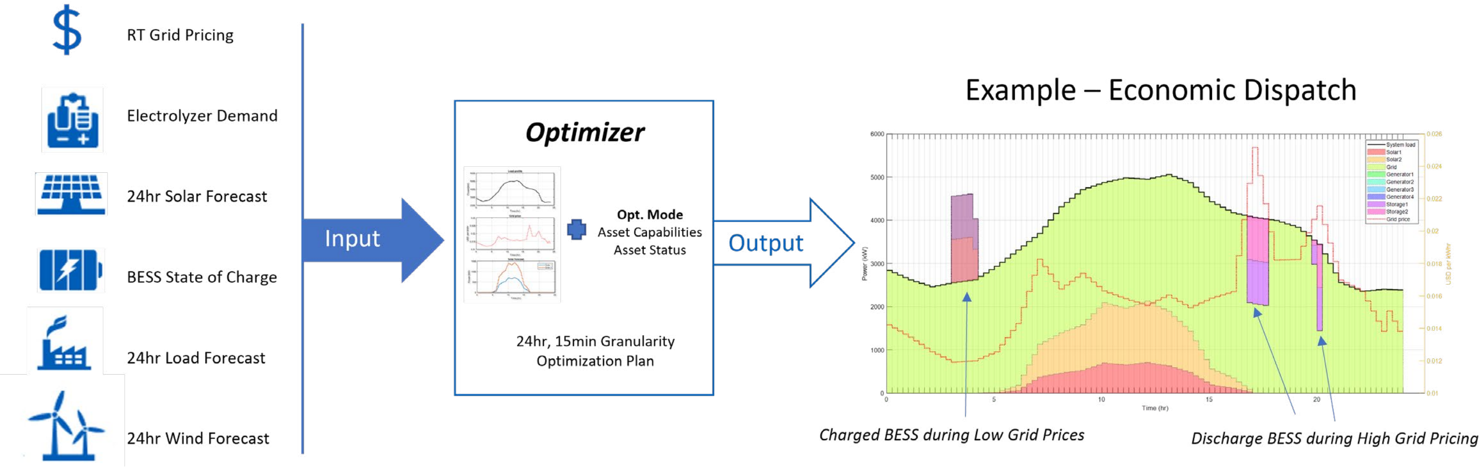
With the recent trends in global, national, and corporate initiatives to reduce carbon emissions, corporations - particularly industrial facilities - can meet these goals while receiving other added benefits with a microgrid. A microgrid is a group of interconnected loads and distributed energy resources (DERs) with a clearly defined electrical boundary that acts as a single, controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable its operations in both grid-connected and islanded mode[1]. To meet carbon neutrality goals, corporations have started to implement sustainability programs at their facilities. When implemented effectively, these programs involve the integration of onsite renewable energy. Onsite renewable integration varies across a broad spectrum, but when leveraged as part of a microgrid, it can provide additional benefits beyond sustainability including energy savings, reliability, resiliency, and increased revenue generation. These benefits are obtained through the integration of advanced control and optimization platforms that are tailored and configured to meet the facility's objectives.

I. INTRODUCTION

An industrial facility's primary goals are centered around production. A key factor that can affect production output is down time caused by an interruption or instability in the supply of energy. Historically, the electric grid is a very secure source of power, enabling most companies to reduce their risk with the deployment of standby gas generation. However, standby generation may no longer be adequate as the percentage of intermittent renewables on the grid continues to increase, threatening the stability and reliability of the electrical network. This is happening while industrial costs of downtime continue to rise. In addition, as many corporations are moving toward carbon neutrality and a net-zero manufacturing footprint, these initiatives could require the deployment and integration of on-site renewable energies to offset some of the emissions of electrical consumption from the grid. The intermittent nature of on-site renewable sources presents a challenge for a facility's network stability, particularly when disconnected from the electric utility grid. This work focuses on a microgrid with renewable energy sources that optimize, control, and balance a facility's power generation and loads based on the customer-defined goal.

