ATS
Leading of Integration

@MicroGrid™

Micro Grid Controller System

A Strategic Partner of 株式会社 東光高岳 TAKAOKA TOKO CO., LTD.

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A. Product Overview

@MicroGrid is a complete solution for a Microgrid designed and provided by ATS. @MicroGrid system is fully compatible with industrial standards.

The Microgrid concept has been built as a power distribution network comprising of multiple electric loads and distributed energy resources with following characteristics:

- Uses renewable energy resources (photovoltaic, wind turbines...), in combination with other energy resources such as diesel generator, small hydro, biomass, biogas, etc. as Distributed Generations (DG) to meet demand of local load and ease pressure on the transmission system capacity, improve the availability of power supply, reduce the cost of power purchasing, and improve economic efficiency while also being environment-friendly.
- Able to operate independently or connected with Utility grid.
- Able to operate all distributed energy resources (DER), including load and energy storage components, in a controlled and coordinated fashion, either while connected to the Utility grid or operating independently.
- Able to interact with the Utility grid in real-time, and thereby optimize system performance and operational savings.

At the heart of the system is a Microgrid Control System that connects to and dispatches distributed generators (DGs) to keep a stable balance status of power supply and demand in the manner of Secure, Reliable and Economical.

Microgrid Control System is an integrated system comprised of the followings:

- Centralized Microgrid control system with visualization and energy management system
- Coordinated protection system
- Metering, power quality monitoring and measurement system
- Communication Infrastructure
- Engineering tools for configuration and system maintenance

The Microgrid control system incorporates the latest technology in the field of Microgrid to provide users with innovative solutions customized to their requirements.

The system provides all necessary monitoring, control, and automaton functions in a flexible system structure for ease of operation. The Microgrid control software system has been modularly designed; its individual modules are specifically designed and tailor-made for each project.

The Microgrid control system complies with all current de jure and de facto industrial standards for open system. Such compliance allows for communication between the control system and other devices and systems from other vendors.

