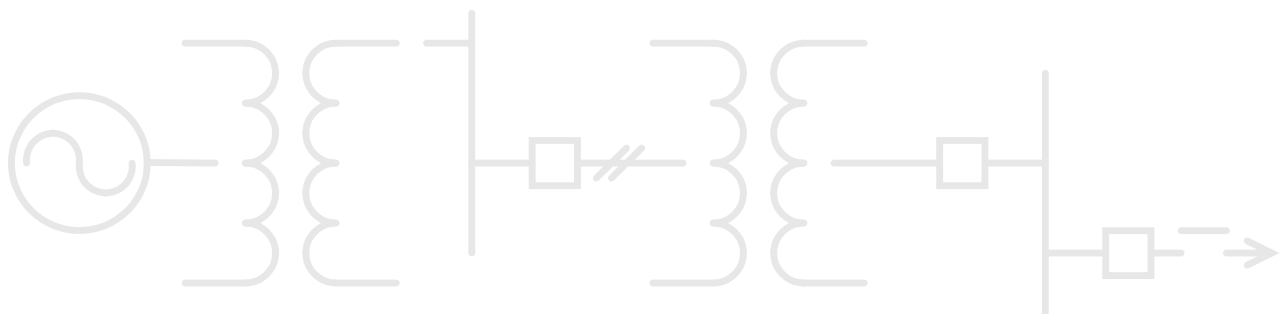# U90Plus Microgrid Generation Optimization
- Instruction Manual

AJV Document Identification Block	
AJV Document ID	UR Plus-26-300
AJV Document Version and Revision	1601-0039-A1-AJV
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Notes (optional)	

GE imagination at work

GE
Digital Energy

U90^{Plus}

Microgrid Generation Optimization

Instruction manual

U90^{Plus} firmware revision: 1.1
GE publication code: 1601-0039-A1 (GEK-113242)

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ISO 9001
GE MULTILIN

GE Multilin's Quality
Management System is
registered to ISO 9001:2008
QMI # 005094
UL # e83849

GENERAL SAFETY PRECAUTIONS - U90^{Plus}

⚠ CAUTION

• The use of Omega-level safety shoes, safety gloves, safety glasses, and protective clothing are recommended during equipment installation, maintenance, and service.

• Failure to observe and follow the instructions provided in the instruction manual can cause damage to the equipment and can lead to property damage, personal injury, and/or death.

• Before attempting to use the equipment, review all danger and caution indicators.

• If the equipment is used in a manner not specified by the manufacturer or functions abnormally, proceed with caution. Otherwise, the protection provided by the equipment can be impaired and can result in damage and/or injury.

• Hazardous voltages can cause shock, burns, or death.

• Installation/service personnel must be familiar with general device test practices and electrical awareness. Safety precautions must be followed.

• Before performing visual inspections, tests, or periodic maintenance on this device or associated circuits, isolate or disconnect all live circuits and sources of electric power.

• Failure to power equipment off prior to removing the power connections can lead to exposure to dangerous voltages causing injury or death.

• All recommended equipment that can be grounded should be and must have a reliable and uncompromised grounding path for safety purposes, protection against electromagnetic interference, and proper device operation.

• Equipment grounds should be bonded together and connected to the facility's main ground system for primary power.

• Keep all ground leads as short as possible.

• The equipment ground terminal must be grounded at all times during device operation and service.

• In addition to the safety precautions mentioned, all electrical connections made must respect the applicable local jurisdiction electrical code.

• LED transmitters are classified as IEC 60825-1 Accessible Emission Limit (AEL) Class 1M. Class 1M devices are considered safe to the unaided eye. Do not view directly with optical instruments.

FCC/Industry Canada

This device complies with Part 15 of the FCC Rules and Industry Canada rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

L'appareil conforme aux CNR d'Industrie Canada applicable aux appareils radio exempts de licence. L'exploitation est autorisé aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radiolectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

U90^{Plus} Microgrid Generation Optimization

Table of contents

U90^{Plus} Microgrid Generation Optimization

Chapter 1: Getting started

This section outlines the symbols used in the document, what is in the box, and how to get help.

Safety words and definitions

Before attempting to install or use the device, review all safety indicators in this document to help prevent injury, equipment damage, or downtime.

The following safety and equipment symbols are used in this document.

⚠ DANGER — **Indicates a hazardous situation which, if not avoided, will result in death or serious injury.**

⚠ WARNING — **Indicates a hazardous situation which, if not avoided, could result in death or serious injury.**

⚠ CAUTION — **Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.**

NOTICE — Indicates practices not related to personal injury.

Unpacking and inspection checklist

Use this procedure to unpack and inspect the U90^{Plus} Microgrid Generation Optimization^{TM} unit.

1. Inspect the packaging for physical damage.
2. Open it and inspect the U90^{Plus} for physical damage.
3. Check that the following items have been delivered:
   – U90^{Plus} Microgrid Generation Optimization unit
   – GE EnerVista^{TM} CD (software and documentation)

- Instruction Manual (if ordered)
- Test Report
- EC Declaration of Conformity

4. View the rear nameplate of the product and verify that the correct model has been delivered.

5. For product information, instruction manual updates, and software updates, visit the GE Multilin website at http://gedigitalenergy.com/multilin.

6. If any of the contents listed are missing or there is physical damage to the product, contact GE Digital Energy immediately using the contact information in the For Further Assistance section.

For further assistance

For product support, contact the information and call center as follows:

GE Digital Energy
650 Markland Street
Markham, Ontario
Canada L6C 0M1
Worldwide telephone: +1 905 927 7070
Europe/Middle East/Africa telephone: +34 94 4854 88 54
North America toll-free: 1 800 547 8629
Fax: +1 905 927 5098
E-mail: multilin.tech@ge.com
Website: http://www.gedigitalenergy.com/multilin/

Comments about new features or modifications for specific requirements are welcome.

U90^{Plus} Microgrid Generation Optimization

Chapter 2: Product description

This chapter provides an overview and specifications of the U90^{Plus} Microgrid Generation Optimization unit.

Device overview

The U90^{Plus} is a controller that optimizes the dispatch of electrical generation, thermal generation, and energy storage to minimize operating cost. It operates in a supervisory mode, issuing on/off and dispatch commands every few minutes. The U90^{Plus} works in a grid-connected or standalone microgrid.

The U90^{Plus} package is hardware and software. The unit is controlled while connected directly to a computer running the EnerVista U90^{Plus} Setup software, remotely using the software, and some functions are accessible from the front panels.

Up to 32 electrical and heating resources are supported, including the following:

- Renewable, such as wind turbines, hydro, solar panels

- Dispatchable generators, such as diesel generators

- Combined heat and power (CHP) generation, or cogeneration

- Heating elements, such as boilers

- Storage, specifically hydrogen-based and batteries

- Utility grid connections

The following figure shows the microgrid approach. When the resources include Modbus server functionality, the UR controllers are unnecessary. For example, when a wind turbine is added to the microgrid and it has Modbus server capability, a UR controller is not needed for it.

Figure 1: Microgrid optimization approach
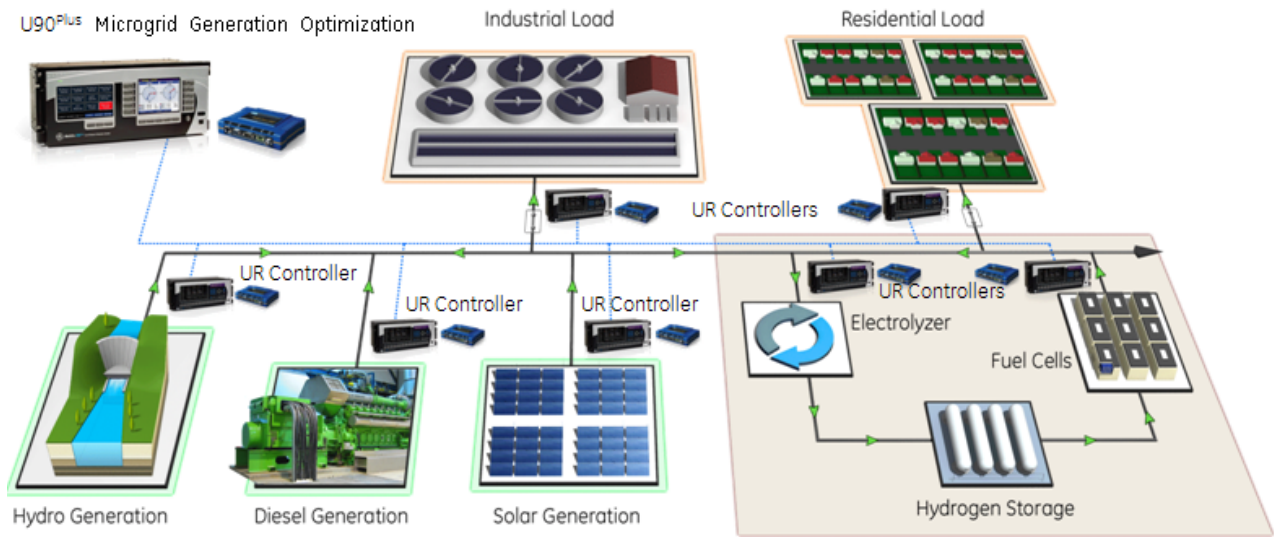
The storage can be short or long-term. Short-term storage functions of the U90^{Plus} help in step-load changes resulting from load-generation variations or in transferring to an islanded microgrid. Long-term storage from tens of minutes to several hours helps during peak demand periods and in shifting power generation to environmentally friendly renewable sources.

Hardware architecture

The U90^{Plus} is microprocessor-based hardware. The chassis has one power supply module and one CPU module. There are no optional modules.

Rear terminal and port layout

The following figure shows the back of the unit.

Figure 2: Rear terminal view
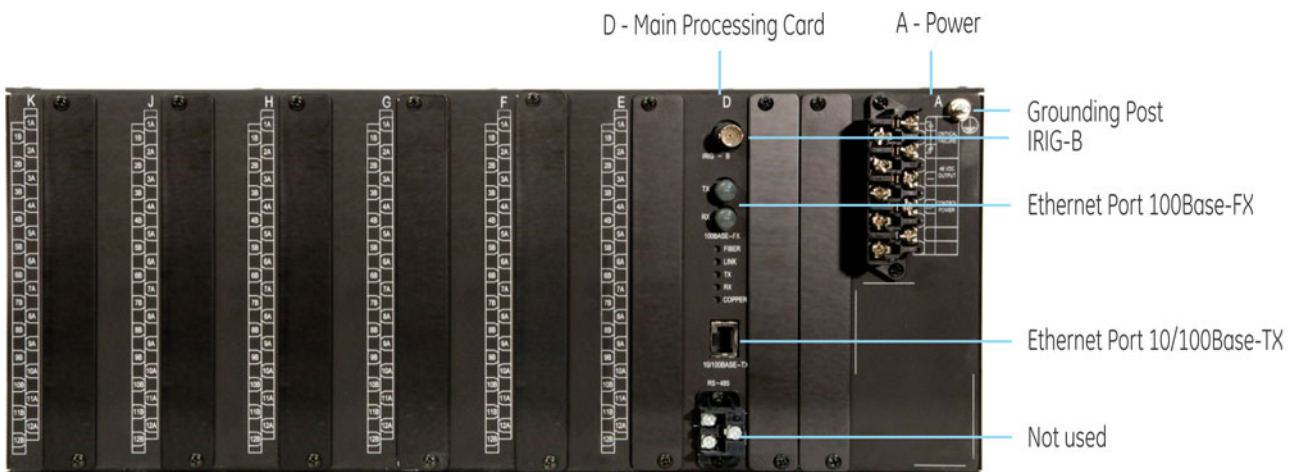
Modules are housed in slots. The slots are labelled from right to left from A to K. Active slots are as follows:

- **Slot A** — Contains the power supply module, which conditions the AC or DC station service power such that it is suitable for internal use, and contains the critical failure control. Terminals on the power supply module are designated 1 thorough 10 with a slot letter (slot A) prefix.
- **Slot D** — Contains the main processing card, which handles central processing tasks. Ports used from top to bottom are IRIG-B and Ethernet.

Other slots are not used.

Power supply module

The power supply module in slot A provides power to the unit. It receives AC or DC power from an external supply and produces conditioned 12 V DC power for all modules in the chassis. The power supply also generates 48 V DC power for external contact wetting. The output contact indicating a critical failure of the unit also resides on this module.

Figure 3: Power supply in slot A

Main processor module

The main processor module contains ports for Ethernet communication and IRIG-B.

The module contains the firmware for the U90^{Plus}. The firmware contains the algorithms required for the various functions provided by the device. The module has a rear Ethernet port for configuration and record retrieval and one IRIG-B port for clock synchronization.

Figure 4: Main processing card in slot D

COMMUNICATIONS OVERVIEW

CHAPTER 2: PRODUCT DESCRIPTION
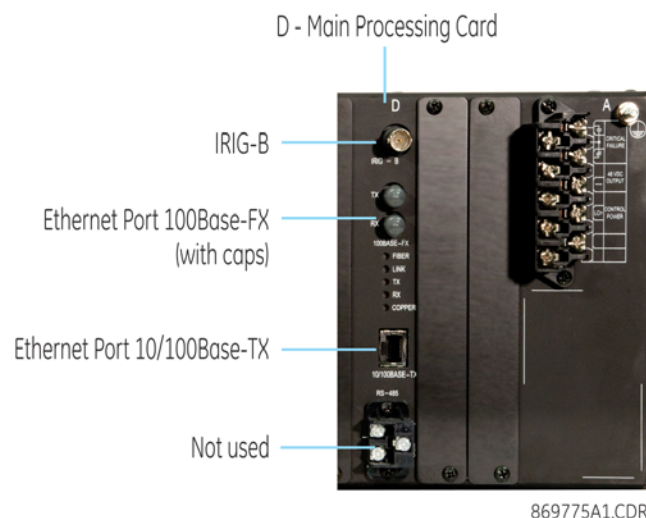
Ethernet port   The Ethernet port is the port used to communicate with other devices in the microgrid. It allows communication at high speed (100 Mbps) with resources and computers running the EnerVista software.

Optical fiber can be connected to the device supporting a wavelength of 1310 nm in multimode. The optical fiber sizes supported are 50/125 μm and 62.5/125 μm. The fiber optic port is designed such that the response time does not vary for any core that is 62.5 μm or less in diameter. For optical power budgeting, splices are required every 1 km for the transmitter-receiver pair. When splicing optical fibers, the diameter and numerical aperture of each fiber must be the same. In order to engage or disengage the ST type connector, only a quarter turn of the coupling is required.

IRIG-B port   A clock performs time-stamping. There are three options for clock source and synchronization: use IRIG-B; use the U90^Plus internal clock; or enter the date and time manually using the EnerVista software.

IRIG-B is a standard time code format that allows stamping of events to be synchronized among connected devices within one millisecond. The IRIG time-code formats are serial, pulse width-modulated codes that can be either DC level-shifted or amplitude modulated (AM). DC Shift refers to direct connection to digital systems. Amplitude modulation refers to audio tones or pulses.

Third-party equipment is available for generating the IRIG-B signal. This equipment can use a global positioning system (GPS) to obtain the time reference so that devices at different locations can also be synchronized. When using third-party equipment to set the date and time of the system, you connect it to the U90^Plus using the IRIG-B port.

Figure 5: IRIG-B schematic to set the date and time used in the microgrid
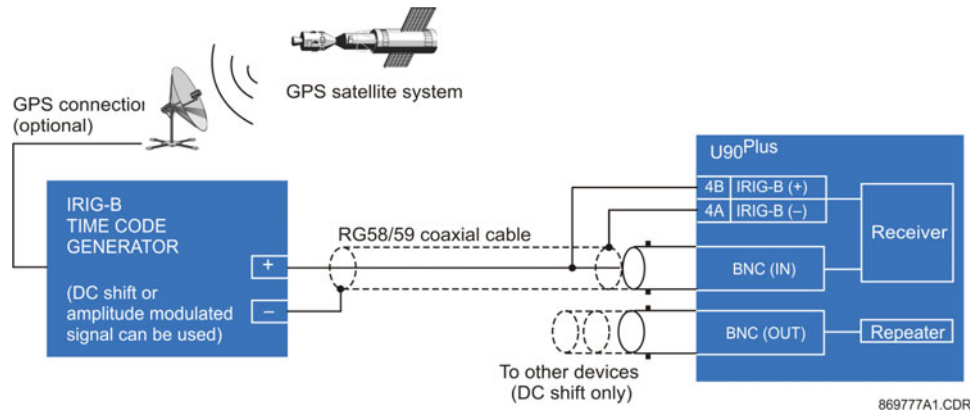
Configuration is outlined later in the Real Time Clock section.

Communications overview

The U90^Plus has a rear Ethernet port for communication with microgrid devices, supervisory control and data acquisition (SCADA) systems, and EnerVista. The front USB ports are not used on this product.

Communication via Ethernet requires a connection to an Ethernet network using a standard copper or fiber cable. The Ethernet port can also connect directly to a computer using a cross-over cable.