A microgrid control solution is comprised of two parts: the real-time secondary controller and the tertiary level optimizer. The real-time secondary controller is responsible for the reliability of the system through high-speed communication, control, and automation. The tertiary level optimizer is responsible for the customer-desired outcome by producing a day-ahead operating or optimal dispatch plan. This plan is tailored based on the facility's desired outcome or mode of operation such as economics, reducing emissions, maximizing time of life, maximizing renewables, or peak shaving. These two systems work together to provide the facility with an optimal solution to manage the system in either grid connected and islanded mode, maintaining reliability, resiliency, and customer outcome.

The microgrid real-time controller is responsible for maintaining the reliability of the system, while following the optimal dispatch plan generated by the optimizer. This is achieved through communication with various intelligent electrical devices (IEDs) and the on-site DERs. DERs can be considered as any type of on-site energy delivery asset, such as gas generation, battery energy storage system (BESS), or renewables like photovoltaics (solar) and wind. The microgrid controller dispatches setpoints and command structures to the DER assets and loads to manage the amount of grid power flow imported or exported based on the optimized dispatch schedule. The optimal dispatch schedule should incorporate grid electricity prices, renewable generation forecasts, facility load forecasts, individual asset information and limits, as well as the chosen method of optimization. In addition, when called upon, the microgrid controller can be configured and integrated into the energy markets to provide grid-related services in the form of demand response, voltage support, and frequency regulation, driving additional revenue for the facility.



Figrue 1: High-level illustration of the inputs required to produce an optimization dispatch schedule

Day-ahead generation and load forecasting help to determine the most effective time of day to utilize each generation asset. This plan can also incorporate dynamic load management to reduce or shed certain loads based on energy costs or to maintain the reliability of the system operations. However, when there are short-term events like wind gust, cloud cover, or large load fluctuations that affect the reliability of the system, these events are managed by the real-time controller. The real-time controller is in continuous communication with the optimizer, enabling the next dispatch schedule to make any needed adjustments.

II. ARCHITECTURE OF A RESILIENT MICROGRID

The figure below shows the simplified single-line diagram of a basic microgrid that utilizes photovoltaic, battery energy storage, and fossil generation.

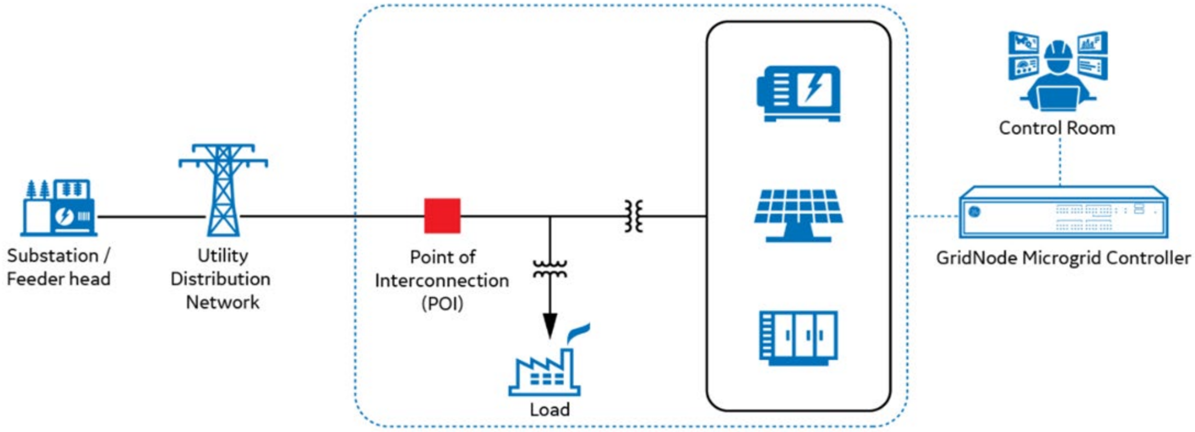


Figure 2: High-level single line diagram of a microgrid

During the design phase of the microgrid project, proper consideration should be given to the type of DERs being utilized, DER sizing, production operations and type, environmental regulations, and energy incentives for the given location.

These considerations should be coupled with the facility's objectives such as reliability, resiliency, energy savings, and sustainability, as well as the facility's current load profile and energy rates. Together these inputs help provide a design that not only meets the facility's goals but also provides a solution that is economical and avoids oversizing.