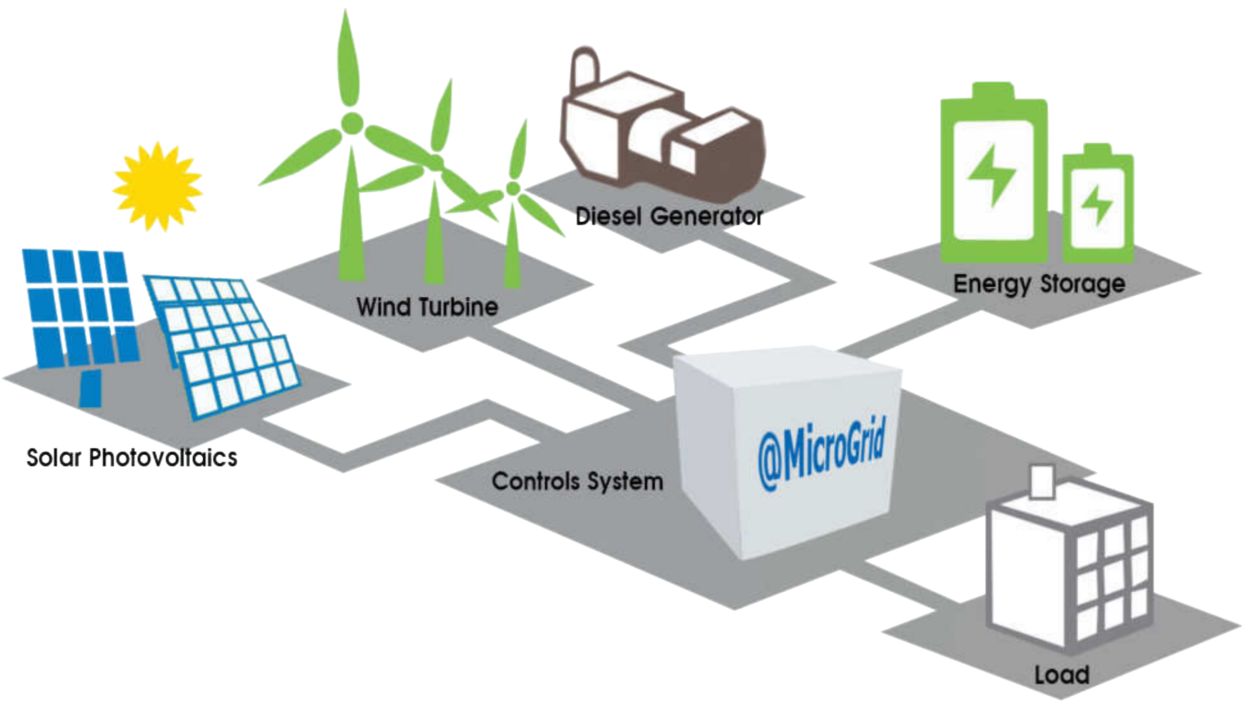

Figure 1. Microgrid Overview

1. SOFTWARE SYSTEM
1.1. Software Architect

The Microgrid control system includes data acquisition, processing, storage, visualization and energy management functions. The control system will communicate with and collect all data of the Microgrid system from generators, protection devices, measurement devices, etc.

The primary data acquisition tasks shall be performed via the Data Acquisition module with appropriate protocol (IEC 61850, Modbus RTU/TCP, DNP3, FTP, Telnet, SNMP, etc.) and interfaces via Ethernet LAN or dedicated serial communication system. Here, the data will be pre-processed, checked for reliability, signal quality and limits to ensure the accuracy of the data and removal of unreliable data.

Acquired operation real-time data will be transferred to Real-time Database. Here, operation real-time data will be processed and converted to specific format for all function applications of the system. The data stored in Historian Database includes processed real-time data, alarm, event signals, and communication data from other databases. It also stores the results of energy management functions such as load forecast, PV power generation forecast, etc.

Data from databases will be used for user-interface monitoring display, Microgrid control, reporting evaluating, analyzing, load forecast, PV power generation forecast, as well as operation planning (short-term and long-term). Simultaneously, the system data is ready to communicate with SCADA/EMS system or remote monitoring system at head office via secure and encryption communication channels.

The system is based on redundant client/server architecture and is designed to meet functional, performance, availability, reliability and expandability requirements. With Microgrid control system, users have the complete tools and information to monitor the system and to make decisions based on the information provided.

Detailed software architect of the Microgrid control system is shown in **Figure 2**.

Main software modules of Microgrid control system include:

- Data Acquisition (DA)
- Real-time Database (RTDB) Processing
- Historical Information System (HIS) and applications
- Microgrid controller
- Human – Machine Interface (HMI)
- Fault record collection and after fault analysis (FR)
- Energy management system (EMS):
  - Load forecast
  - Solar generation forecast
  - Unit commitment (Long-term plan)
  - Economic dispatch (Short-term plan)
- System Engineering