U90^Plus MICROGRID GENERATION OPTIMIZATION – INSTRUCTION MANUAL

The U90^{Plus} supports the Modbus communication protocol, as client and server. It communicates with microgrid devices as a Modbus client, reading status information and sending commands. It also communicates as a Modbus server, accepting commands and providing access to information to SCADA and user interface systems.

The U90^{Plus} is compatible with the following products, with which it communicates using the Modbus protocol:

- UR-series
- UR^{Plus}-series

Front panel interface

The front panel of the U90^{Plus} has an annunciator display and a human-machine interface (HMI) display. The keys/button below each display are used for navigation. The buttons at the sides of the HMI display and the two front USB ports are not used.

Figure 6: Front panel
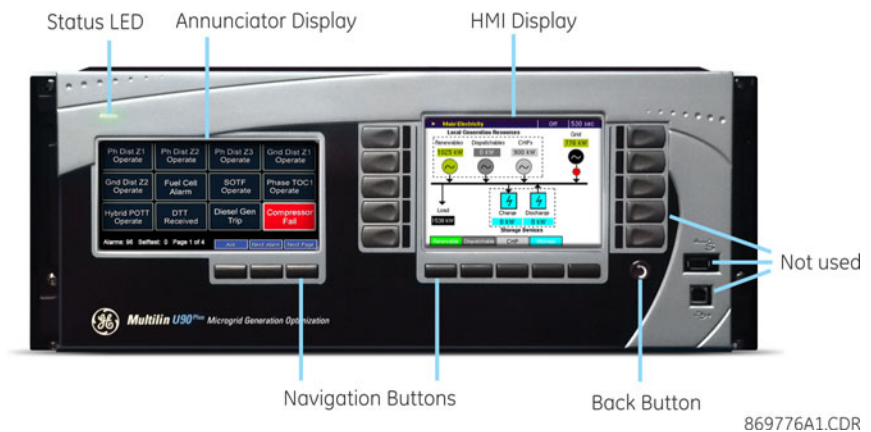
Annunciator display

The annunciator panel on the left side of the unit indicates alarms and product information.

Alarm pages

The annunciator displays alarm information.

Figure 7: Example of annunciator display

Up to 96 alarms can be configured by selecting from a list of pre-configured alarms. They display on the annunciator and in the EnerVista software. The colors are also configurable. When alarms are not configured, no alarms are generated.

There are up to three control buttons at the bottom of the display:

- **Ack** — Acknowledges the alarm selected
- **Next Alarm** — Cycles through the active alarms, paging as required
- **Next Page** — Cycles through pages of alarms (when multiple pages present) and to the Product Information page

In the event of an alarm, the page containing the alarm is promoted to the active page. If there are multiple pages with alarms, the page with the lowest page number is promoted.

If there are alarms on multiple pages and alarms on some pages have already been acknowledged (but not cleared) by the user, then the pages with active alarms move ahead of the pages that have acknowledged alarms.

Display of alarm pages is prioritized according to active window (unacknowledged or flashing alarm) and page number (for example, if two pages have an unacknowledged alarm, the page with the lowest number is automatically promoted as the displayed page).

Alarm configuration is outlined later in the Annunciator (alarms) section.

Product Information page

This page displays the name, firmware version, and IP addresses of the U90^{Plus}.

Figure 8: Product Information page
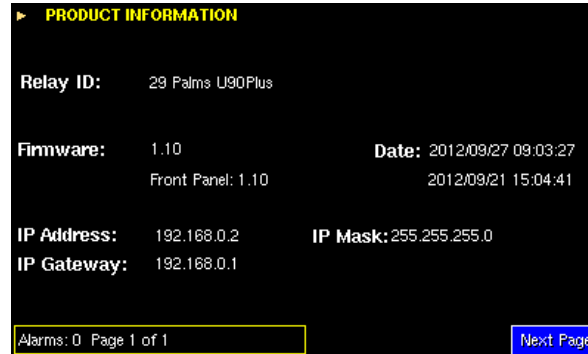
To view the Product Information page on the front panel:

1. Press the **Next Page** button repeatedly below the annunciator display until the page displays. This scrolls through any alarm pages to the Product Information page. The first **Date** is the last firmware revision date, and the second **Date** is the last front panel revision date.

The information is also viewable in the EnerVista software. To configure the IP addresses, navigate in the software to **Settings > Product Setup > Communication > Network**.

HMI display

The HMI panel on the right side of the front panel provides the following information:

- Status, including time until next optimal dispatch communication
- Electrical system, including output and capacity
- Heat and combined heat and power (CHP) system, including output and capacity
- Event records

The following figure shows the main HMI panel display. In this example, the U90^{Plus} has not been completely configured, because the optimal cost does not display. The **SOE** button refers to sequence of events records.

The top part of the panel is explained as follows. The bar provides a visual display of the time remaining until the next communication of commands from the U90^{Plus}. When a dispatch time period is set, for example six minutes or longer, the bar is white and no activity displays until data collection starts. **Reading Data** is when the U90^{Plus} collects data

from the devices, as indicated by the green progress bar and which typically starts when 720 or 360 seconds remain (12 or 6 minutes). The part of the bar called **Running Optimal Dispatch** refers to a two-minute period allotted for the U90^{Plus} to perform optimization calculations. The bar is orange at this time, starting when there are two minutes remaining. Upon successful calculation and when set to communicate commands, the U90^{Plus} does so after the two minutes.

Figure 9: Main HMI display
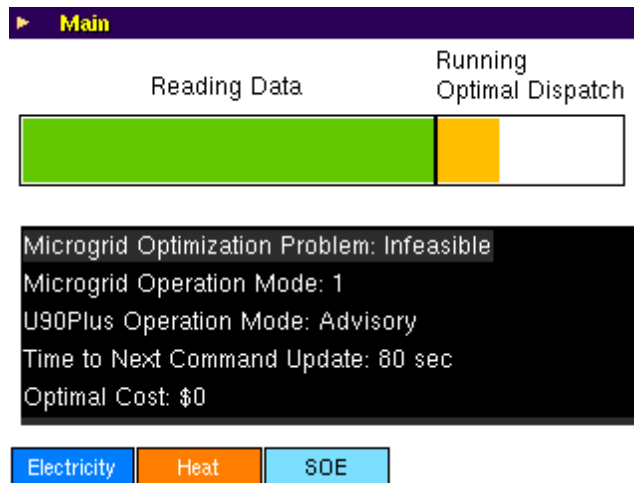
Table 1: HMI main panel

Field	Description
Microgrid Optimization Problem	Infeasible — The generated optimization problem is infeasible, meaning that there is no solution that can satisfy all the constraints. In this case, the U90^{Plus} switches to Advisory mode for the operation mode, which means that commands are not sent to resources in the microgrid. To rectify, check all connections and all configuration. This field is viewable in the software under **Actual Values > Optimal Dispatch > Problem Status**.
Microgrid Operation Mode	One of four operating modes for the microgrid as configured by you, such as: 1. Dispatchable isochronous load share (default) 2. Renewable in isochronous 3. Single dispatchable or CHP in isochronous 4. Grid in isochronous The mode is set under **Settings > System Setup > Microgrid Operation Mode** in the **Active Mode** field.

Field	Description
U90Plus Operation Mode	One of four modes to specify if optimization calculations are performed and if commands are to be communicated to resources in the microgrid: 1. Legacy (Off) 2. Auto (calculations on, commands sent) 3. Advisory (calculations on, commands not sent) 4. Test When there is a problem in the microgrid, the mode automatically switches to Advisory mode, for which optimization calculations are performed but commands are not communicated to resources. Possible reasons are calculating an infeasible optimization problem, loss of communication with an online device, or an unsuccessful attempt to turn off an online device. The mode is set in the **Commands > Optimizer Operation Mode** field.
Time to Next Command Update	The time until the U90^{Plus} next sends optimization commands to devices in the microgrid. This field reflects the **Dispatch Time** setting in the **Economic Dispatch Setup** panel of the software. This time is viewable in the software under **Actual Values > Optimal Dispatch > Problem Status**.
Optimal Cost	The cost over the prediction horizon in dollars (or other currency if entered as such) to run the microgrid based on the cost settings entered into the setup software. This includes but is not limited to fuel costs and power import/export costs/revenue (if grid exists). In the figure shown, because the cost displays as $0, the unit has not been configured.

Pressing the **Electricity** button below the HMI panel displays information for such resources, including renewable and dispatchable generators. The panel displays active grids, output, load, and storage. When a grid connection exists and import/export power is possible (meaning that the grid is online), the point of common coupling (PCC) indicator displays in red. The Charge and Discharge display separately in the HMI panel because they can be related to different devices; for example, Charge power can be the input power of an electrolyzer and Discharge power can be the output power of a fuel cell. The combination of the whole (that is, an electrolyzer, a hydrogen storage, and a fuel cell) is assumed to be a single storage device in the U90^{Plus}.

Figure 10: HMI panel showing active grid
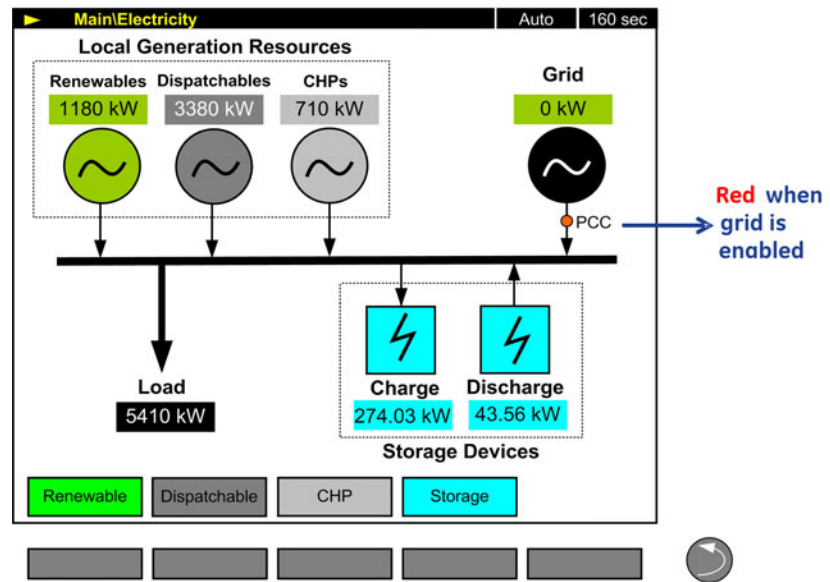
Active and inactive devices in the microgrid are displayed, for example as follows. The inactive devices display as grey squares.

Figure 11: HMI display of active and inactive devices in the microgrid
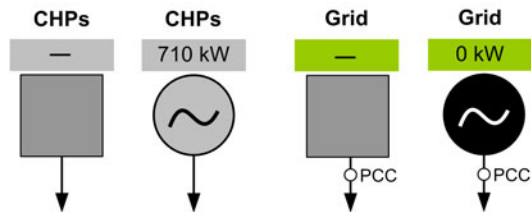
When renewable resources are present in the system, pressing the **Renewable** button below the HMI panel displays the renewable energy output compared to its rated power, meaning the electricity being generated compared to full capacity. Use the buttons at the bottom of the display to scroll through the list. In the following figure, the Capacity Factor is calculated by dividing the total Actual Value by the total Rated Power, that is 1180.82 kW / 2140 kW x 100 = 55 percent.

Figure 12: HMI display of output from renewable resources

When dispatchable resources are present in the system, pressing the **Dispatchable** button below the HMI display shows similar information as well as whether the resources are started automatically or manually. The Command output is how much the system asked the resource to generate, the Actual Value is what was output, and the Rated Power is full capacity.

Figure 13: HMI display of output from dispatchable resources

When cogenerators are present in the system, pressing the **CHP** button below the HMI panel displays the electrical output from combined heat and power equipment and rated power.

Figure 14: HMI display of output from cogenerators

When storage devices are present in the system, pressing the **Storage** button below the HMI panel displays how much stored energy is available for use and capacity of storage devices. SOC refers to state-of-charge. It indicates how much storage is charged, similar to a fuel gauge. In the example shown as follows, the status of storage device STG 1 is explained as follows:

*   The U90^{Plus} sent a request to charge the storage with an input power of 50 kW
*   51.26 kW is the actual charging power
*   The U90^{Plus} sent a request to discharge zero kW
*   0.35 kW is the actual discharging power
*   The current level of charge available for use is 75 kWh
*   The capacity or total charge possible is 125 kWh

The differences in values between command and actual are explained by the measurement errors.

Figure 15: HMI display of storage charging/discharging powers and available charge
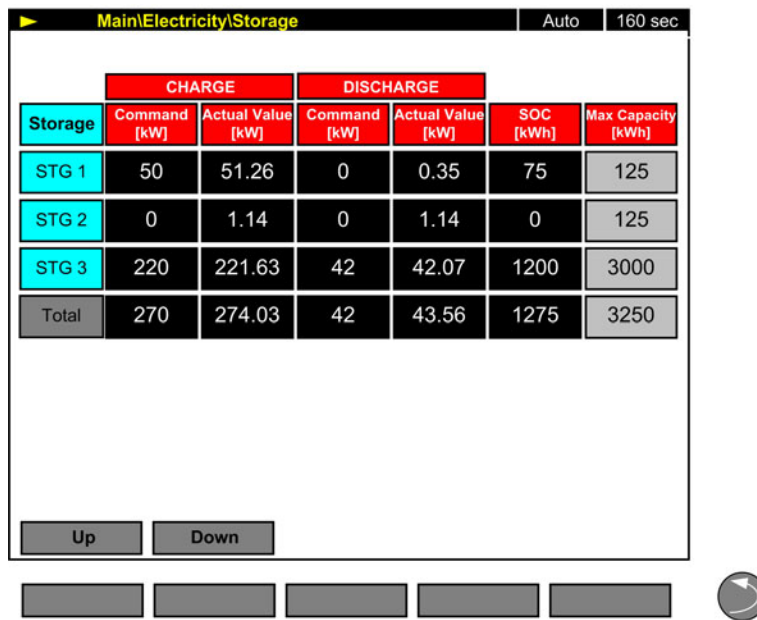
Pressing the **Heat** button below the main HMI panel displays the heat output from boilers and CHPs, as well as heat demand/load. Similarly pressing the **Boiler** or **CHP** button displays information about each resource.

Figure 16: HMI display of boiler and cogenerator output and load
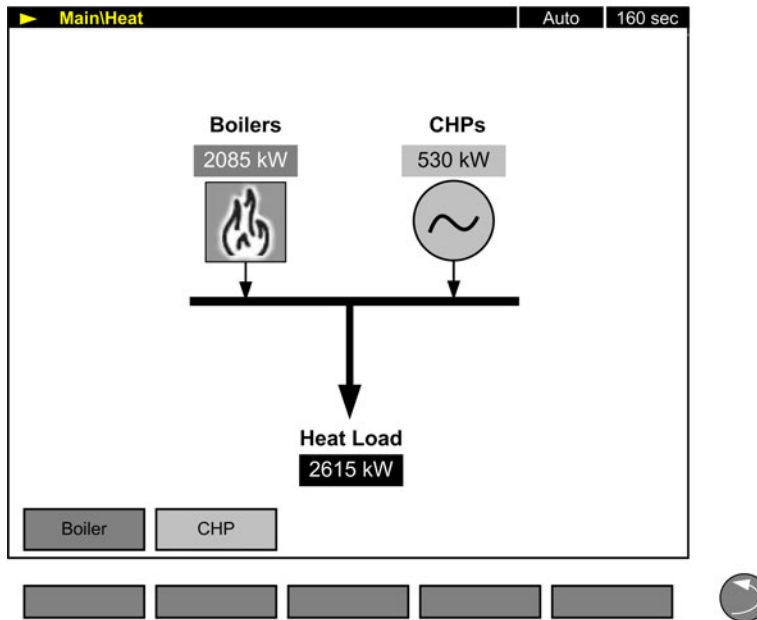
The **SOE** button below the main HMI display refers to sequence of events and displays the event records. Examples are when the unit was turned on (Power On) and when settings were sent from the software (Settings Changed).

Figure 17: Event records on the HMI panel

EnerVista software

The EnerVista software supplied with the U90^{Plus} provides tools to configure and monitor resources. You typically install the U90^{Plus}, configure it using the software, then use the software or third-party software to manage the unit. For example, using GE CIMPLICITY software or a third-party product allows for automatic notification of alarms instead of having to manually check the unit or the software.

The EnerVista U90^{Plus} Setup software provides a graphical user interface (GUI) to configure, monitor, and maintain the U90^{Plus} device connected locally to the computer or over local or wide area networks.

The software can be initiated in either offline mode (not communicating with a U90^{Plus}) or in online mode (communicating with a U90^{Plus}). Offline mode provides a subset of functions. In this mode, a device settings file can be created or configured for eventual upload to the U90^{Plus}. In online mode, all settings and functions can be browsed, individually modified, uploaded, or downloaded in real-time.

The EnerVista U90^{Plus} Setup software is provided with every U90^{Plus} unit and is available for download on the GE website at
http://www.gedigitalenergy.com/multilin/software/index.htm

The following figure shows the main software window. The software supports drag-and-drop functionality. For example, files dropped in the selected device in the **Online Window** area are sent automatically to the device.