Once the determination has been made that a microgrid aligns with needs of the facility, a secondary part of the design process consists of designing the most effective communications and controls architecture for the solution. This architecture must be designed to enable the solution to provide the functionality and benefits required by the customer. Some key considerations in this design include redundancy, speed, utilization of industry standard protocols, and cybersecurity. The architecture will frequently consist of a microgrid real-time controller and optimization server that communicates to the various DER controllers, protective relays, meters, building management system (BMS), and plant SCADA. In addition, the controller may be connected to external sources for weather forecasts, real-time energy pricing, or energy market interfaces for demand response or frequency services participation. Below is an example.

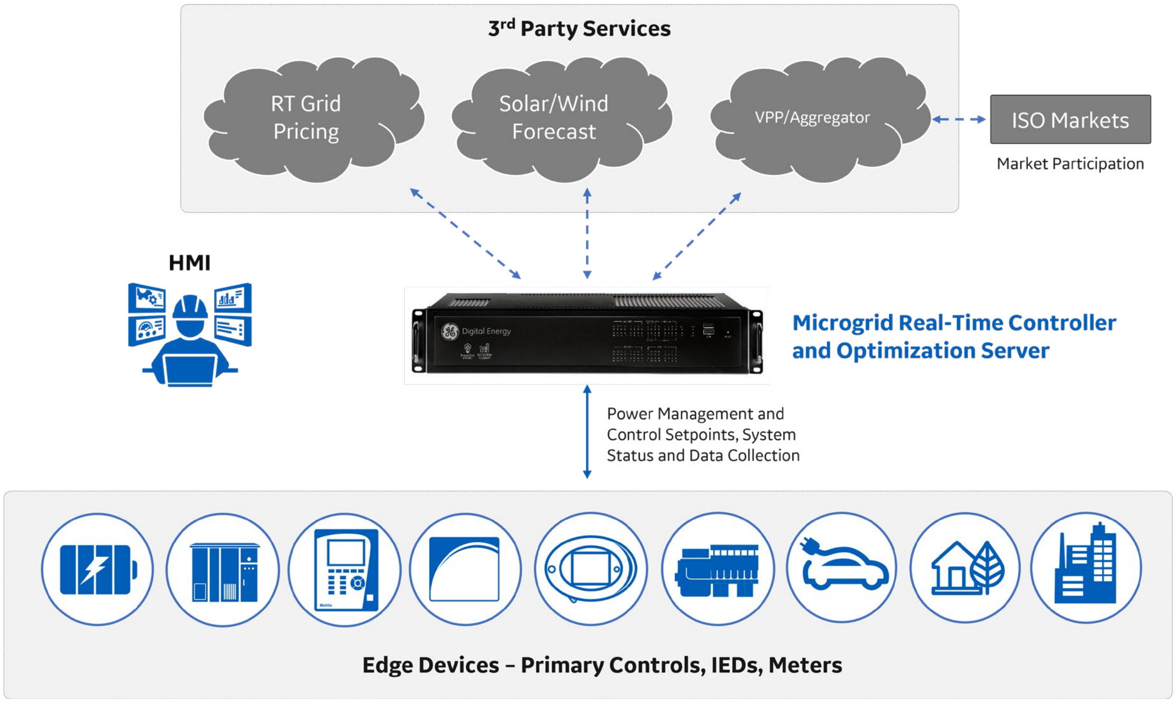


Figure 3: High-level architecture of a microgrid

III. CONTROL AND OPTIMIZATION

A microgrid is required to operate in grid-connected and islanded mode, as well as manage the transition between the two operating modes. There are certain functions that are utilized during each microgrid mode of operation to maximize the reliability and resiliency of the system (see Figure 5).