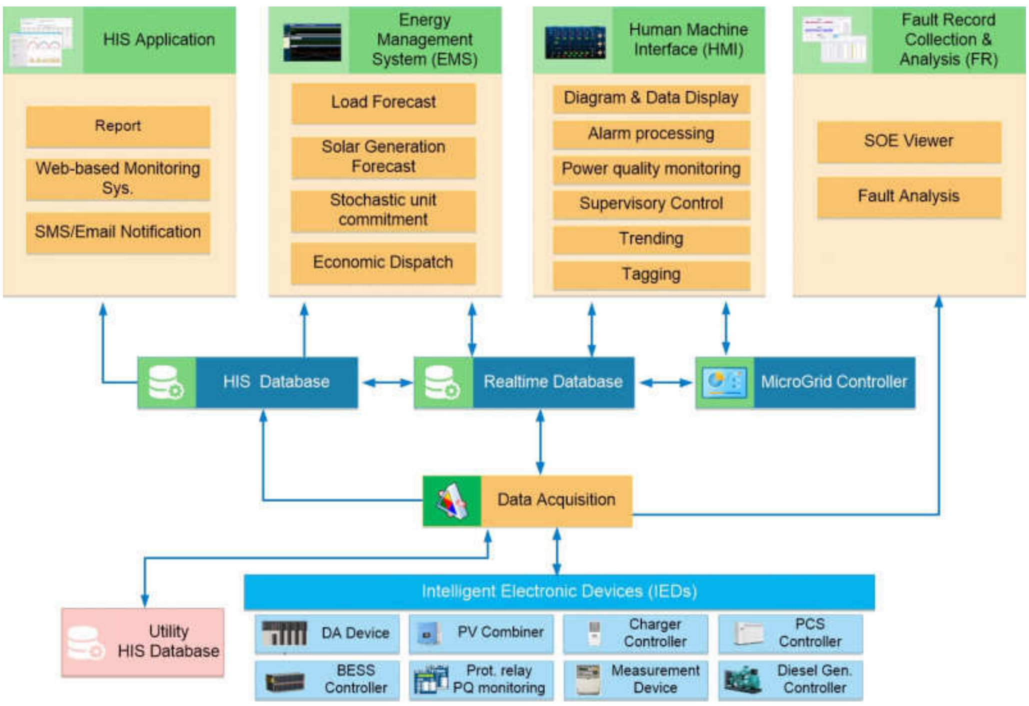

Figure 2. Microgrid Control Software Architecture

B. Technical Highlights

1.2. Software Functions

1.2.1. Data Acquisition (DA)

The Data Acquisition module will perform initialization and management of real-time information channels and communicate these data with monitoring and control devices and other systems. This is an integral part of any data acquisition, data processing and control system.

DA is compatible with various types of protocols such as DNP3, IEC61850, Modbus, IEC101, IEC103, IEC104, OPC UA, etc.

1.2.2. Real-time Database (RTDB) Processing

The Real-time Database module is a central component of the system. RTDB is a data bridge between the Data Acquisition module and other application modules (Energy Management System, Microgrid controller, HMI, HIS, etc.), which manages and processes all real-time data of the system.

The real-time data collected from IEDs, communication processors, meters, etc. will be passed directly with appropriate protocols to real-time database management system or from servers of real-time database management system.

1.2.3. Microgrid Controller

ATS Microgrid Controller (AMC) provides control functions to improve security and reliability of system and to economically dispatch generation resources. The AMC coordinates operating resources such as diesel generator, Solar, Wind, BESS, controllable load and others.

Main control functions of AMC include:

- Active/reactive power control - Voltage/frequency control: AMC also allows power sharing between different sources by adding or dropping generation resources during maintenance process.
- PV Solar, Wind and Batteries control: AMC provides Automation/SCADA functions for remote monitoring and control of the entire system to make variable resources dispatchable by using BESS and controllable loads.
- Diesel Generator control: AMC provides Automation/SCADA functions to send set-point (kW, kVAr, U or PF), start/stop, synchronization commands, and operation modes to the diesel generation controller.
- BESS dispatch to optimize and smooth out PV output: AMC provide control functions of BESS to achieve ramp rate control, frequency droop response, and power factor correction for smoothing PV output. AMC can control both active and reactive power output from BESS to maintain system frequency and voltage.
- Peak shaving: AMC provides economic dispatch functions that support peak shaving aimed to reduce overall energy costs and to maintain system frequency and voltage.
- Reduction of GHG emission: AMC calculate greenhouse gas emission of a generation mix and take this into account in economic dispatch process, calculating a value for GHG reduction based on avoidance of diesel and on grid generation.
- Black start: Restoration of the MG and MV grid following a blackout

FREQ. DROOP PARAMETERS

PARAMETERS	Active Value	Input Value	
Frequency Droop 1 (%)	0	0	Set
Frequency Droop 2 (%)	5	0	Set
Active Power High Limit (kW)	144000	0	Set
Active Power Low Limit (kW)	0	0	Set
High Limit (Hz)	52	0	Set
Low Limit (Hz)	47	0	Set
Frequency Deadband (Hz)	1	0	Set

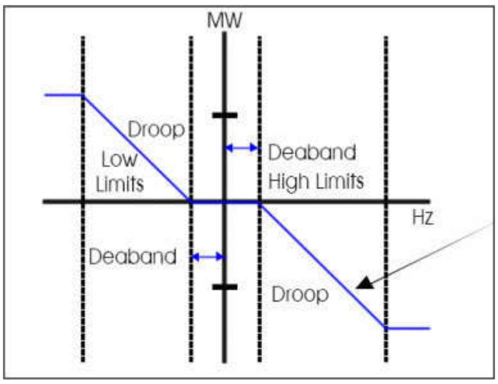

Figure 3. Frequency Droop Control

CONTROL MODE

MODE	Active Mode	Input Mode	
Active Power Control	No Ramp Rate	No Ramp Rate	Set
Reactive Power Control	Power Factor	OFF	Set

RAMP RATE CONTROL

RAMP RATE	Active Value	Input Value	
Active Power (kW)	5000	0	Set
Reactive Power (kVAr)	0	0	Set
Ramp Rate Interval (s)	5	0	Set

SETPOINT

SETPOINT	Active Value	Input Value	
Active Power (kW)	145000	0	Set
Reactive Power (kVAr)	10000	0	Set
Power Factor	1	0	Set
Voltage (kV)	114.5	0	Set

Figure 4. Active and Reactive Power Control

1.2.4. Human – Machine Interface (HMI)

User Interface is defined as the link between users and the Microgrid control system that monitors and controls programs and applications in general. The User Interface provides users with the ability to monitor and control the power system, and to access any information item contained in the database in an intuitive and user-friendly manner.