The U90^{Plus} is compatible with EnerVista Viewpoint Monitoring software as a generic device for data point read and writes using the U90^{Plus} Modbus server. Viewpoint Monitoring needs to be upgraded with specific support for the U90^{Plus} in order to be able to retrieve U90^{Plus} COMTRADE files.

Use of the software is outlined through this document.

Figure 18: EnerVista software main window
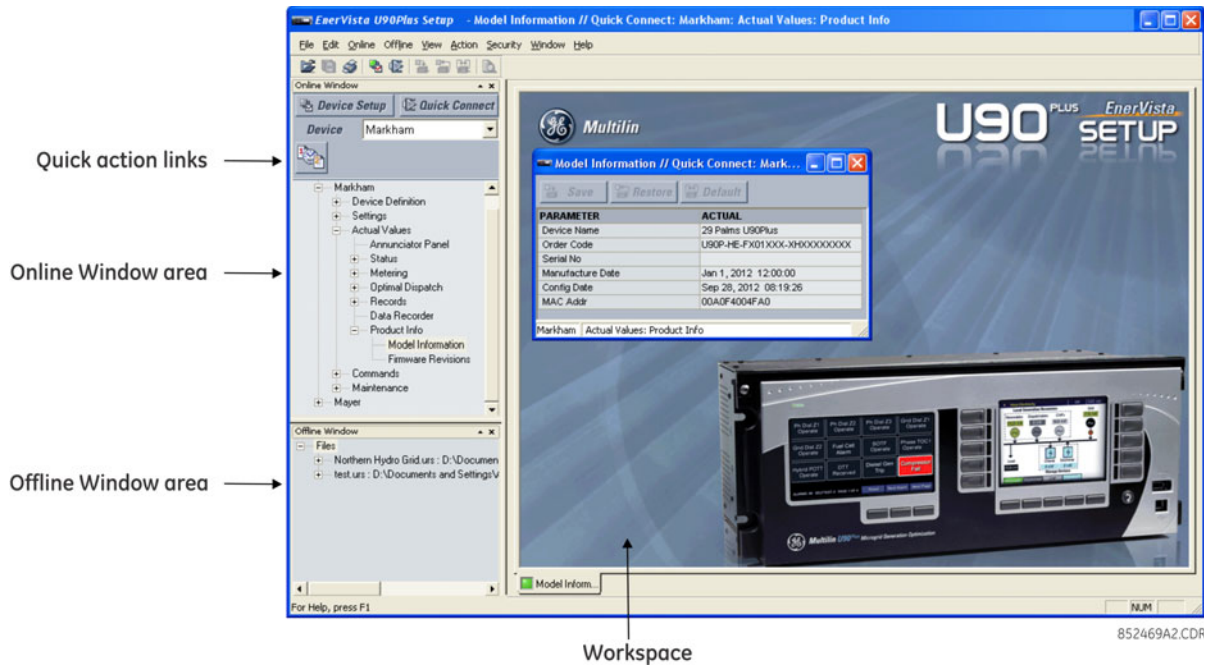
Microgrid operation

The U90^{Plus} controls microgrid generation and storage assets to optimize operation for the lowest cost based on load and renewable forecasts.

A microgrid is a distribution network that operates with local (distributed) generation or islanded (grid connection open). Both types can include renewable sources, such as wind, photovoltaics, and hydro. Because the output from renewable sources can be intermittent and variable, and energy from these resources is not always available when needed, renewable sources can be better utilized when there is storage in the microgrid, such as an electrolyzer/fuel cell system or conventional battery storage.

Figure 19: Typical microgrid
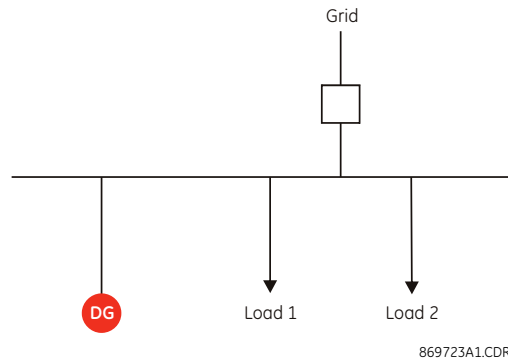
Islanded power system operation

Within any power system, the generated power must match the demand. The loading in the system is variable. Consider the following single-generator power system.

Figure 20: Single-generator power system
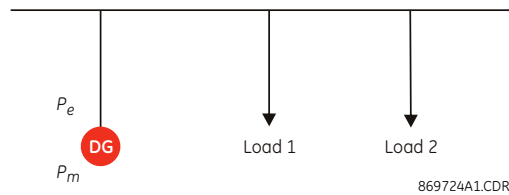
P_e refers to electrical power and P_m refers to mechanical power. They result from multiplying the torque with the angular velocity (speed).

We can write the basic torque balance equation for the generator as follows:

$$T_m - T_e = J \times \frac{d\omega}{dt}$$

Eq. 1

where T_m is the mechanical torque provided by the prime mover, T_e is the electrical torque exerted by the loading of the power system, J is the inertia constant of the machine, and ω is the rotational speed. Solving for $d\omega/dt$, we have:

$$\frac{d\omega}{dt} = \frac{1}{J} \times (T_m - T_e)$$

Eq. 2

Multiplying by the top and bottom of this equation by rated speed, ω_0, we have:

$$\frac{d\omega}{dt} = \frac{1}{\omega_0 \times J} \times (P_m - P_e)$$

Eq. 3

We see that speed is constant ($d\omega/dt = 0$) whenever mechanical power matches electrical power. This fact allows us to control a generator to supply the required load by regulating the speed of the generator at a fixed value. This method is known as isochronous control and is shown in the following figure.

Figure 21: Isochronous control
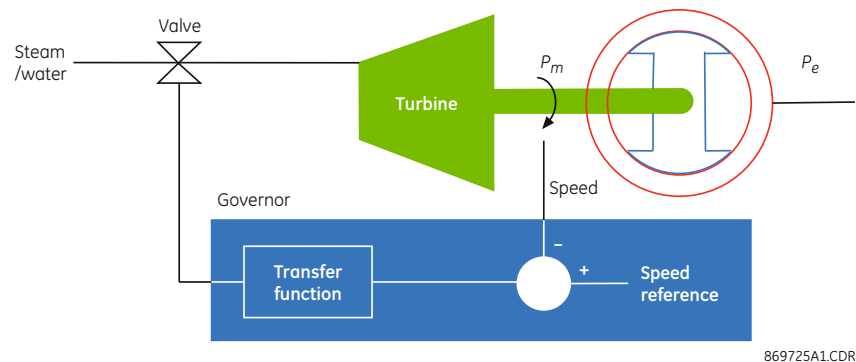
Assume that electrical and mechanical power are initially equal and speed is equal to the reference speed. When the loading of the system increases, then P_e becomes greater than P_m. As seen in the previous equation, the machine speed drops. The governor takes a measurement of machine speed and compares it with a reference speed (nominal speed). The difference is an error signal that is applied to a transfer function (typically a proportional/integral regulator). The output of the governor drives an actuator (for instance a valve in the case of a steam turbine). This acts to increase the flow of steam to the turbine, increasing the mechanical power to balance the electrical power.

The operating characteristic of an isochronous generator is shown in the following plot of frequency (proportional to mechanical speed) and power.

Figure 22: Isochronous operating characteristic
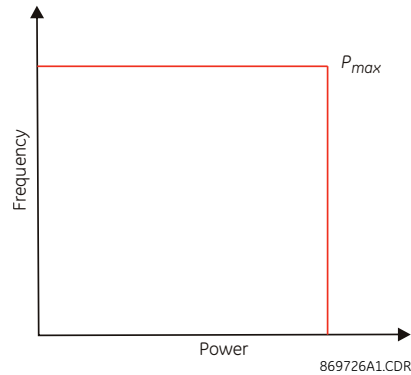
An isochronous machine maintains a constant frequency for any value of power up to its maximum rating.

Having more than one generator operating in isochronous control creates a challenge. Measurement error results in each machine having a slightly different idea of the actual system frequency, and each machine tries to bring this value to the nominal frequency. To resolve this potential conflict, one machine is typically operated in isochronous mode and the remaining generators are operated in droop control, whereby the machine receives an additional power signal that it compares to a power reference.

Figure 23: Droop control used for two or more sources of power
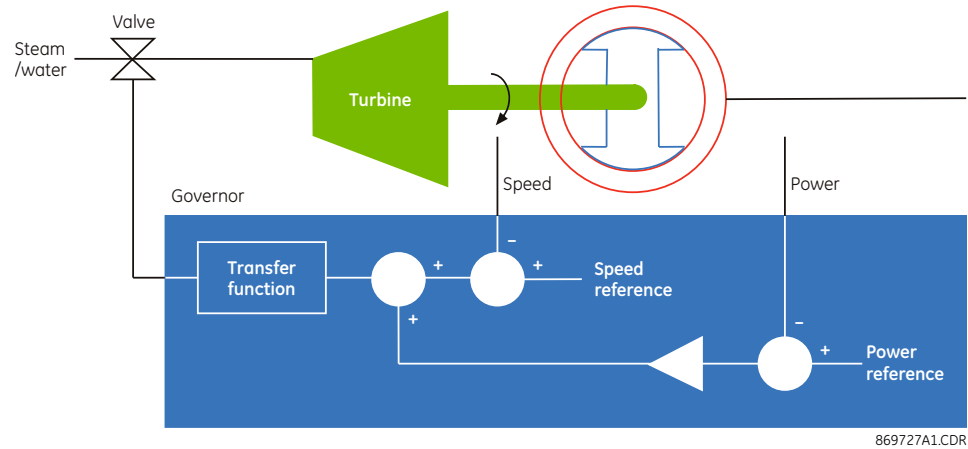
At nominal frequency, the level of power output is determined by the power reference command because the speed error signal is zero. When there is a drop in frequency, the generator increases output power according to its droop setting. For example, a generator with a droop setting of 5% produces a 100% change in output power for a 5% change in frequency.

Taken together the power and speed signals produce a sloped operating characteristic as shown in the following figure.

Figure 24: Droop control operating characteristic

869728A1.CDR
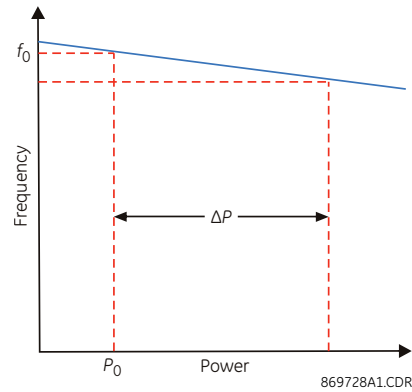
In grid-connected microgrids, the grid compensates for any imbalance between load and generation in the microgrid, behaving like an isochronous machine for the microgrid. However, for islanded microgrids, there is a need for an isochronous machine to maintain load-generation balance, and stabilize the frequency around the nominal value in response to instantaneous load and renewable generation variations above or below the forecasted values. Such an isochronous machine provides reserve margins in both positive and negative directions to address the deficit or surplus of power, respectively. These margins are defined as a percent of the total load in the microgrid.

Isochronous/non-isochronous operation of a generator impacts the behavior of the U90^{Plus} in the process of optimally dispatching the generation/storage devices in the microgrid. Thus, generating power of a dispatchable generator (genset) operating in non-isochronous mode can pick any value between its lower and upper bounds; however, for an isochronous dispatchable genset, lower and upper bounds of generating power need to be changed in the optimization problem solved by the U90^{Plus} so that the reserve margins are respected. These concepts are demonstrated in the following two figures, where the highlighted regions specify the intervals that the generating power (P_D) is allowed to change. P_{Dmin} and P_{Dmax} represent the lower and upper bounds of dispatchable generating power.

Figure 25: Demonstration of non-isochronous operation of a dispatchable generator

$$P_{Dmin} \le P_D \le P_{Dmax}$$
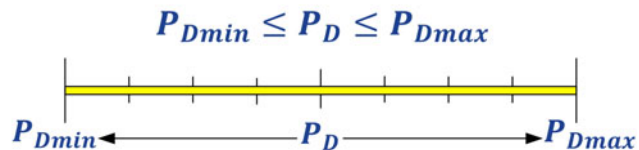
Figure 26: Demonstration of the isochronous operation of a dispatchable generator

$$P_{Dmin} + P^- \le P_D \le P_{Dmax} - P^+$$
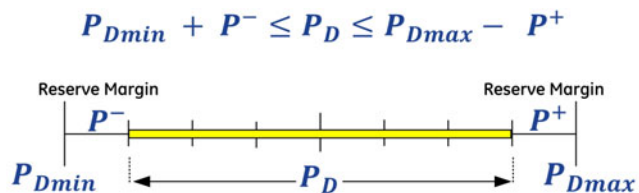
A diesel or a CHP unit can usually operate in isochronous mode due to the non-variable nature of their fuel source, while highly-intermittent renewable power sources such as wind or solar cannot fulfill the requirements of an isochronous machine. However, the U90^{Plus} supports the isochronous operation of renewable power generation units that are relatively less intermittent, such as run-of-the-river hydro units with reservoirs. In order to support such a feature, a parameter entitled Renewable Capability is defined in the setup

program. This is a parameter between 0 and 1, multiplied by the upper bound of renewable power generation unit, and decided by the operator based on meteorological observation data.

Optimal dispatch

The primary function of the U90^{Plus} is optimal dispatch, which is the process of allocating the required load demand among the available resources such that the cost of operation is minimized. The U90^{Plus} minimizes cost of electricity and/or heat in a microgrid, for example daily, and the prediction horizon can extend up to 48 hours.

Within a microgrid, resources include conventional generators and storage devices. The cost of operation is typically defined by fuel cost but can include maintenance and other costs.

An optimal dispatch algorithm is used to minimize the total operational cost of the microgrid. This cost is the sum of the fuel cost required to run the non-renewable generators, cost of electricity, which needs to be bought from a grid when one exists, and the operational cost of renewable and storage devices. Other factors include maintenance, start-up/shut-down costs, cost/revenue components associated with importing/exporting power to the grid, minimum energy/power requirements for various generation assets and minimum up/down times for some of the assets. The power bought from the grid plus the power generated internally must equal the total load and the power exported to the grid at any instant of time. The algorithm does not treat loads as dispatchable except to avoid situations of grid instability associated with imbalance between supply and demand. In other words, the microgrid always supplies enough power to satisfy its loads provided that this is physically possible given the power limits on the generators.

The optimal dispatch algorithm uses a technique known as model predictive control. It makes use of historical data as follows: daily, weekly, and annual load profiles; hydro, wind, and solar forecasts; and fuel or electricity market pricing information (when a bulk grid connection exists). Given this information, the algorithm determines the cost of operation for a fixed period in the future, typically 24 hours. It then solves the optimization problem with the objective to minimize the total costs and to determine the required control actions. These control actions include selecting the best machines to be operated at any given time, by issuing start/stop commands and sending proper isochronous or non-isochronous commands to dispatchable or renewable power generation units. It determines when energy is stored and when it is supplied to the system. Finally, it determines the best power reference point for each droop (non-isochronous) machine and for each storage device. The following figure shows data flow between the U90^{Plus} and the different component devices within the microgrid.

Figure 27: Data flow for a system with dispatchables, renewables, and storage
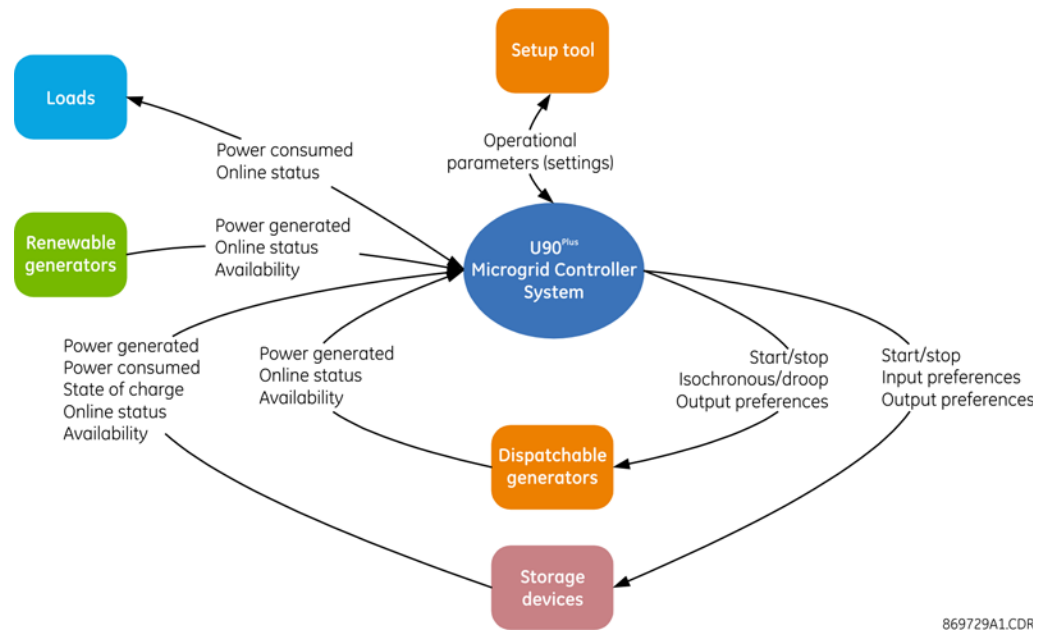
Model predictive control

Model predictive control (MPC) is used for optimal dispatch in the microgrid. In this method, a model of the process to be controlled is used to evaluate the behavior of process outputs in response to control inputs. The model response is evaluated for a finite period extending into the future, known as a prediction horizon. The outputs are optimized over this period in order to arrive at the ideal values of outputs to be applied at the current time.