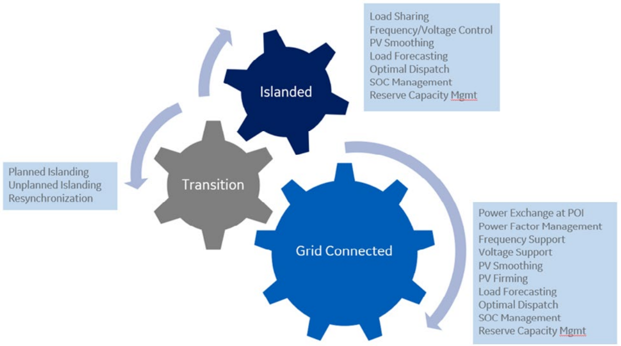


Figure 4: High-level overview of various microgrid functions

When a reliability issue is present on the grid, the microgrid is expected to transition to islanded mode of operation, while maintaining the reliability and stability of the microgrid network. To maintain this stability, proper consideration must be given to the control functionality and design to account for functions such as fast-load shedding, unplanned islanding, voltage and frequency control, load sharing, and reserve capacity management. In addition, the microgrid controller is responsible for assigning the grid forming DER for maintaining the voltage and frequency of the islanded system. Other DERs operate in grid following mode contributing to the voltage and frequency control through secondary control loops to maintain the voltage and frequency at nominal values, after any deviation.

In addition, they can be dispatched through active and reactive power setpoints by the controller based on the optimal dispatch schedule. Any transition may result in a deviation from the planned optimization schedule if the optimizer planned on using power from the grid. Therefore, the event of transitioning between modes of operation should initiate the creation of a new plan to ensure the customer's desired outcome continues to drive the mode of dispatch while maintaining the survivability of the microgrid.

Based on the desired mode of operation, the optimization engine determines the setpoints and utilization for all DERs, as well as potential load management actions. Those setpoints are developed on a day-head basis with 15-minute granularity, equaling 96 dispatch setpoints per asset, which make up the optimal dispatch schedule. This schedule is continuously re-run based on the customer's chosen interval (typically 15 min.) or driven by a user-defined or survivability event on the system such as a transition or asset failure.

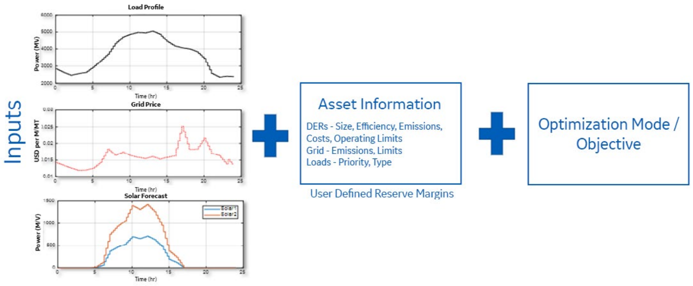


Figure 5: Optimization configuration inputs

A key factor in the effectiveness of the optimization engine reaching the site's desired goals is the ability to accurately model the site's characteristics and forecast load and renewable generation profiles. Therefore, the system must be capable of handling dynamic data and continuously updating the inputs based on the latest information regarding load forecasts, solar or wind generation forecasts, grid pricing and peak demand charges, and the system status.

IV. SIMULATION RESULTS FOR A SAMPLE MICROGRID

The simulation involves an electric grid-connected industrial-based microgrid that consists of the following assets:

- Two BESSs rated at 1MW/2MWhr each
- Two photovoltaic plants rated at 1.5MW and 0.75MW
- Four gas generators rated at 2MWs each
- Three non-critical loads that can be shed

In this simulation the external inputs, the facility load profile, time-of-day grid price, and solar forecasts were not changed for each of the three test scenarios to highlight how a customer's desired optimization methodology and mode affect the 24-hour dispatch plan, as well as highlight the optimizer's ability to dispatch the system for various outcomes and use cases.

SCENARIO 1: ECONOMIC DISPATCH

Economic dispatch is an optimal dispatch mode with the goal of minimizing the cost of electricity for the customer. The optimizer must at a minimum consider the following information for this scenario:

- Grid prices: based on a time-of-day schedule
- Gas generator operating costs, fuel costs, maintenance costs, efficiency curves, emissions costs, as well as loading and ramping times
- BESS, SOC bands, efficiency, charge, and discharge rates
- PV: effective generation costs
- Loads: reduction costs

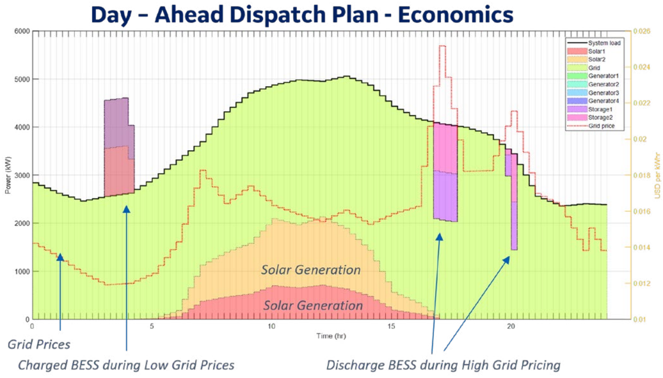


Figure 6: Economic dispatch plan

The 24-hour economic dispatch plan generated shows how the optimizer plans to leverage the BESS to charge during low grid price times and discharge during high grid price times. In addition, all four generators remain off due to the cost of generation.