The following capabilities shall be assigned to each console via displays specifically designed for this purpose:

- Data entry
- Supervisory control
- Application programs selection and execution

The following functions can be performed via monitor/ keyboard:

- Activate and deactivate any device under control
- Observe any parameter that is monitored by the system
- Set tags
- Silence, acknowledge or delete any alarm
- Inhibit or enable the alarm of any monitored device
- Issue audible signals in case of alarms or important events
- Take out of service and restore back in service any monitored device, controlled device or Microgrid system component
- Display the status of all the peripheral devices, controller, IEDs and communication lines.
- Display the most recent alarms by pressing one key. The Operator could delete individual alarms. When the alarm list is full, the system will delete automatically the oldest alarms to let pass the most recent ones
- Display all the system points that are tagged. Each listed point shall include all the warning tags for this point. Each warning tag shall be defined and shall include a message/text describing it.
- Generate a hard copy of any system display and print any report and/or list of events

1.2.5. Historical Information System (HIS)

The Smart Historical Information System (SmartHIS) is the historical repository of all information related to the Microgrid system which is time-series generated under normal operating conditions and/or during disturbances. The SmartHIS implementation will be predicated on the client-server architecture to collect, process, store, manage and retrieve data.

With SmartHIS the operators can store and maintain real-time data from any system point. The data will be stored in its exact resolution for a long period of time.

HIS applications include:

a) Report

Reports can be built using Data Link tool (an add-in for Microsoft Excel). This add-in can allow data to be retrieved directly from within the spreadsheet program. User can create complex reports and graphs using current or historical data from the HIS.

b) Web-based monitoring subsystem

The Microgrid control system supports to display data at utility office for remote monitoring. It can allow for display in web service or mobile application with integration open-source web server (Figure 16).