Figure 28: Model predictive control
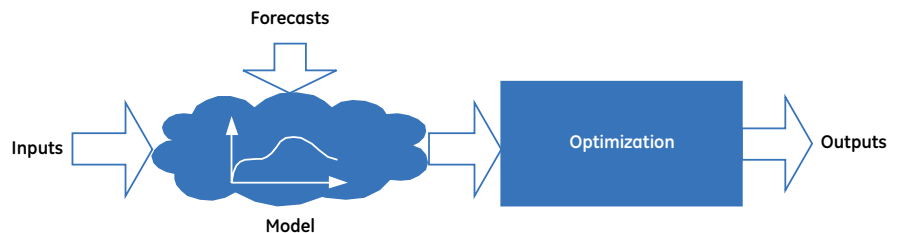
Applied to the dispatch challenge, inputs represent internal physical states of the process such as offline/online, availability, isochronous operation, storage state of charge, and metered power of the devices. Generators and storage devices are modeled by their power ratings and efficiency curves. Forecasts model the loading of the power system, the contribution of renewable sources, and the price of grid power (if one exists). Finally, outputs take the form of start/stop commands and power reference commands applied to generators and storage devices.

Generation must match load in a stable power system. Dispatchable generation including the storage equals the total load minus the total power supplied by renewable sources. These resources are assumed to have local controllers that are designed to maximize the use of available renewable energy.

The problem to be solved by the U90^{Plus} is a multi-interval optimization problem. As shown in the following figure, an assumed prediction horizon of 24 hours is divided into multiple time steps/intervals, such as 120 twelve-minute or 240 six-minute time intervals.

Figure 29: Prediction horizon
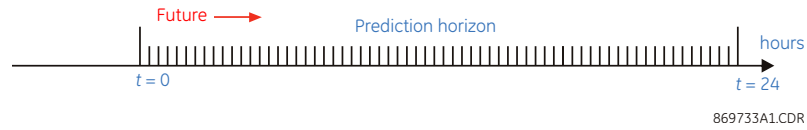
Different routines within the optimization framework are formulated and solved at each time step (for example, 12 minutes) over the prediction horizon (24 hours) based on load, renewable resources, and price forecasts. In this framework, a variety of operational considerations are factored in. These include and are not limited to the support of a hydro unit in isochronous mode, minimum up/down times required for storage charging, interaction with the grid, and support of manual-start dispatchable generators.

The objective function of the optimization problem can, in general, include the following terms:

- Fuel/operation costs of all power generation devices in the microgrid
- Cost/incentive terms for storage device charging/discharging. These are more subjectively determined, being driven by the requirement to prevent simultaneous charging and discharging and the need to limit storage cycling.
- Penalty terms mainly related to those generation/storage devices allowed to have their limits on minimum powers violated (that is, having soft constraints)
- Power importing/exporting costs/revenues when the microgrid is grid-connected

Also, the constraints of the optimization problem capture the following limitations for both electrical and thermal systems:

- Minimum and maximum values of generated power with the consideration of their isochronous or non-isochronous operation, and the microgrid reserve margin requirements
- Limits on importing/exporting powers considering the microgrid reserve power requirements (for grid-connected microgrids)
- Power balance in the microgrid considering the contribution of power generation/storage devices, load, and any grid
- Minimum, maximum, and initial values of storage devices state of charge
- Limits on storage input and output powers
- The energy balance equation of storage devices representing the storage state of charge in each time step based on its value in the previous time step as well as charging and discharging powers with the consideration of the related efficiencies and standby losses

When the prediction horizon is long enough, the algorithm can determine when to charge storage, because it can anticipate times when the loads are large and when the stored power can be utilized. The optimal dispatch algorithm implemented within the microgrid controller can be configured for up to 32 resources. Assuming a worst-case scenario where all resources are committed, the optimization problem can have on the order of 20,000 variables and 40,000 constraints.

Incorporation of CHP plants

Combined heat and power (CHP) is the generation of electricity and heat in a single process. Inclusion of CHP plants in the microgrid significantly increases the overall efficiency of the system by using the hot exhaust gases from the gas turbine to heat water. Recovered heat can also be used for district heating or covering the heat demand requirement of the system. The incorporation of CHP plants introduces another energy source (natural gas) and another energy carrier (heat) into the system.

A CHP plant can be modeled by constant conversion ratios. The conversion ratios indicate efficiency. For example, a gas-to-electricity conversion ratio of 0.35 means that 35% of the energy content of natural gas is converted to electricity and the remainder is in the form of heat. Two dimensionless conversion ratios for gas-to-electricity (r_{ge}) and gas-to-heat (r_{gh}) are defined as shown in the following figure. Typical values of r_{ge} and r_{gh} are 0.35 and 0.45, respectively, considering a 20% parasitic loss.

Figure 30: Representation of the cogenerator model

$$P_{CHPe} = r_{ge} \cdot P_{CHPin}$$

$$P_{CHPh} = r_{gh} \cdot P_{CHPin}$$

Note that different energy source and carriers, meaning natural gas, electricity, and heat, are involved, and that they are all represented in terms of a common unit (kW). Note too that P_{CHPe} and P_{CHPh} are not independently controlled. Also, fuel consumption rate of a CHP unit reflected in the objective function is assumed to be an affine function of its generated electric power; this is similar to all dispatchable units in the microgrid.

Similar to dispatchable generators, CHP units can also operate in isochronous mode to cover the electric system reserve requirements.

Order code

The U90^{Plus} is a 19-inch horizontal rack-mount unit that has two fixed modules. There are no product or module options.

Reading across the order code table, the ordering code is U90P-HE-FX01XXX-XHXXXXXXXX.

NOTE

Order codes are subject to change without notice. See the GE Multilin ordering page at http://store.gedigitalenergy.com/Multilin/front.asp for the latest options.

Figure 31: Order code

	U90P	*	*	*	*	**	*	*	*	*	*	*	*	*	*	*	*	*	
Base	U90P																		Base Unit
Front Panel Interface		H																	Annunciator + HMI (Standard)
Language			E																English (Standard)
Optimization				F															Full Featured
Reserved					X														Reserved
Communications						01													Modbus TCP/IP and serial client + Modbus TCP/IP server
Reserved							X												Reserved
Reserved								X											Reserved
Reserved									X										Reserved
Coating										X									None
Power Supply											H								High (88 to 275 V AC; 80 to 300 V DC)
Reserved												X							Reserved
Reserved													X						Reserved
Reserved														X					Reserved
Reserved															X				Reserved
Reserved																X			Reserved
Reserved																	X		Reserved
Reserved																		X	Reserved
Reserved																		X	Reserved

* single-digit ordering code
** double-digit ordering code

869736A1.CDR

The order code is read in the software under **Actual Values > Product Info > Model Information**.

Specifications

This section outlines specifications, which are subject to change without notice.

Recorder specifications

EVENT RECORDER
Storage capacity:..8192 events
Time tag:..to 1 ms
Triggers: ....any alarm
Data storage:...non-volatile memory

FORECAST RECORDER
Record generation:...after each optimal dispatch

Front panel interface

ANNUNCIATOR DISPLAY
Alarm inputs:...96
Alarm pages:...up to 8
Sequence:..manual reset, locking
Off indication:..alarm inactive and reset
Flashing indication:..alarm active and not acknowledged, alarm inactive and not
                                                                         acknowledged
Priority:..by active window and page number
Data storage:...non-volatile memory

HMI DISPLAY
Status displays:...optimization, electrical assets, thermal assets, storage
                                                                         assets

EVENT RECORDER DISPLAY
Sequence of events:...displays the stored event records

Hardware specifications

ETHERNET PORTS
Standard:...1 port supporting Modbus TCP
100Base-FX media type:...............................1310 nm, multimode, half/full-duplex, fiber optic with ST
                                                                         connector
 Power budget:...10 dB
 Maximum optical input power:...................–14 dBm
 Receiver sensitivity: ....–30 dBm
 Typical distance:...2.0 km
10/100Base-TX media type:..........................RJ45 connector

IRIG-B INPUT
Amplitude modulation:....................................1 to 10 V pk-pk
DC shift:..TTL
Input impedance:...50 kΩ
Isolation: ....2 kV

POWER SUPPLY

Nominal DC voltage:..125 to 250 V
Minimum DC voltage:..80 V
Maximum DC voltage: ....300 V
Nominal AC voltage:...100 to 240 V at 50/60 Hz
Minimum AC voltage:.......................................88 V at 48 to 62 Hz
Maximum AC voltage:......................................275 V at 48 to 62 Hz
Voltage withstand: ....2 × highest nominal voltage for 10 ms
Voltage loss hold-up:..200 ms duration at nominal
Power consumption: ....30 VA typical, 65 VA maximum

Communications specifications

CLIENT/SERVER APPLICATIONS

Client applications:..Modbus over TCP/IP
Server applications: ....FTP, TFTP

Test specifications

Test	Reference standard	Test level
Dielectric voltage withstand	EN 60255-5	2.3 KV
Impulse voltage withstand		5 KV
Insulation resistance		500 V DC
Damped oscillatory	IEC 61000-4-18 / IEC 60255-22-1	2.5 KV CM, 1 KV DM
Electrostatic discharge	EN 61000-4-2 / IEC 60255-22-2	Level 4
Radio frequency (RF) immunity	EN 61000-4-3 / IEC 60255-22-3	Level 3
Fast transient disturbance	EN 61000-4-4 / IEC 60255-22-4	Area B
Surge immunity	EN 61000-4-5 / IEC 60255-22-5	Level 3
Conducted RF immunity	EN 61000-4-6 / IEC 60255-22-6	Level 3
Voltage interruption and ripple DC	IEC 60255-11	15% ripple, 200 ms interrupts
Radiated and conducted emissions	CISPR 11 / CISPR 22 / IEC 60255-25	Class A
Sinusoidal vibration	IEC 60255-21-1	Class 1
Shock and bump	IEC 60255-21-2	Class 1
Seismic	IEC 60255-21-3	Class 2
Power magnetic immunity	IEC 61000-4-8	Level 5
Pulse magnetic immunity	IEC 61000-4-9	Level 4
Damped magnetic immunity	IEC 61000-4-10	Level 4
Voltage dip and interruption	IEC 61000-4-11	0, 40, 70, 80% dips, 250/300 cycle interrupts
Voltage ripple	IEC 61000-4-17	15% ripple
Ingress protection	IEC 60529	IP30 front
Environmental (cold)	IEC 60068-2-1	-40°C / 16 hours
Environmental (dry heat)	IEC 60068-2-2	85°C / 16 hours
Relative humidity cycle	IEC 60068-2-30	6 day, variant 1
Electrostatic discharge	IEEE ANSI C37.90.3	8 KV contact, 15 KV air
Damped oscillatory	IEEE ANSI C37.90.1	2.5 KV, 1 MHz
Fast transient disturbance	IEEE ANSI C37.90.1	4 KV, 2.5 KHz
RF immunity	IEEE ANSI C37.90.2	20 V/m, 80 MHz to 1 GHz

Test	Reference standard	Test level
Safety	UL 508	e83849 NKCR
	UL C22.2-14	e83849 NKCR7
	UL 1053	e83849 NKCR

Environmental specifications

TEMPERATURE

Cold: .... IEC 60068-2-1, 16 hours at –40°C
Dry heat: .... IEC 60068-2-2, 16 hours at 80°C
Humidity: .... up to 95°C non-condensing at 55°C, as per IEC 60068-2-30 variant 1, 6 days
Storage temperature: .... -40 to 85°C
Operating temperature: .... -40 to 60°C

OTHER ENVIRONMENTAL SPECIFICATIONS

Altitude: .... up to 2000 m
Insulation class: I
Overvoltage category: II
IP rating: .... IP30 for front, IP10 for back
Pollution degree: II

Approvals and certification

APPROVALS AND CERTIFICATION

Compliance: .... CE, CSA, UL, ISO

Compliance	Applicable council directive	According to
CE	Low voltage directive	EN 60255-27 (normative sections)
	EMC directive	EN 60255-26 / EN 50263
		EN 61000-6-5 (Area G)
C-UL-US	---	UL 508
		UL 1053
		C22.2 No 14
ISO	---	ISO 9001:2008

Dielectric strength

Dielectric strength is the maximum electric strength that can be sustained without breakdown. It is measured in volts.

The table outlines the dielectric strength of the U90^{Plus} hardware.

Table 2: Dielectric strength for the U90^{Plus}

Function	Terminals		Dielectric strength
	from	to	
Power supply module	high (+), low (+), (–)	chassis	2000 V AC for 1 minute
Power supply module	48 V DC (+) and (–)	chassis	2000 V AC for 1 minute
Power supply module	unit terminals	chassis	2000 V AC for 1 minute
Main CPU	RJ45 port	chassis	1500 V AC for 1 minute
Main CPU	IRIG-B port	chassis	2000 V AC for 1 minute

Filter networks and transient protection clamps are used in the hardware to prevent damage caused by high peak voltage transients, radio frequency interference (RFI), and electromagnetic interference (EMI).

NOTICE

The protective components can be damaged by application of a test voltage for longer than the specified minute.

U90^{Plus} Microgrid Generation Optimization

Chapter 3: Modbus communication

Modbus is the protocol used for communication among the devices in the microgrid. This chapter outlines Modbus communication and its support by the U90^{Plus} Microgrid Generation Optimization unit.

Modbus overview

Modbus is a serial communications protocol developed by a company called Modicon. It is a standard protocol for communication among devices. Modbus is typically available via a RS485 serial link (Modbus RTU) or via Ethernet (Modbus/TCP) whereby IP addresses are used to communicate with devices. The U90^{Plus} supports TCP/IP Modbus.

The U90^{Plus} TCP/IP Modbus allows connection to external devices, such as digital governors, programmable logic controllers, relays, and meters. The Ethernet port at the back of the unit supports 100Base-FX over multi-mode fiber and 10/100Base-TX over twisted-pair, with auto-negotiation.

The U90^{Plus} acts as both a Modbus client and Modbus server, which means that it can both initiate communication and respond to communication. A Modbus server (slave) serves requests and responds to communication but cannot initiate communication.

The communications client supports up to 32 connections. Data flow is half-duplex, so communication is in one direction at a time. (When bidirectional communication is required, the trivial file transfer protocol, or TFTP, is used, such as when sending commands to resources and sending the configuration to the U90^{Plus} unit.)

All values are represented internally within the U90^{Plus} using a double-precision, floating point format.

Each connection sends requests and processes responses independently, which means waiting for a response on one connection does not block the sending and receiving of another connection.

The following Modbus function codes are supported. Function codes supported are device-specific, though the ones supported by the U90^{Plus} are very common. In the following table, a function code is a number that represents a command for the receiving device, such as read or write.

Table 3: Modbus function codes supported

Function code	Description
03	Read holding register
04	Read input register
06	Write single register
16	Write multiple registers

U90^{Plus} Microgrid Generation Optimization

Chapter 4: Installation

The process for installation of the U90^{Plus} Microgrid Generation Optimization unit is as follows:

- Install the unit in a rack and wire it
- Install the software on a computer
- Connect the computer to the unit
- Add site(s) and unit(s) in the software
- Configure the microgrid in the software.
  - Specify the number of dispatchable generators, loads, boilers, renewable resources, and so on (**Settings > Product Setup > Installation**)
  - Add register maps for device types (**File > Register Map Editor**)
  - Add devices (**Settings > Inputs/Outputs > Communication Devices**)
  - Add inputs and outputs for the devices (**Settings > Inputs/Outputs**)
  - Configure devices (**Settings > System Setup > Microgrid Assets > Electrical Assets** and **Thermal Assets**)
  - Set the time periods for the forecasts (**Settings > Economic Dispatch Setup**)
  - Configure annunciator alarms (**Settings > Product Setup > Annunciator**)
  - Send all settings to the U90^{Plus} (**Settings > Send Setup to Device** when working online, or right-click and select **Write to Device** when working offline)
  - Set the operating mode of the U90^{Plus} (**Commands > Optimizer Operation Mode**)
  - Configure forecast settings for optimization (**Commands > Forecasts**)
- Verify operation (see the Verify Operation section)

Configuration can be done offline or online. When working offline, you work in the **Offline Window** area of the EnerVista software. When working online, you work in the **Online Window** area of the software.

After installation, monitoring and management of the U90^{Plus} is done using EnerVista software or customized SCADA HMI software, such as GE CIMPLICITY.

Installation and configuration takes up to a day.

Install unit in a rack

The U90^{Plus} is a 19-inch horizontal rack-mount unit.

The following figures show the cutout dimensions for panel mounting and case dimensions. When planning the location with the panel cutout, provide space for the faceplate to swing open from the top. Under normal operating conditions, the unit has no special cooling requirements, but provide adequate clearance to the bottom, sides, and top of the device to allow air to circulate. Do not block the ventilation openings of the chassis.