SCENARIO 2: PEAK REDUCTION

In a peak reduction scenario, the optimizer will look to dispatch the units in the same economic dispatch mode while limiting the grid import based on the user configured data. The optimizer utilizes all the same inputs as in Scenario 1 with the addition of the following:

- Grid limit equals 1MW from 2:45 pm – 10:30 pm

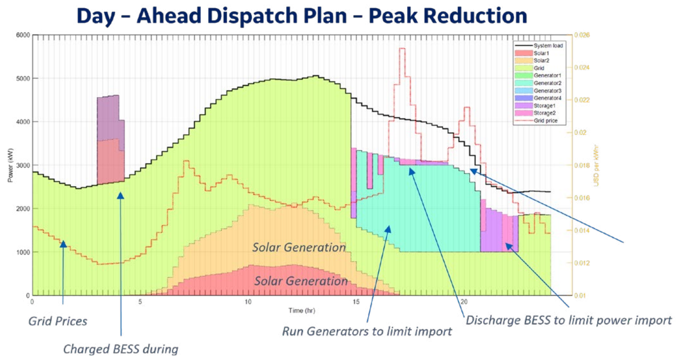


Figure 7: Economic dispatch with peak reduction

The 24-hour economic dispatch plan generated shows how the optimizer plans to leverage the BESS to charge during low grid price times and discharge during the timeframe where the grid limit is applied. In addition, the optimizer sheds non-critical loads as well as starts a gas generator to support the facility's critical load demand that is greater than the 1MW grid import, BESS discharge, or renewable generation available.

Scenario 3: Planned Islanding

In a planned islanding scenario, the optimizer will look to dispatch the units in the same economic dispatch mode while removing the grid import based on the user configured data. The optimizer utilizes all the same inputs as in Scenario 1 with the addition of the following:

- Planned islanding between 2:45 pm – 10:30 pm

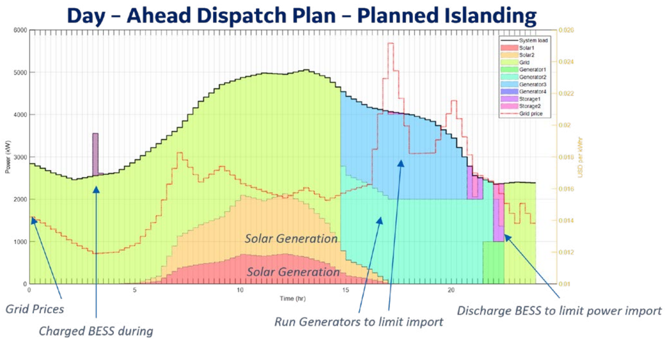


Figure 8: Economic dispatch with planned islanding

The 24-hour economic dispatch plan generated shows how the optimizer schedules the islanding of the system and disconnection from the grid power in the dispatch plan. The physical islanding of this system would be the responsibility of the real-time control functions as part of the system operations. Furthermore, this scenario required the start-up and operations of multiple generators to maintain the facility during the islanded period.

Across all three scenarios, it is important that the optimization server generates key performance indicators, as well as provides the outcome summary of the optimization cases to be previewed and compared prior to implementing. This capability provides proper visibility to the operations team prior to enabling a case or implementing an optimization change.

VI. SUMMARY

This paper highlights how a properly designed microgrid with optimization capabilities may enable a facility to meet their sustainability initiatives and integrate renewable assets on-site while providing the added benefits of reliability, resiliency, and energy savings. From the results, it is evident that the optimizer and controller can be tuned to enable multiple outcomes for the facility and provides the flexibility to support future changes the facility may encounter.

V. REFERENCES

[1] US Department of Energy Exchange Group, 2010

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