Figure 5. Displaying Microgrid Project on Map

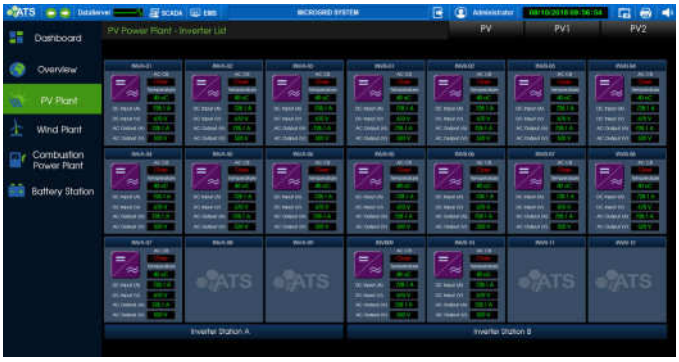

Figure 7. Power Conversion System Monitoring

Figure 6. Microgrid Overview Display

Figure 8. Specific Inverter Unit Monitoring

B. Technical Highlights

Figure 9. Diesel Generator Overview

Figure 10. Specific Diesel Generator Monitoring

Figure 11. Battery Management System

Figure 12. Weather Data Display

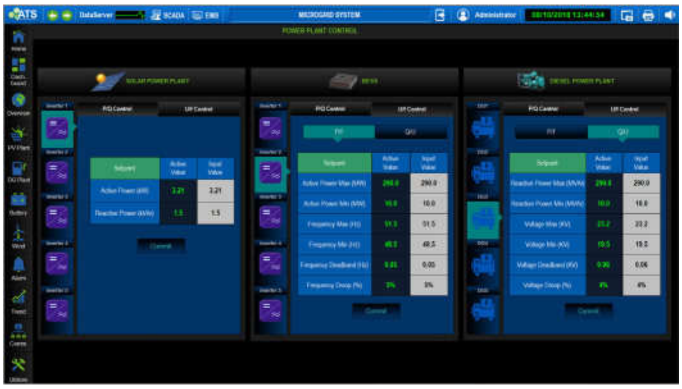

Figure 13. User Control Interface of Distributed Generation

Figure 14. Substation Operation Trending

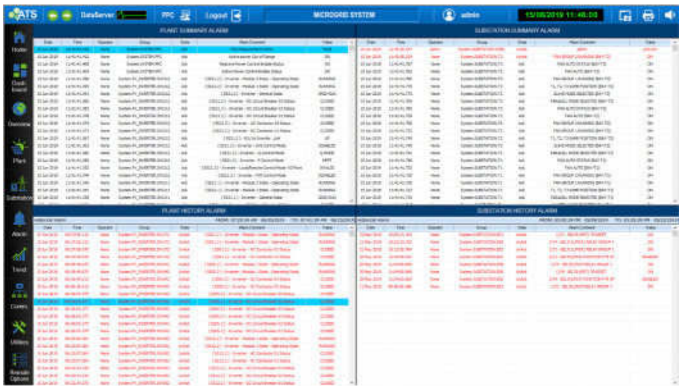

Figure 15. Alarm Presentation Window

Figure 16. Real-time and Historical Data Presented on Web

1.2.6. Energy Management System (EMS)

Microgrid-EMS system maximizes the use of renewable energy by forecasting its fluctuations and optimizing the multiple resources, while ensuring the power stability.

EMS in power systems looks at processes ranging from minute to day/week/month:

- Long-term schedule: is performed from one day to one week/month with 30-minute time resolution.
- Short-term schedule: is performed from few minutes to few hours with one-minute time resolution

The main control functions of EMS include (Figure 17):

- Load Forecast
- RE Forecast
- Unit Commitment
- Economic Dispatch

(1) Load forecast

Electricity demand forecasting is a central and integral process for planning periodical operations and facility expansion in the electricity sector.

@MicroGrid provide AI-powered SaaS Solutions. This solution makes use of Machine Learning/AI and Deep Learning Model to provide Electricity demand forecasting for a multitude of applications.

The system offer hour-ahead, day-ahead, week-ahead for Electricity demand in multiple level of locations. Application can run on cloud or standalone. Power forecasts for several levels can be produced:

- Single location
- Areas
- Countries

Cloud-based platform is utilized for this system, with the following advantages:

- Scale unlimited
- Work cross platforms

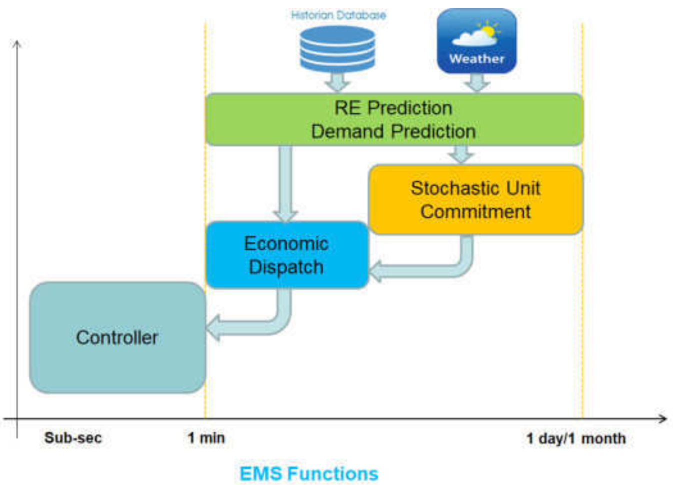

Figure 17. Microgrid Energy Management Functions

- Easily to export to API to integrate with other system
- Can run multiple predictions simultaneously on demands
- Easy to custom model from a certain base model
- Easily to integrate many models to one platform

Features of Load Forecast:

- Hour-ahead/ Day-ahead/ Week-ahead forecasting
- Custom modeling and development
- Highest Accuracy
- Uncertainty bands
- Support multiple formats such as xml, csv, sql and multiple data sources including but not limited to mysql, cloud sql, and bigquery.