The unit is typically installed in a control center at a substation.

To install the unit:

1. Mount the unit in a 4U rack such that the front faceplate sits semi-flush with the panel or switchgear door, allowing the operator access to the front panel keys. Leave a 1U (1 rack-unit) space below the chassis for ventilation and for the front panel to swing open from the top. No extra space is required above the chassis. Clearance is provided by the shape of the mounting plate. Do not install other equipment or panels that obstruct this clearance.

2. Secure the unit to the rack using the four screws supplied.

Next, wire the unit as outlined in the next section.

Figure 32: Panel cutout dimensions
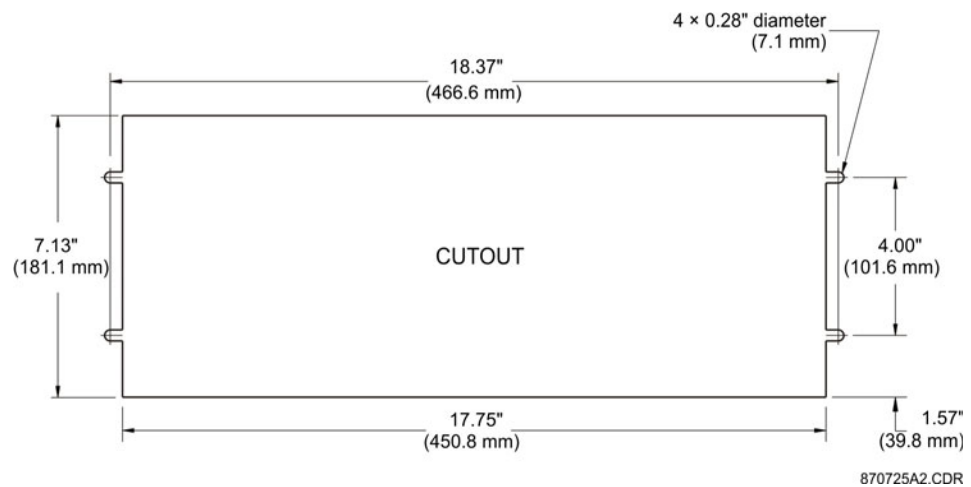
Figure 33: Dimensions and location of mounting screws
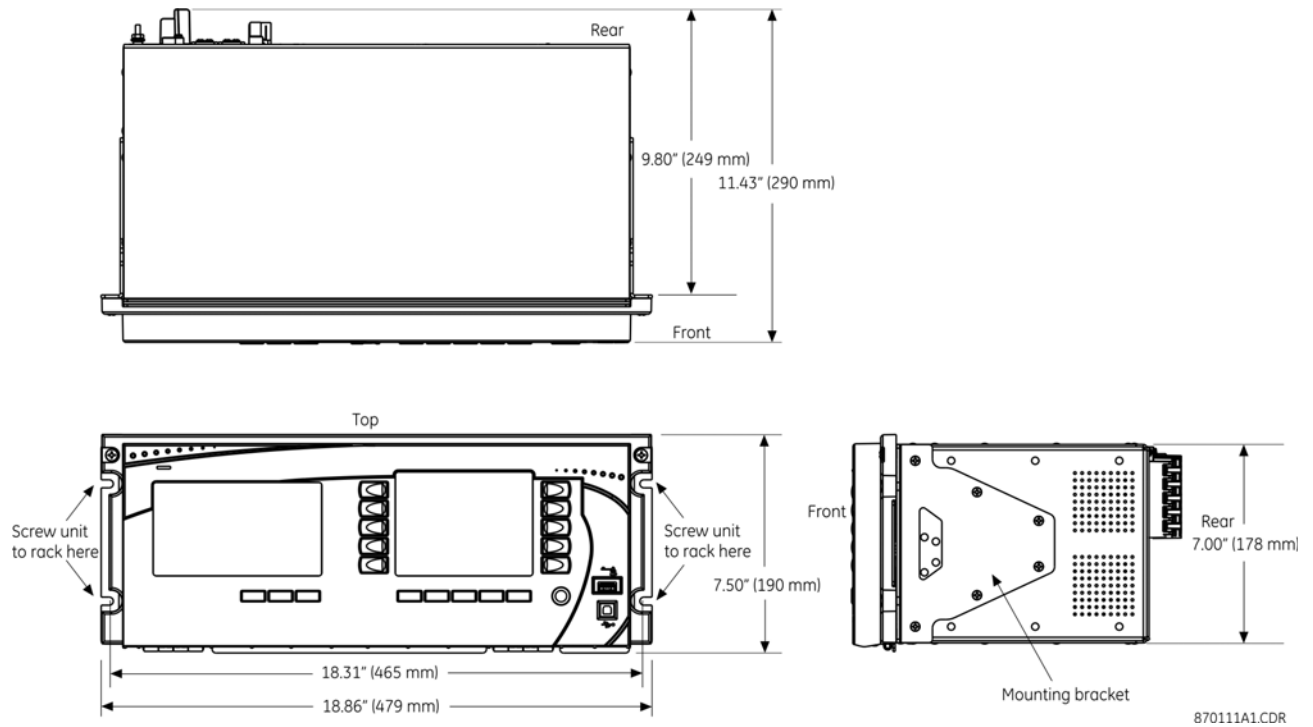
Typical wiring diagram

This section outlines the electrical installation of the U90^{Plus}.

The unit can be connected to AC or DC power. Use of DC power is typical in the field. See the Hardware Specifications section for acceptable voltages.

The control power to the power supply card is protected by a non-replaceable 4 Amp slo-blo fuse.

The following wiring diagram provides an example of how to wire the unit. Actual wiring varies according to application.

Figure 34: Typical wiring diagram
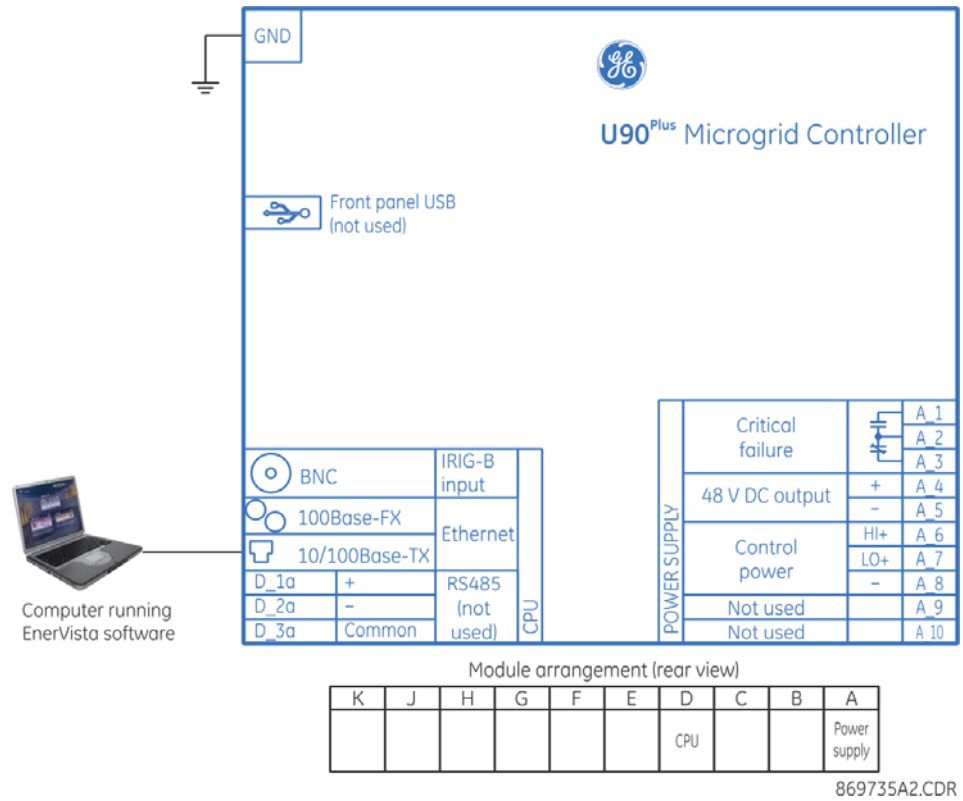
The following figure shows the labelling on the back of the unit.

Figure 35: Power supply in slot A

The following figure shows the power setup schematically.

Figure 36: Control power connection
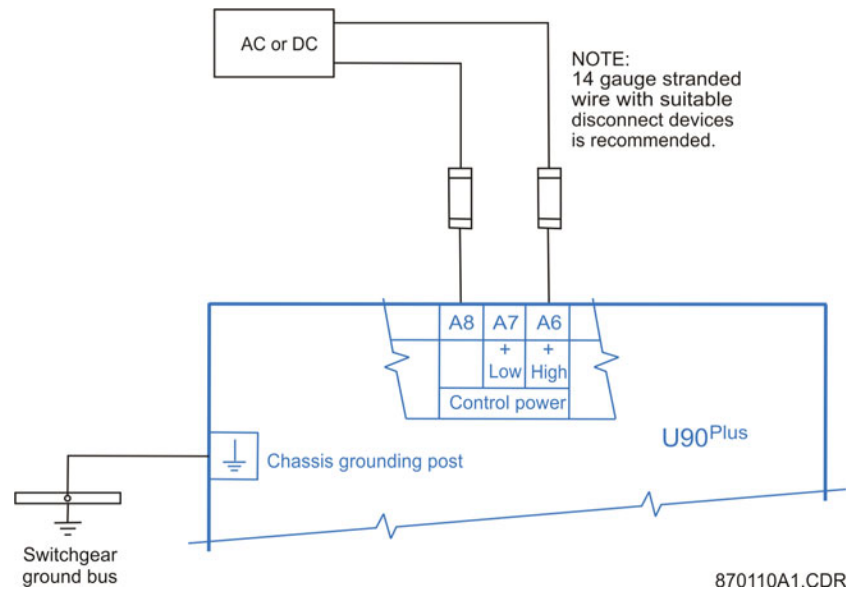
⚠ WARNING

Ensure that power is not live when connecting the wires to the unit, else injury or death can result.

An example of wiring is to connect the two wires of the power cord to the Control Power terminals as marked on rear of the unit, plus the ground wire to the grounding post.

To connect power:

1. Wire the unit according to the wiring diagrams. For control power connection, 14 AWG or larger stranded wire is recommended. A ring terminal is recommended to ensure integrity of the connection. The rated torque for the terminal screw is 9 in lb (1 N m). External downstream disconnects and external overcurrent protection of 5 to 10 Amps are recommended for both control power inputs.

NOTICE

Power supplied to the unit must be connected to the matching power supply terminal of the unit. If the voltage is applied to the wrong terminals, damage can occur.

NOTICE

The U90^{Plus}, similar to almost all electronic relays, contains electrolytic capacitors. These capacitors are well-known to be subject to deterioration over time if voltage is not applied periodically. Avoid deterioration by powering up the unit once a year.

The power supply card provides critical failure control, with form-C contacts that are energized once control power is applied and the unit successfully boots up with no critical self-test failures. If ongoing self-tests detect a critical failure or power is lost, then the critical failure control de-energizes. This feature gives external indication when the unit has failed.

Install the EnerVista software

Check the minimum requirements, then install the software, as outlined.

Minimum requirements

The minimum requirements for installing the EnerVista U90^{Plus} Setup software on a computer are as follows:

- 1 GHz processor
- Windows XP, Vista, 7, or Windows Server 2008 or higher
- 1 GB of RAM
- 200 MB of available space on installation disk
- Video capable of displaying 1024 × 768 or higher in high-color mode

Install the software

The software can be installed from the CD supplied or via download.

To install the EnerVista U90^{Plus} Setup software from the Internet or CD:

1. To download, access http://www.gedigitalenergy.com/multilin/. Use **Product Lookup** to navigate to the U90^{Plus} page. Under **Resources**, select **Software**. Click the EnerVista U90^{Plus} Setup software entry. Enter the requested information, then click the download button.

2. To install from the download or CD, locate and click the EnerVista U90^{Plus} Setup file.

   The software installs in the directory selected. Use either the desktop shortcut or start menu to launch the software.

Next, connect the computer and U90^{Plus}, as outlined in the next section. Content of this manual is also contained in the online Help accessible from the main menu of the software.

Configuration can be done offline or online. When working offline, you work in the **Offline Window** area of the EnerVista software. When working online, you work in the **Online Window** area of the software.

Establish connection to the unit

Communication between the U90^{Plus} and the EnerVista software is via Ethernet. Connection between the U90^{Plus} and the computer can be point-to-point or within a local area network (LAN). If point-to-point, use either a straight-through or cross-over cable. The default IP address of the U90^{Plus} is 192.168.251.251. First-time communication with the unit requires a computer with TCP/IP configured to reach this address. If local network constraints prevent the use of this address, use a point-to-point connection between the computer and the U90^{Plus}. If wanted, a USB-Ethernet adapter can be deployed to avoid changing the computer's primary IP address settings.

To connect to the unit:

1. Connect the Ethernet cable to the Ethernet port at the back of the U90^{Plus}.
2. Connect the other end of the cable to the computer or network.

3. In the EnerVista software, click the **Quick Connect** button at the top left. In the window that displays, enter the unit's IP address. Click the **Connect** button. The unit is now configured to communicate with the computer.

Once connected, to change and complete the IP address configuration:

1. Navigate to **Settings > Product Setup > Communication > Network**. Configure the Ethernet port settings with an IP address, subnet mask, and gateway address compatible with the target network. These settings are typically assigned by the network administrator.

⚠CAUTION

Observing any fiber transmitter output can cause injury to the eye.

NOTE

Ensure that dust covers are installed on the 100Base-FX connectors when not in use. Dirty or scratched connectors can lead to high losses on a fiber link.

To move the unit after its IP address has been configured, you need a USB-Ethernet adapter. This is because the U90^{Plus} software is configured for one IP address to reach the unit, but you are moving it to a network with another IP address.

To move the unit:

1. Connect the USB port of the adapter to the computer.
2. Connect the Ethernet cable of the U90^{Plus} to the other end of the adapter.
3. Configure the computer to use the adapter, for example install the adapter driver from its CD. If that does not work, consult GE Digital Energy.

Add sites and units

The EnerVista software allows for multiple U90^{Plus} devices to run from it. The software is organized in a hierarchical tree structure, with "sites" at the top level and U90^{Plus} devices allocated to specific sites. Sites can contain any number of devices.

Figure 37: One site and two devices

When connecting to the unit in the previous section, you added the device to the default Quick Connect site. Use the instruction here to change the name or description, or to add additional sites and devices.

There are four options to add sites and devices, as follows:

*   The **Device Setup** button in the software window
*   Right-clicking in the **Online Window** area of the software window and selecting **Device Setup**
*   The **Edit Device Setup** icon on the tool bar
*   Clicking the **Online > Device Setup** menu option

Use one of these options to configure the sites and devices now. One example follows.

To add a site and device to the software:

1. Click the **Device Setup** button.
2. In the window that opens, click the **Add Site** button.
3. Change the **Site Name** field to a descriptive name.

4. Click the **Add Device** button.

5. Change the **Device Name** field to a descriptive name.

6. From the **Interface** drop-down list, select **Ethernet** to connect to the U90^{Plus} device over a network.

7. Add the **IP address**.

8. Click **OK** to exit from the window.

Once configured, access the U90^{Plus} unit by clicking its **+** in the **Online Window** area of the software. Files dragged and dropped into the **Online Window** area are sent automatically to the device.

Connect to the unit

There are two ways to connect to a U90^{Plus} in the EnerVista software:

•   Click the **Quick Connect** button

•   Expand its entry in the **Online Window** area. This is the normal method for configured units.

Recall that you also have the option to work online or offline.

To access a unit using the **Quick Connect** button:

1. In the **Online Window** area of the EnerVista software, click the **Quick Connect** button.

2. Enter or check the IP address of the unit, and click the **Connect** button. A Quick Connect entry is added to the navigation tree.

3. Click **+** to expand the entry of the unit and connect to it. When the category does not expand and a message "Failed to retrieve configuration information from relay" displays, it means that the unit is turned off, that there is a configuration error such as IP address, or that there is a firmware error. Turn on the unit, or try restarting the unit and the software.

To access a unit by expanding its entry:

1. In the **Online Window** area of the EnerVista software, click **+** to expand the entry of the unit and connect to it. When the category does not expand and a message "Failed to retrieve configuration info from relay" displays, it means that the unit is turned off, that there is a configuration error such as IP address, or that there is a firmware error. Turn on the unit, or try restarting the unit and the software.

Specify microgrid configuration

You specify the number of dispatchable generators, loads, boilers for heat, renewable resources, and so on in the EnerVista U90^{Plus} Setup software.

Up to 32 resources can be connected in the microgrid, with maximum per device type as follows.

Table 4: Maximum configuration by device type

Resource	Maximum number (up to total of 32)
Boilers	8
CHPs	8
Dispatchables (auto-start)	16
Grids	1
Heat Loads	16
Loads	16
Renewables	16
Storage	16

To configure microgrid setup:

1. In the EnerVista software, connect to the unit by expanding the **+**, and navigate to **Settings > Product Setup > Installation**.

2. Enter the name of the U90^{Plus} unit or microgrid in the **Device Name** field, for example 29 Palms U90Plus.

3. Specify the number of grids, loads, resources, and so on by clicking the field and the arrow buttons. Co-located renewable resources count as one. For example, when you have 10 solar panels co-located and connected to the microgrid at the same location, this counts as one renewable resource.

4. Click the **Save** button, which saves the configuration in the software only.

Figure 38: Configuring the number of microgrid components
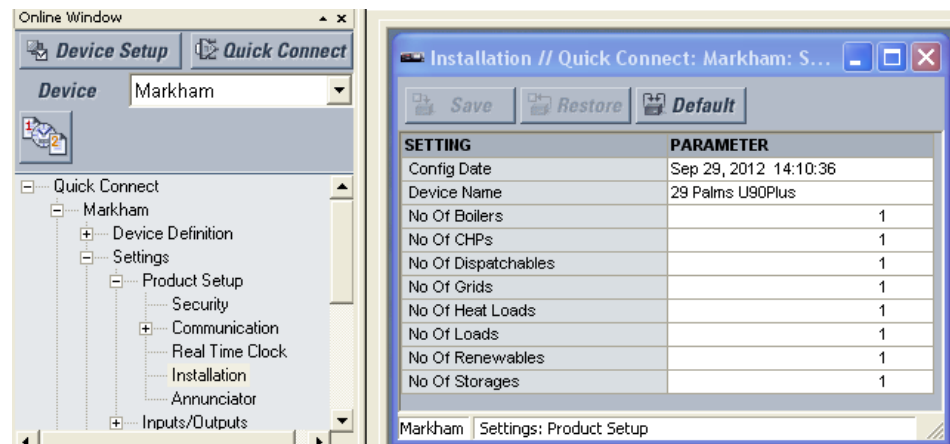
Register maps

Resources in the grid need to be configured in the EnerVista U90^{Plus} Setup software, starting with the Modbus memory maps. For example, when there is a diesel generator, you configure information for it in the software by entering Modbus memory map information. When the resource has Modbus server capability, you add parts of its Modbus memory map. When the resource does not have Modbus server capability, you add parts of the memory map of the Modbus device that provides this functionality for the resource, such as a UR controller. Only the memory map points that are important are added, for example 10 or 12 entries per device type, not the entire memory map.

The Modbus register maps are used for communicating with devices in the microgrid.

The U90^{Plus} ships with memory maps already added for several GE devices, such as the UR products, and otherwise you add the memory map information for other equipment.

The following sections explain register maps, then how to add them. The Modbus protocol uses boolean (bit) and integer (word) addresses.

Reading a floating point or integer value

A read operation uses the following formula for conversion:

$$\text{Internal value} = \frac{\text{External value} - \textbf{Offset}}{\textbf{Scale}}$$

Eq. 4

The internal value represents the value stored within the U90^{Plus} and the external value represents the value stored within the external device (controller).

When the Data Type is floating-point, then no rounding or truncation is performed during conversion.

Example:Integer read calculation

Consider the following register map definition.

If the register at Modbus address 2000h contains the value "A05Eh" (decimal 41054), then the "input" point takes the value shown as follows after a read operation.

$$Internal\ value = \frac{External\ value - Offset}{Scale}$$

$$= \frac{41054 - 50000}{100} = -89.46$$

Eq. 5

Writing a floating point or integer value

A write operation uses the following formula for conversion:

Eq. 6

$$External\ value = (Internal\ value \times Scale) + Offset$$

The internal value represents the value stored within the U90^{Plus}, and the external value represents the value stored within the external device (controller).

When the Data Type is floating-point, then no rounding or truncation is performed during conversion. When the Data Type is integer, then the value is rounded up, if necessary, during a write operation.

Example:Integer write calculation

Consider the following register map definition.

Figure 40: Definition for integer write example

If the "output" point contains the value "157450.5", then the converted value in decimal is calculated as follows.

Eq. 7

$$\text{External value} = (\text{Internal value} \times \textbf{Scale}) + \textbf{Offset}$$
$$= (157450.5 \times 5) + 200$$
$$= 787452.5$$

This value is rounded up to 787453 (C03FDh in hexadecimal). Therefore, register 2001h is written with the value "000C" and register 2001h is written with the value "03FD" following a write operation.

Reading a bitmask value

Bitmask values are used to extract the values of one or more bits from a register during a read operation. The following logic equation is used for conversion:

Internal value = (External value AND **Mask**) RIGHT-SHIFT by **Shift**, if Shift ≥ 0
Internal value = (External value AND **Mask**) LEFT-SHIFT by **Shift**, if Shift < 0   **Eq. 8**

Example:Bitmask read calculation

Consider the following register map definition.

Figure 41: Definition for bitmask read example

If the register at Modbus address 2000h contains the value "A05Eh", the value is binary and expressed as 1010000001011110. As shown, the Mask value in binary is 0000000000001000.

We have 1010000001011110 AND 0000000000001000 = 0000000000001000. Right shifting this value by "3" produces a binary value of 0000000000000001, which equals decimal 1.

Writing a bitmask value

The bitmask data type is also used in a Modbus write coil operation. In Modbus, a coil can have discrete values of 0 or 1. The following logic equation is used for conversion:

$$\text{External value} = (\text{Internal value LEFT-SHIFT by } \textbf{Shift}) \text{ AND } \textbf{Mask} \qquad \textbf{Eq. 9}$$

Example:Bitmask write calculation

Consider the following register map definition.

Figure 42: Definition for bitmask write example

The value of the Mask setting is "1" and the value of the Shift setting is "0". Therefore, if the value of bit 0 of the "Output" is 1, then the coil at Modbus address 0010h is set. Otherwise, the coil is cleared.

Reading a Boolean value

The Boolean data type compares the register against the arbitrary values of true and false during a read operation. Using the Boolean data type in conjunction with a read operation converts the external 16-bit register to a Boolean value using the following algorithm:

$$
\begin{aligned}
&\text{If external value} = \textbf{False} \\
&\text{then internal value} = \textbf{False} \\
&\text{else internal value} = \textbf{True}
\end{aligned}
$$

Eq. 10

Example:Boolean read calculation

Consider the following register map definition.

Figure 43: Definition for Boolean read example

If the register at Modbus address 0011h is exactly "0", then it is equal to the configured value of False and "Input" takes a false value following a read operation.

Writing a Boolean value

The Boolean data type sets the register with the arbitrary values of true and false during a write operation. Using the Boolean data type in conjunction with a write operation converts the internal Boolean representation to a 16-bit register value using the following algorithm:

$$
\begin{aligned}
&\text{If internal value} = \textbf{False} \\
&\text{then external value} = \textbf{False} \\
&\text{else external value} = \textbf{True}
\end{aligned}
$$

Eq. 11

Example:Boolean write calculation

Consider the following register map definition.

Figure 44: Definition for Boolean write example

If the "Output" is true, then Modbus register 0010h takes the value "1" following a write operation. Otherwise, the register takes a value of "0".

Add register maps

Each type of device in the microgrid requires Modbus memory map information for communicating with the U90^{Plus}.

There are likely several devices within the microgrid that have the same internal register mapping. For example, there can be several generators, each with the same model of controller. The register map editor allows a single register map to be configured for all of these devices. In addition, the devices added in the register map editor are global and can be shared by any number of U90^{Plus} units and offline configuration files.

The U90^{Plus} ships with memory maps already added for several GE products, such as the UR products. Otherwise, you add custom device definitions using the editor or import them as XML files.

To import a register:

1. Close all windows open in the software.
2. Select the **File > Register Map Editor** menu option.
3. In the window that opens, click the **Import** button.
4. Navigate to and select the XML file to import.
5. Click the **Open** button. An error message displays when the file content is invalid.

To add a register:

1. Select the **File > Register Map Editor** menu option.
2. In the window that opens, click the **New** button.

Figure 45: Register map window listing devices
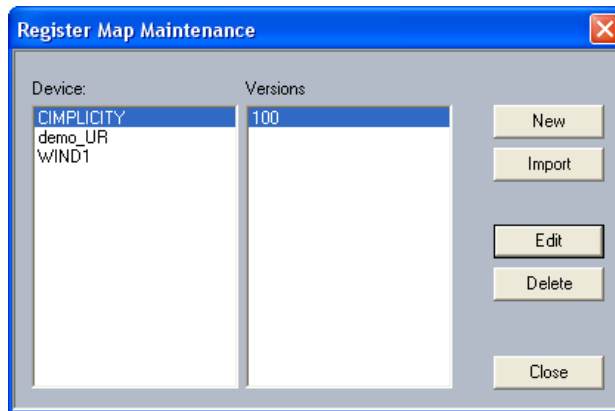
3. In the window that opens, enter a name for device type or setup and the version number. Examples are UR version 60 (for version 6.0) and CIMPLICITY 100 (for version 1.00). The version number must end with a zero. Click the **OK** button to add the device.

Figure 46: Add device type and version
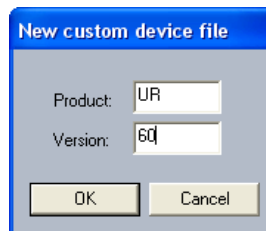
4. With the device type and version number selected, click the **Edit** button. Add the memory map set points that are important, for example 10 to 12 per device type; you do not need to add the entire memory map. Be sure to include all inputs to the U90^{Plus} and outputs from the U90^{Plus}. The fields are explained as follows.

As shown in the following figure, note that typically either a read or write function is configured for a set point label.

Figure 47: Register map example

Label

Range: unlimited alphanumeric characters
Default: blank

Enter a text string that uniquely identifies each instance of a point definition. Examples are RX2020B, WX1000B, RenewableNetMtrPower, GridAvailability, LoadOnline, and LoadWatchDog.

This field must contain at least one ASCII character.

Address (Hex)

Range: unlimited alphanumeric characters
Default: blank

Identifies the location of the register within the external device. Enter the address as a hexadecimal number. Do not include the 0x prefix, for example enter 0000 for 0x0000. Other examples are 000f, 0012, and 001e. The registers are likely outlined for the resource in its user manual or available online, for example by entering the IP address of the device in a web browser when such access is supported.

Figure 48: Viewing memory map address in a web browser (B95^Plus example)

Read Function

Range: None, Read Holding Reg (0x03), Read Input Reg (0x04)
Default: blank

Select "None" if read access is not required for the register.

Select "Read Holding Reg" to read the contents of the holding register specified by the Modbus Address setting. To have the U90^Plus obtain data from a resource and hold it for later execution, select this option.

Select "Read Input Reg" to read the contents of the input register specified by the Modbus Address setting. To have the U90^Plus obtain the online status, availability, power output, or mode of a resource, such as a generator, select this option. As such, input registers can only be read.

Write Function

Range: None, Write single (0x06), Write multiple (0x10), Write force coil (0x05)
Default: blank

A coil is a boolean bit value.

Select "None" if write access is not required for the register.

Select "Write Single" to write to a single 16-bit register (used for 16-bit integer, bitmask, and Boolean data types). To have the U90^Plus write to the resource, select this option.

Select "Write Multiple" to write to multiple 16-bit registers (used for 32-bit integer and floating-point data types). To have the U90^Plus write to the resource, select this option.

Select "Write Force Coil" to write on/off discrete values. This function is not supported by the U90^Plus firmware.

Data Type

Range: CFT_FLOAT, CFT_FLOAT2, CFT_SINT16, CFT_SINT32, CFT_UINT16, CFT_UINT32, CFT_BIT, CFT_BOOL
Default: blank

CFT refers to format type. SINT refers to a signed integer, which can be a positive or negative number. UINT refers to an unsigned integer, which is a positive number.

Integers are used in the software to define analog inputs/outputs. Boolean values are used in the software to define digital inputs/outputs, where a Boolean value can have two possible values, such as true or false, or 0 or 1.

Select "CFT_FLOAT" for a 32-bit IEEE floating-point value.

Select "CFT_FLOAT2" for an IEEE floating-point value with upper and lower 16-bit words reversed.

Select "CFT_SINT16" for a 16-bit signed integer value.

Select "CFT_SINT32" for a 32-bit signed integer value.

Select "CFT_UINT16" for a 16-bit unsigned integer value.

Select "CFT_UINT32" for a 32-bit unsigned integer value.

Select "CFT_BIT" for a 16-bit bitmask value that is converted using mask and shift operations.

Select "CFT_BOOL" for a 16-bit value that is internally represented as a Boolean value (0 or 1, or true or false). Use this type for digital outputs that are to be sent from the U90^{Plus}. In the example shown earlier, the RenewableWatchDog output is to be sent from the U90^{Plus} to the resource.

In the case of 32-bit data types, the higher-order (or most significant) word is stored in the register specified by the Modbus address, and the lower-order (or least significant) word is stored in the register following the Modbus address.

Scale Mask

Range: unlimited alphanumeric characters
Default: blank

This Scale/Mask/True setting and the Offset/Shift/False setting are used in conjunction with the Data Type to provide signal conversion during a read or write operation.

When the Data Type is a floating-point number, a signed integer, or an unsigned integer, the scale operation applies. When the data type is a bitmask, the mask operation applies. When the data type is Boolean, the true operation applies.

Offset Shift

Range: unlimited alphanumeric characters
Default: blank

Select a value for the Offset/Shift/False setting.

When the Data Type is a floating-point number, a signed integer, or an unsigned integer, the offset operation applies. When the data type is a bitmask, the shift operation applies. When the data type is Boolean, the false operation applies.

Complete the installation

The following items remain to finish installing the U90^Plus. Use the specific sections referenced here, then work through the remaining panels in the software.

- Finish configuring the microgrid in the software
  - Add devices (**Settings > Inputs/Outputs > Communication Devices**)
  - Add inputs and outputs for the devices (**Settings > Inputs/Outputs**)
  - Configure devices (**Settings > System Setup > Microgrid Assets > Electrical Assets** and **Thermal Assets**)
  - Set the time periods for the forecasts (**Settings > Economic Dispatch Setup**)
  - Configure annunciator alarms (**Settings > Product Setup > Annunciator**)
  - Send all settings to the U90^Plus (**Settings > Send Setup to Device** when working online, or right-click and select **Write to Device** when working offline)
  - Set the operating mode of the U90^Plus (**Commands > Optimizer Operation Mode**)
  - Configure forecast settings for optimization (**Commands > Forecasts**)
- Verify operation (see the Verify Operation section)

Verify operation

To verify operation of the U90^Plus:

- Check that generation and storage devices are Online and Available in the **Actual Values** panels under **Optimal Dispatch**
- Check that the optimization results are feasible on the front panel or under **Actual Values > Optimal Dispatch > Problem Status**
- Check the alarms on the front panel or under **Actual Values > Annunciator Panel**. See the Annunciator (alarms) section.

The following tool is also helpful: **Actual Values > Data Recorder**. All input and output variables as well as the optimization internal variables for the prediction horizon are saved as COMTRADE files that can be checked in the Data Recorder.

Monitor microgrid

The system can be monitored in the software and on the front panels of the U90^Plus. The following functions can be used to monitor the microgrid:

- Verify operation (previous section)
- **Settings > System Setup > System Summary**
- View **Actual Values** (later section)
- View and turn off alarms (section in Maintenance chapter)
- View events in the event recorder (section in Maintenance chapter)

U90^{Plus} Microgrid Generation Optimization

Chapter 5: EnerVista software

This chapter outlines most panels in the EnerVista software. The sections and order largely reflect the software. After working through the panels in the **Settings** category, send the configuration to the device using **Settings > Send Setup to Device**.

Settings

This section outlines the panels under the **Settings** category. The panels are accessible in the **Online Window** or **Offline Window** area of the software, providing the option to work online in real-time or offline. In both cases, you need to send the setup to the unit.

Product Setup

This section outlines the panels under **Settings > Product Setup**.

Security   The unit supports password use for Ethernet connections. This command password controls the following operations:

- All settings in the **Commands** category of the software, including entry of data used for forecasts
- Changing the command password

The unit is shipped with the feature disabled and a password of 0.

If you enter a password in the panel, its entry is required to save changes in the **Commands** category. If you later return the password to the default of 0, it must be entered when saving changes. In other words, if you change the password, the password requirement cannot later be removed and you must always enter a password.

Figure 49: Set a password for the Commands category
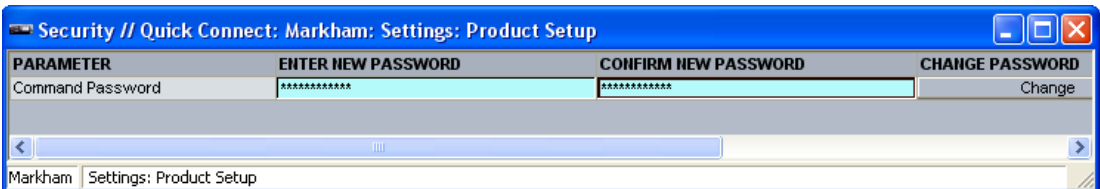
To set the command password:

1. In the **Online Window** area of the EnerVista software, navigate to **Settings > Product Setup > Security**.
2. To add a password for the first time, enter it in the two fields, click the **Change** button, and enter the default password of 0 at the prompt. A confirmation displays.
3. To change an existing password, enter a new password in the two fields, click the **Change** button, and enter the existing password at the prompt. A message displays for confirmation or failure.