Highlight Functions of Load Forecast:

- Create AI model with parameters
- Custom model function
- Report tool:
  - Weather toolkit
  - Model comparison tool
  - Predict tool
  - Job monitor
  - Add managed model (with NEP protocol)

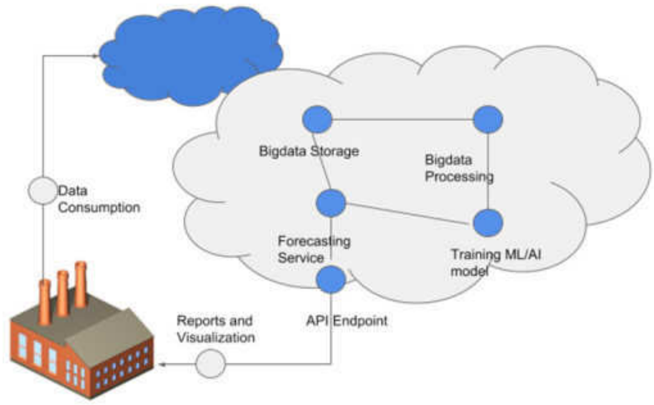

Figure 18. Overall System Architecture of Load Forecast Function

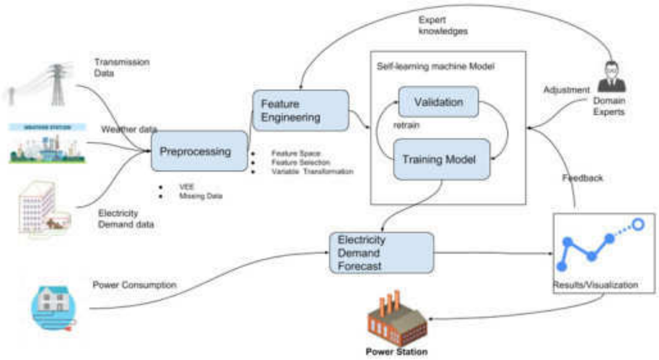

Figure 19. Load Forecasting Engine

B. Technical Highlights

(2) Solar Generation Forecast

Accurate solar generation forecast is one of the key tools to mitigate challenges created by intermittent nature of energy generation from Renewable Energy systems.

@MicroGrid offer hour-ahead, day-ahead, week-ahead for individual PV power plants or distributed solar power systems.

The system deliver power forecasts for several levels:

- Single solar parks
- Areas
- Countries

AI-powered SaaS Solutions is provided with @MicroGrid, with features including:

- Hour-ahead/ Day-ahead/ Week-ahead forecasting
- Custom modeling and development
- High Accuracy
- Uncertainty bands
- Support multiple formats such as as xml, csv, sql and multiple data sources including but not limited to mysql, cloud sql, and bigquery.
- SCADA Interfaces

The System includes two key components:

- Offline Training:
  * Use multiple ML/AI models for PV power dynamics modeling and Pattern Discovery method.
  * Methods used include artificial neural networks, regression models, autoregressive models, support vector machines, and Markov chains, as well as composite methods, such as using genetic algorithms to optimize a neural network.
- Online Forecasting:
  * Use temperature, solar irradiance and history measured PV power with ML/AI model to forecast PV power at time (t + k)

(3) Stochastic Unit Commitment

The Stochastic Unit Commitment is performed from one-day to one-month ahead providing the start-up and shut-down schedule for each generation and allocates the total power demand to the available generation units in such a way that the overall power system cost is minimized. Due to the stochastic nature of the renewable resources such as solar and wind, the mismatch in forecast and realized power may result in extra operating costs for committing costly reserve units or penalty cost for curtailing demand. To address these problems, the stochastic model of renewable energy is incorporated into the Unit Commitment.

The main model features can be summarized as follows:

- Monthly/Weekly/Daily schedule
- Uncertainty in renewable resource data
- Battery operation cost model
- Minimum and maximum power for each unit
- Power plant ramping limits
- Minimum up/down times
- Load Shedding
- Start-up and no-load costs
- Constraints on the targets for CO2 emissions

The goal of the Stochastic Unit Commitment problem to minimize the expected operation cost of a Microgrid over a time horizon.

Results of the calculation include:

- Committed status of each diesel generation in each period
- Power output of each diesel generation, in each period, scenario
- Power charge/discharge of each battery, in each period, scenario
- SOC status of each battery in each period, scenario
- Power purchases from main grid in each period, scenario
- Power shed in each period, scenario
- Total cost of the Microgrid in each period, scenario
- Total cost of the Microgrid over time horizon
- Total expected cost of the Microgrid over time horizon

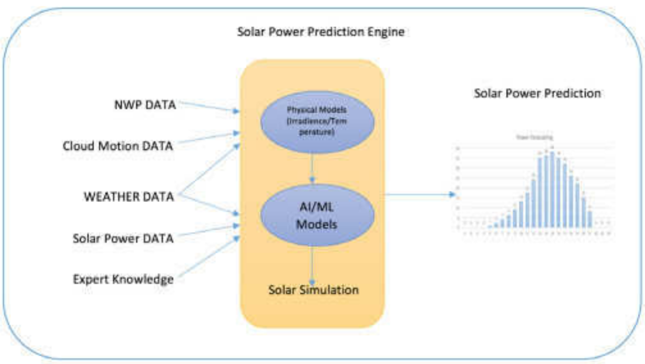

Figure 20. Solar Generation Forecast Engine

Figure 21. Stochastic Unit Commitment Results

(4) Economic Dispatch

Economic Dispatch uses load and renewable generation data from forecasting module and the committed status of diesel generation from Unit Commitment module to economically allocate demand to on-line units while considering all unit and system constraints, few minutes to few hours in advance.

Every minute, Economic Dispatch uses inputs including real-time values of the system (power out of diesel generations, power charge/discharge of batteries, SOC status of batteries) and demand & supply imbalance to determine DG output and storage battery charging/discharging as well as to implement load controls.

The main model features include:

- 1-minute time resolution
- Battery operation cost model
- Minimum and maximum power for each unit
- Power plant ramping limits
- Load Shedding
- Constraints on targets for CO_2 emissions

The goal of Economic Dispatch function is to minimize the operation cost of a Microgrid over a time horizon.

Results of the calculation include:

- Power output of each diesel generation, in each period
- Power charge/discharge of each battery, in each period
- SOC status of each battery in each period
- Power purchases from main grid in each period
- Power shed in each period
- Total cost of the Microgrid in each period
- Total cost of the Microgrid over time horizon
- Total expected cost of the Microgrid over time horizon

2. COMMUNICATION AND CYBER SECURITY

2.1. Communication

The communication system allows for establishment of connection of Microgrid control system with distributed resources as Solar, Wind, BESS, diesel generators, controllable loads and others via private and public networks.

2.2. Cyber Security

Interactions between the Microgrid control system, corporate networks and the outside world are usually handled at the system level, which means that ensuring a high level of security at the boundary is vital to the security of the system itself. All communication from the outside world to the Microgrid control system must, for instance, be protected by using a firewall and/or VPN-enabled communication.

Verified antivirus software is supported to protect system computers from attacks and viruses. Additionally, security mechanisms such as advanced account management and detailed security audit trails can be built into local area network level supporting various security features. This allows clients to easily address NERC CIP requirements and maintain compliance according to the standards and beyond.

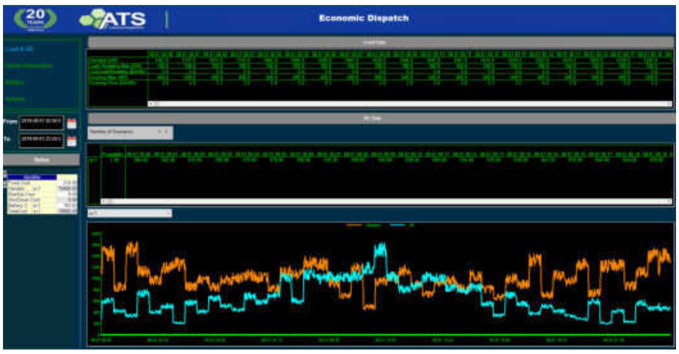

Figure 22. Economic Dispatch Dashboard

Figure 24. Battey Results

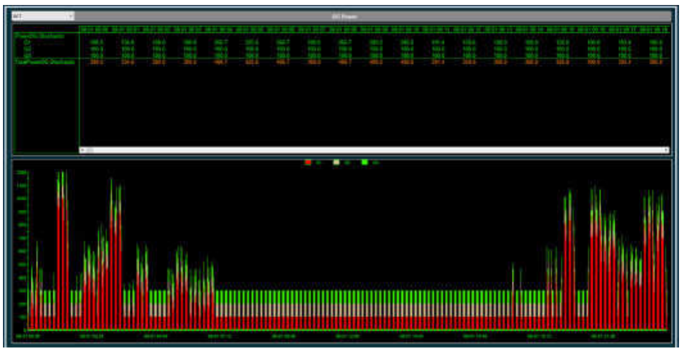

Figure 23. Diesel Generation Results

Figure 25. Economic Dispatch Results

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