The following settings are available.

Enter New Password
Range: up to 20 alphanumeric characters
Default: blank

The password to use for the **Commands** category of the software.

Confirm New Password
Range: up to 20 alphanumeric characters
Default: blank

The password to use for the **Commands** category of the software. It must match the **Enter New Password** field.

Communication

This section outlines the panels under **Settings > Product Setup > Communication**.

Network

The IP, subnet mask, and gateway addresses need to be configured for the U90^{Plus}. If you configured the IP address of the U90^{Plus} during installation as outlined in the Add Sites and Units section, use this panel to set the other addresses and other network settings. This panel configures the network settings for communication between the U90^{Plus} and the EnerVista software on the computer.

Also use this panel to change the IP address of the U90^{Plus} when the address on the unit and in the software are the same (meaning the unit has not been moved from one location to another).

If you move the unit from one location to another and the IP address of the unit differs from that in the software, contact GE Digital Energy. In this case, you cannot change the IP address in the software and send it to unit.

To configure network settings:

1. Navigate to **Settings > Product Setup > Communication > Network**.
2. Enter the IP address, subnet mask address, and gateway address.
3. Complete the rest of the fields, which are explained as follows.
4. Click the **Save** button. This saves the IP addresses in the software.
5. Send the IP addresses to the U90^{Plus} by navigating to **Settings > Send Setup to Device**, and confirming the change. The IP addresses change on the U90^{Plus}, though there can be a delay before they appear on the unit.

Figure 50: Network configuration
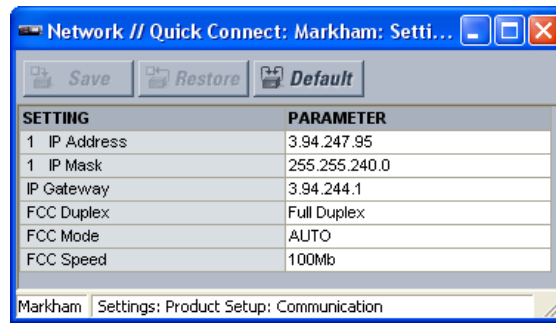
The addresses are used with the Modbus/TCP protocol. The following settings are available. FCC refers to Fast Communication Controller.

IP Address
Range: standard IP address range
Default: blank

This setting specifies the dedicated IP address for the Ethernet port of the U90^Plus.

IP Mask
Range: standard IP address range
Default: blank

This settings specifies the dedicated subnet mask for the Ethernet port of the U90^Plus.

IP Gateway
Range: standard IP address range
Default: blank

This setting specifies the dedicated gateway address for the Ethernet port of the U90^Plus.

FCC Duplex
Range: Full Duplex, Half Duplex
Default: Full Duplex

For both full duplex and half duplex, two-way communication takes place. With full duplex, communication in both directions can occur simultaneously. An example is a telephone conversation. With half duplex, communication can occur in one direction at a time, not simultaneously, such as a walkie-talkie conversation.

This setting specifies if half or full duplex communication is to take place. Generally, you want to use full duplex, unless there are network elements that do not support full duplex, such as between the U90^Plus and microgrid resources, the resources themselves, or the computer running the setup software.

FCC Mode
Range: AUTO, 10_100_BASE_TX, 100_BASE_FX
Default: AUTO

This setting selects the Ethernet connection hardware type used on the U90^Plus, either 10/100Base-TX (twisted-pair) or 100Base-FX (fiber optic). Select "Auto" to automatically detect either of these.

FCC Speed
Range: 100Mb, 10Mb
Default: 100Mb

This setting specifies the speed of the Ethernet connection used on the U90^Plus. Select 10Mb when using 10Base-TX. Select 100Mb when using 100Base-TX or 100Base-FX. The speed can be indicated on the cable being used and is also determined by the network.

Modbus Protocol

The U90^Plus has a Modbus server for communication with operators and SCADA systems, and a Modbus client for communication with microgrid resources, such as diesel generators and storage devices. This panel configures the Modbus server. The server provides an upstream interface for user commands and information displays, forecast updates, and system interaction. It is used for receiving commands and forecast data. It serves data requests and control commands from SCADA systems.

The Modbus client is configured separately in the **Settings > Inputs/Outputs > Communication Devices** panel.

The ID and port number for communication with the Modbus server of the U90^Plus need to be configured.

Ta configure the Modbus unit ID and communication port:

1.   Navigate to **Settings > Product Setup > Communication > Modbus Protocol**.

Figure 51: Modbus server configuration
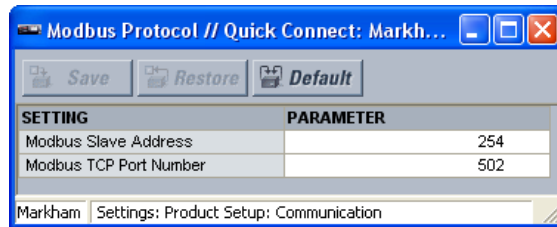
The following settings are available.

Modbus Slave Address

Range: 1 to 254

Default: 1

This setting is the slave ID field (unit ID) within the Modbus protocol. It is the ID of the U90^Plus. Each slave in the network is assigned a unique address/ID, so assign an ID to the U90^Plus here.

Modbus TCP Port Number

Range: 1 to 65535

Default: 1

The standard Modbus TCP port is 502, and the external resources and devices likely listen on that port. If you change the port number here, ensure that all devices use the same port number.

Real Time Clock

There are three options for clock synchronization to time-stamp events: use IRIG-B; use the U90^Plus internal clock; or enter it manually using EnerVista software. Both IRIG-B and the internal clock/calendar have the same accuracy as an electronic watch, approximately ±1 minute per month. When IRIG-B is not used, the U90^Plus internal real-time clock/calendar free-runs.

The date and time can be synchronized to a known time base and to other devices using an IRIG-B signal.

Two methods are outlined here:

•   Set date and time using IRIG-B

•   Manually set date and time in EnerVista software

To configure the date and time settings using IRIG-B:

1. Connect the third-party time-code generator to the U90^Plus via the IRIG-B port at the back of the U90^Plus. See the IRIG-B Port section earlier for information on how to set that up.

2. In the EnerVista software, navigate to **Settings > Product Setup > Real Time Clock**.

Figure 52: Clock configuration settings
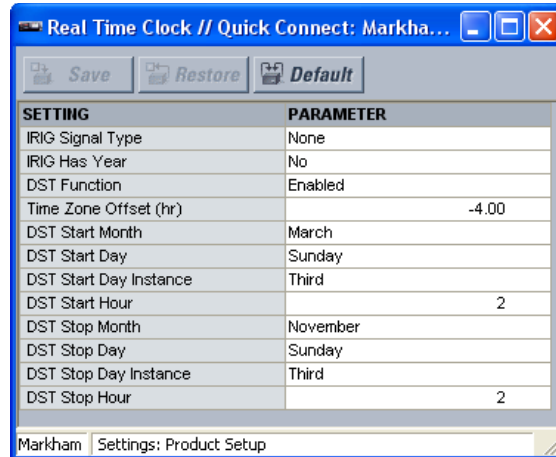
The following settings are available.

IRIG Signal Type

Range: None, DC Shift, Amplitude Modulated

Default: None

This setting selects the type of IRIG-B signal. Select "None" to disable IRIG-B. DC Shift refers to direct connection to digital systems. Amplitude modulation refers to audio tones or pulses. This selection is determined by the third-party equipment connected to the system.

IRIG Has Year

Range: No, Yes

Default: No

This setting enables and disables the inclusion of the year in the time-stamp when using IRIG-B. To explain why, year information was not specified in the IRIG standard prior to revision in 2004. Before 2004, the IEEE adopted a standard (IEEE 1344) that included year data as part of the IRIG-B signal. Always set this field when using IRIG-B.

DST Function

Range: Disabled, Enabled

Default: Disabled

This setting enables and disables the daylight saving time (DST) function. The DST settings can be used to allow the U90^Plus clock to follow the DST rules of the local time zone. The DST settings are used when IRIG-B is not used. They are ignored when IRIG-B synchronization is active because the IRIG-B signal takes care of DST.

Time Zone Offset

Range: –24.0 to 24.0 hours in steps of 1

Default: 0 hours

This setting specifies the local time zone offset from Coordinated Universal Time (UTC, or Greenwich Mean Time) in hours. An example is -4 hours for Toronto.

DST Start Month

Range: January through December

Default: January

This setting specifies the start month for daylight saving time. Examples are March in the northern hemisphere and November in the southern hemisphere.

DST Start Day

Range: Sunday to Saturday

Default: Sunday

This setting specifies the day of the week to start daylight saving time, for example Sunday.

DST Start Day Instance

Range: First, Second, Third, Fourth

Default: First

This setting specifies the week to start daylight savings time. For example, when daylight saving time begins on the third Sunday in March, select Third.

DST Start Hour

Range: 0 to 24 hours

Default: 0

This setting specifies the hour to start daylight saving time. For example, when daylight saving time begins at 2:00 AM, enter 2 here.

DST Stop Month

Range: January through December

Default: January

This setting specifies the month to stop daylight saving time, for example November.

DST Stop Day

Range: Sunday to Saturday

Default: Sunday

This setting specifies the day of the week to stop daylight saving time, for example Sunday.

DST Stop Day Instance

Range: First, Second, Third, Fourth

Default: First

This setting specifies the week to stop daylight saving time. For example, when daylight savings time stops on the third Sunday in November, select Third.

DST Stop Hour

Range: 0 to 24 hours

Default: 0

This setting specifies the hour at which daylight saving time ends. For example, when daylight saving time ends at 2:00 AM, enter 2 here.

To manually set the date and time:

1. Navigate to **Commands > Set Date and Time**.

2. In the window that opens, click the **Sync Device to Computer** button, which sets the U90^{Plus} date and time values to the date and time of the computer running the EnerVista software. Verify the action at the prompt.

Or set the date and time in the **Manual Date** and **Manual Time** fields, then click the **Select** button beside the **Set Manual Data and Time** field. Verify the action at the prompt.

3. If prompted, enter the password. This is the commands password set under **Settings > Product Setup > Security**. A message displays indicating success.

Figure 53: Set date and time using computer
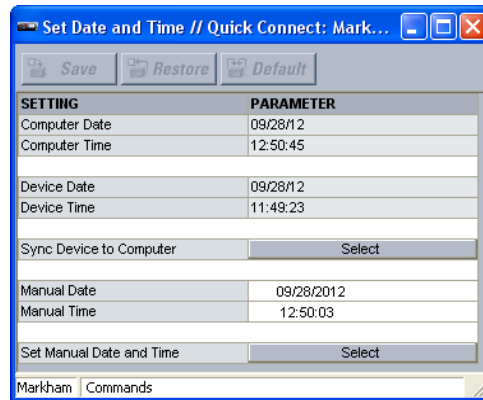
The following actual values display.

Computer Date

Range: date in MM/DD/YY format

This field displays the date specified by the computer running the EnerVista software.

Computer Time

Range: time in HH:MM:SS format

This field displays the time specified by the computer running the EnerVista software.

Device Date

Range: date in MM/DD/YY format

This actual value displays the date being used by the U90^{Plus} .

Device Time

Range: time in HH:MM:SS format

This actual value displays the time being used by the U90^{Plus} .

The following commands are available.

Sync Device to Computer

This command sets the U90^{Plus} date and time values to the date and time of the computer running the EnerVista U90^{Plus} Setup software.

Set Manual Date and Time

This command sets the U90^{Plus} date and time values to the date and time values specified in the **Manual Date** and **Manual Time** fields.

Installation   Configure the name of the U90^{Plus} and the number of resources connected to it. As an example, a microgrid that has 10 solar panels connected on one circuit is considered one installation, not 10.

Up to 32 resources can be connected in the microgrid, with maximum per device type as follows.

Table 5: Maximum configuration by device type

Resource	Maximum number (up to total of 32)
Boilers	8
CHPs	8
Dispatchables (auto-start)	16
Grids	1
Heat Loads	16
Loads	16
Renewables	16
Storage	16

To configure the system name and number of resources:

1. In the software, navigate to **Settings > Product Setup > Installation**.

Figure 54: Installation settings
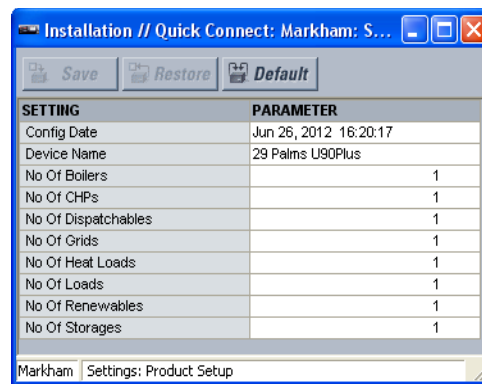
The following settings are available.

Config Date
Range: alphanumeric characters
Default: 0

This setting records the date and time of the last setting change through the EnerVista software. Each time any settings are changed or a new settings file is loaded, this value is updated. It can also be manually changed here.

Device Name
Range: alphanumeric characters
Default: blank

This setting allows the user to uniquely identify the U90^{Plus}. This name appears on all generated reports. An example is 29 Palms U90Plus.

No of Boilers
Range: 0 to 8
Default: 0

This setting specifies the number of boilers in the microgrid used to generate heat.

No of CHPs
Range: 0 to 8
Default: 0

This setting specifies the number of combined heat and power (CHP) devices in the microgrid that generate heat and/or electricity.

No of Dispatchables

Range: 0 to 16

Default: 0

This setting specifies the number of dispatchable resources in the microgrid that are turned on an off when required. Examples are diesel generators and natural gas turbines. Include traditional generators, such as hydro and coal, when used specifically as a dispatchable resource to meet demand, and otherwise exclude them. Dispatchable generators that start automatically are supported; manual-start dispatchable generators are not.

No of Grids

Range: 0 to 1

Default: 0

This setting indicates when the microgrid is connected to a grid and can supply or draw power from the grid. Only one grid can be specified at this time.

No of Heat Loads

Range: 0 to 16

Default: 0

This setting indicates the number of systems drawing heat from the microgrid. For example, a residential area counts as one load and a commercial area counts as a second load.

No of Loads

Range: 0 to 16

Default: 0

This setting indicates the number of systems drawing electricity from the microgrid. For example, a residential area counts as one load and a commercial area counts as a second load.

No of Renewables

Range: 0 to 16

Default: 0

This setting indicates the number of resources in the microgrid that generate power from a renewable source, such as solar, wind, and hydro. As an example, for an installation of 20 solar panels connected to the same circuit, enter 1. For installations of 10 solar panels at an office building and 10 solar panels in a residential area, enter 2.

No of Storages

Range: 0 to 16

Default: 0

This setting indicates the number of storage resources in the microgrid. As an example, for an installation of 15 batteries connected to the same circuit for two wind turbines, enter 1.

Annunciator (alarms)

You configure the annunciator by configuring alarms. Configuration consists of selecting the alarm, naming it, and selecting the alarm color. The alarms display on the annunciator panel and in the software.

Up to 96 alarm entries can be configured.

You need to manually check for any triggered alarms. To be automatically notified of alarms, use control software, such as GE CIMPLICITY or third-party software.

Table 6: Alarm events

Alarm event	Action
IRIG-B failure	The external clock source failed. Check the connection at the back of the unit and the time-source equipment to which it is connected.
System exception	Unexpected unit reset
File system trouble	Unauthorized external change to the local file system (somebody tampered with the local files)
Ethernet port failure	Check that the cable is connected to the Ethernet port at the back of the U90^{Plus}. Then check the cable itself.
Unit not programmed	The U90^{Plus} has not been configured. Configure it using its EnerVista software.
Power failure diagnostic lost	Not able to retrieve the power failure diagnostic info
Low memory	System is running with low memory resources
Prototype firmware	The system is running a prototype release of the firmware
File "mod": can't open	Solver related error: the required modle file is missing
File "dat": can't open	Solver related error: the required data file is missing (was not generated)
File solution: can't create	Solver related error: the firmware is unable to write the solution file
Actuals reading timeout	Modbus client times out when trying to retrieve data from remote IEDs
Solver time limit exceeded	Solver related error: unable to find a solution within a reasonable amount of time
Solver failed	Solver related error: the solver fails to find a solution, for example due to insufficient memory
Solver no primal/dual solution	Solver related error: the problem has no feasible solution, meaning that there is no solution that satisfies all the constraints
Solver no convergence	Solver related error: no converge to an optimal solution
Solver invalid data	Solver related error: data file parsing fails; error with the generated data file
Solver result out of range	Solver related error: solution is out of range
Solver solution is undefined	Solver related error: undefined solution
Solver solution is unbounded	Solver related error: solution is not finite (feasibility condition is not violated but the value of one or more decision variables and the objective function approach infinity)
Comm Data Failure: Dev [1...32]	The U90^{Plus} is unable to communicate with one of the devices
Unexpected Disp [1...16] Offline	One of the dispatchable resources went offline unexpectedly
Unexpected Disp [1...16] Online	One of the dispatchable resources came online unexpectedly
Unexpected Disp [1...16] in Droop	Discrepancy between the "Isoch" command and actual reading from the device
Unexpected Disp [1...16] in Isoch	Discrepancy between the "Droop" command and actual reading from the device
Unexpected Renew [1...16] in Droop	Discrepancy between the "Isoch" command and actual reading from the device
Unexpected Renew [1...16] in Isoch	Discrepancy between the "Droop" command and actual reading from the device
Unexpected StoreChg [1...16] Offline	One of the charging storage devices went offline unexpectedly
Unexpected StoreChg [1...16] Online	One of the charging storage devices came online unexpectedly
Unexpected StoreDischg [1...16] Offline	One of the storage devices supplying electricity to the microgrid went offline unexpectedly
Unexpected StoreDischg [1...16] Online	One of the storage devices that supplies electricity to the microgrid came online unexpectedly

The U90^{Plus} monitors the alarms every 10 seconds.

Figure 55: Alarm configuration
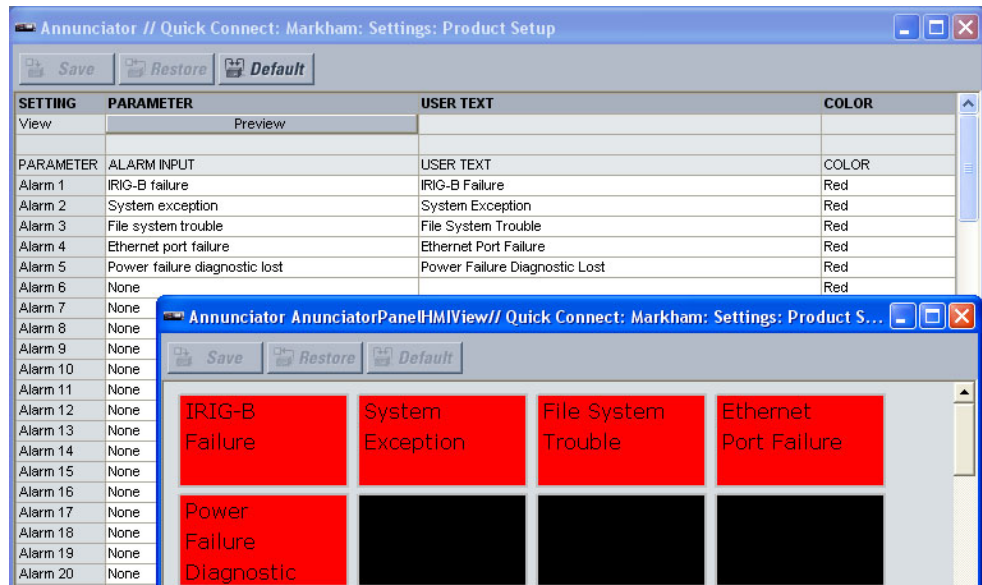
To configure the annunciator alarm display:

1. In the software, navigate to **Settings > Product Setup > Annunciator**.

2. Configure one alarm as follows. Select the alarm type by selecting it from the drop-down list in the **Parameter** column. Type a name for the alarm in the **User Text** column. Specify a color to display when the alarm is triggered in the **Color** column.

3. Click the **Preview** button to view the alarm display similar to that on the front panel of the unit.

4. Configure any other alarms by repeating steps 2 and 3.

5. To send the configuration to the unit, navigate to **Settings > Send Setup to Device**.

6. To view the alarm status, there are three options: click the **Preview** button; navigate in the software to **Actual Values > Annunciator**; or view the annunciator display.

The following settings are available and apply to all 96 alarms.

Parameter
Range: selectable from configured alarms
Default: None

This setting specifies the input signal connected to the alarm.

User Text
Range: up to 36 alphanumeric characters
Default: blank

This setting specifies the text to display for the alarm, for example on the front panel.

Color
Range: Red, Yellow, Blue
Default: Red

This setting specifies the color of the alarm background.

Inputs/Outputs

Identify in the software the inputs and outputs of each resource. For example, for a wind turbine you enter its generated power as an output. There is no input for this resource.

These inputs/outputs are those that are read from or written to the system. They are also referred to as Communication Inputs (ComIns) and Communication Outputs (ComOuts), and they differ from the main or internal U90^{Plus} inputs/outputs used in the optimization model.

Using the following sections, enter the input and output information for all resources, such as diesel generators, the grid, cogenerators, boilers, and storage.

Communication Devices

Each device in the microgrid other than the U90^{Plus} needs to be configured in this panel, for example to specify its IP address for communication purposes. The table provides an example of the information required.

Table 7: Example of device information required in EnerVista software

Setting	Example
Name	F35-1
Type	UR
IP address	192.168.0.174
Slave ID	254
Response time-out (RESPTOUT)	0.5
Connection time-out (CONNTOUT)	500

The number of UR units, UR^{Plus} units, and resources supported is 32.

To add a resource to the software:

1. Navigate to **Settings > Inputs/Outputs > Communication Devices.**
2. Select the device from the **Type** drop-down list. When it does not appear, it means that it needs to be configured first under **File > Register Map Editor**.
3. Complete the rest of the fields.

Figure 56: Add information for each device in the microgrid
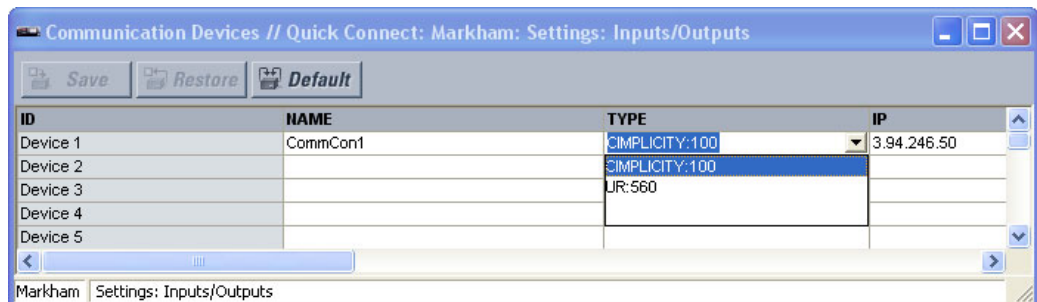
The following settings are available.

Name

Range: up to 24 alphanumeric characters
Default: blank

Specify a name for the resource, such as F60, CommCon1, or Wind Turbine 1. This is the name used in other panels of the software.

Type

Range: selectable from register map editor entries
Default: blank

This setting specifies the type of resource and includes the version number, for example UR version 5.6. The resource needs to be entered under **File > Register Map Editor** to be selectable here. The memory map used for communication can be shared among several devices of the same type, for example there can be three F60 devices that use the same register map for UR version 5.6.

IP

Range: standard IP address
Default: blank

This setting specifies the IP address of the resource. On a UR or UR^{Plus} device, the IP address can be viewed on the annunciator panel or in the EnerVista software.

Slave

Range: 0 to 254
Default: blank

This setting is the slave ID field (unit ID) within the Modbus protocol. It is the ID of the resource, and each device in the microgrid has a unique ID. On a UR or UR^{Plus} device, the ID is set and viewable in the EnerVista software, for example under **Settings > Product Setup > Communications > Modbus Protocol**.

Resptout

Range: 0 to 60 seconds
Default: blank

This setting specifies the response time-out in seconds, which is the time allowed for the resource to respond to the U90^{Plus}.

Conntout

Range: 0 to 60 seconds
Default: blank

This setting specifies the connection time-out in seconds, which is the time allowed for the resource to be disconnected or inaccessible before it is considered offline by the U90^{Plus}.

Inputs   An input is a data point that is read by the U90^{Plus} from a resource. Configure in the software the digital, analog, and virtual inputs of the resources.

Virtual inputs are virtual digital inputs that are either 0 or 1. An example is to use two virtual inputs to build HMI availability for a diesel generator, which is explained as follows:

- Virtual input 1 and Virtual input 2 can be assumed to be Availability and Unavailability, respectively

- The above virtual inputs are latched, and the result is assigned to virtual output 1. We can call this virtual output as HMI availability.

- Virtual output 1 is ANDed with the diesel 1 availability that U90^{Plus} reads from the device (remote input) and defined in the Register Map Editor

- The outcome is assigned to virtual output 2

- Virtual output 2 represents the final availability of the dispatchable that can be assigned to the main U90^{Plus} input (DISPATCHABLE_INPUT_1.Availability) in the Equation Editor; this is explained in the Equation Editor section.

The inputs need to be already defined in the register map under **File > Register Map Editor**. There is no one-to-one correlation of the inputs in the register map and those configured in the panels. For example, 21 inputs can be defined in the **Digital Inputs** panel

and eight in the **Analog Inputs** panel, while there are 25 inputs defined in the register map for the device type. The register map can contain all inputs that can be required, while the input panels contain a subset that you want the U90^{Plus} to actually read.

Digital, analog, and virtual inputs can each have 256 inputs configured.

To configure an input in the software:

1. Navigate to **Settings > Inputs/Outputs > Digital Inputs**, **Analog Inputs**, or **Virtual Inputs**.

When done, all inputs also need to be configured in the Equation Editor.

Figure 57: Configure inputs from each resource

The following settings are available.

Name

Range: up to 100 alphanumeric characters
Default: blank

Enter a unique name for the input, such as RENEWABLE_INPUT_1_Online to indicate when a renewable generator is online. Select the **ID** field first to help with naming here, such as selecting RenewableOnline as the ID.

Device

Range: selectable list
Default: blank

Select the resource providing the input. The name needs to be added in the **Communication Devices** panel to be selectable here.

ID

Range: selectable list
Default: blank

Select the type of input. The items selectable are those that are defined in the **Label** field of the register map under **File > Register Map Editor**.

Sample Rate

Range: 0, 1
Default: 0

This setting is the rate at which the output is written to the configured server. 0 means that the output is sent at the control loop period (typical 10 sec) when Auto mode is enabled. 1 means that the output is sent regardless of the mode of operation at the same rate.

Outputs   An output is information or data sent from the U90^{Plus} to a resource. Configure in the software the digital, analog, and virtual outputs to be communicated to the resources.

Virtual outputs are virtual digital outputs that are either 0 or 1. An example is to use two virtual inputs to build HMI availability for a diesel generator, as outlined in the previous section.
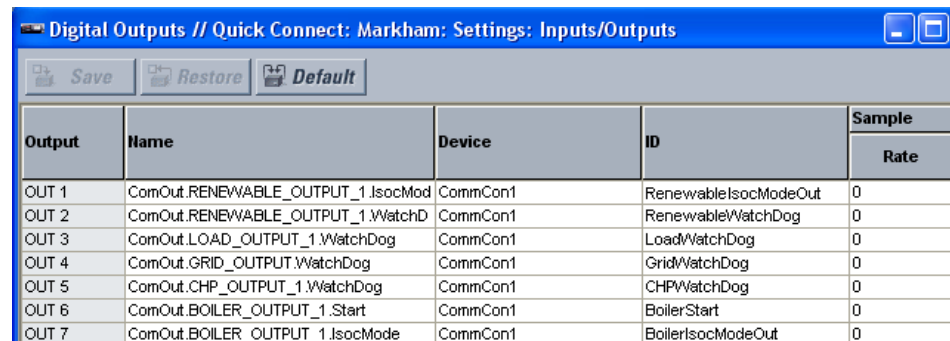
Digital, analog, and virtual outputs can each have 256 outputs configured.

To configure an output in the software:

1.   Navigate to **Settings > Inputs/Outputs > Digital Outputs**, **Analog Outputs**, or **Virtual Outputs**.

When done, all outputs also need to be configured in the Equation Editor.

Figure 58: Configure outputs from the U90^{Plus} to resources

The following settings are available.

Name

Range: up to 100 alphanumeric characters
Default: blank

Enter a unique name for the output, such as BOILER_OUTPUT_1_Start to indicate when a boiler is to start. Select the **ID** field first to help with naming here, such as selecting BoilerStart as the ID.

Device

Range: selectable list
Default: blank

Select the resource to receive the output from the U90^{Plus}. The name needs to be added in the **Communication Devices** panel to be selectable here.

ID

Range: selectable list
Default: blank

Select the type of output. For digital outputs, the options selectable are those that are defined as outputs (write function) with Boolean data types in the register map under **File > Register Map Editor**. For analog outputs, the options selectable are those that are defined as outputs (write function) with integer data types in the register map.

Sample Rate

Range: 0, 1
Default: 0

This setting is the rate at which the output is written to the configured server. 0 means that the output is sent at the control loop period (typical 10 sec) when Auto mode is enabled. 1 means that the output is sent regardless of the mode of operation at the same rate.

Virtual Analogs

Virtual analogs (like all other virtual entities) are intrinsic values to the U90^{Plus} device (hence not defined in the register map). These are mainly used in equations (see the Equation Editor section). Their purpose is to give the user the ability to store intermediate results or to control certain parameters (for example, asset inputs/outputs), usually during the system commissioning stage. The only entry is the name. This is used in connection with the specific VA in the equation editor (if the user defines such an equation).

Up to 512 entries are possible.

To configure a virtual analog value:

1. Navigate to **Settings > Inputs/Outputs > Virtual Analogs**.

The following settings are available.

Name

Range: up to 100 alphanumeric characters
Default: blank

The only entry is the name. This is going to be used in connection with the specific VA in the equation editor (if the user defines such an equation).

Equation Editor

One step in the configuration of the microgrid is to make assignments between the microgrid resources and the dispatch algorithm. These assignments are done in the equation editor. All inputs and outputs added in the **Inputs/Outputs** panels need to be added here. The configuration here outlines for the software what to do with the inputs/outputs.

To explain in more detail, there are some readings from the microgrid, and there are some writings to the microgrid. We call them communication Inputs (ComIn) and communication Outputs (ComOut), respectively. For example, we read power and the online or offline status of a dispatchable resource. These are ComIns. The U90^{Plus} also has some Inputs. We have to assign those ComIns to these Inputs. Sometimes we directly assign what we read (ComIn) to U90^{Plus} Input without doing any particular mathematical calculations (the following figure shows examples).
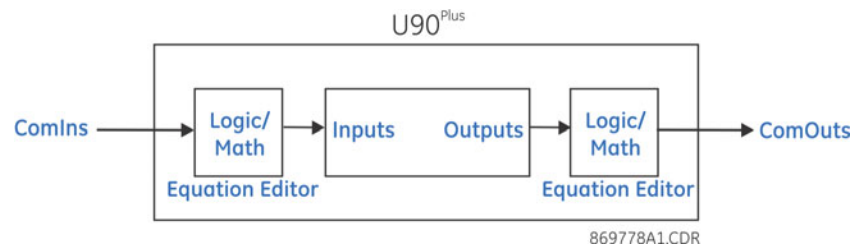
Figure 59: Microgrid logic configuration settings

FLEXLOGIC ENTRY	TYPE	SYNTAX
View Graphic	View	View
Logic Entry 1	Comms Input	ComIn.RENEWABLE_INPUT_1.NetMtrPower [COM I]
Logic Entry 2	Assign Input	= RENEWABLE_INPUT_1.NetMtrPower [I]
Logic Entry 3	Comms Input	ComIn.RENEWABLE_INPUT_1.Online [COM I]
Logic Entry 4	Assign Input	= RENEWABLE_INPUT_1.Online [I]
Logic Entry 5	Comms Input	ComIn.RENEWABLE_INPUT_1.IsocMode [COM I]
Logic Entry 6	Assign Input	= RENEWABLE_INPUT_1.IsocMode [I]
Logic Entry 7	Comms Input	ComIn.RENEWABLE_INPUT_1.Availability [COM I]
Logic Entry 8	End of List	
Logic Entry 9	Comms Input	ComIn.LOAD_INPUT_1.NetMtrPower [COM I]
Logic Entry 10	Assign Input	= LOAD_INPUT_1.NetMtrPower [I]

Sometimes ComIn is multiplied by a fixed number to change the scale (for example, converting Watt to KWatt), and sometimes we need to do more complicated calculations. These are all done in the Equation Editor. For example, for each storage device the U90^{Plus} has one internal Input for State of Charge (SOC), which is used in the optimization model. If this is hydrogen, we usually read Temperature and Pressure, and based on an equation the value of SOC is calculated and finally assigned to the corresponding U90^{Plus} internal input variable. In this example, Temperature and Pressure are ComIns. The same applies to Outputs and ComOuts. The U90^{Plus} comes up with some optimal

decisions; these decisions need to be communicated with the assets, or in other words they need to be assigned to ComOuts. With the Equation Editor, you build the logic between Outputs and Comouts, as summarized in the following figure.

Figure 60: Concept of Equation Editor

Up to 512 variables can be entered in an equation. Up to 16 variables can be stacked per entry.

To configure microgrid logic:

1.   Navigate to **Settings > Equation Editor**.

Click the **View** button at the top of the equation to display a graphical representation of the microgrid logic. All inputs defined in the equation must be used by either a corresponding assignment operator or a flex log item, such as ADD. When an error message displays that no code is allowed between the last assigned virtual output and the end of the program, it means that the last line in the equation has to be an assignment operation.

Figure 61: Microgrid logic display
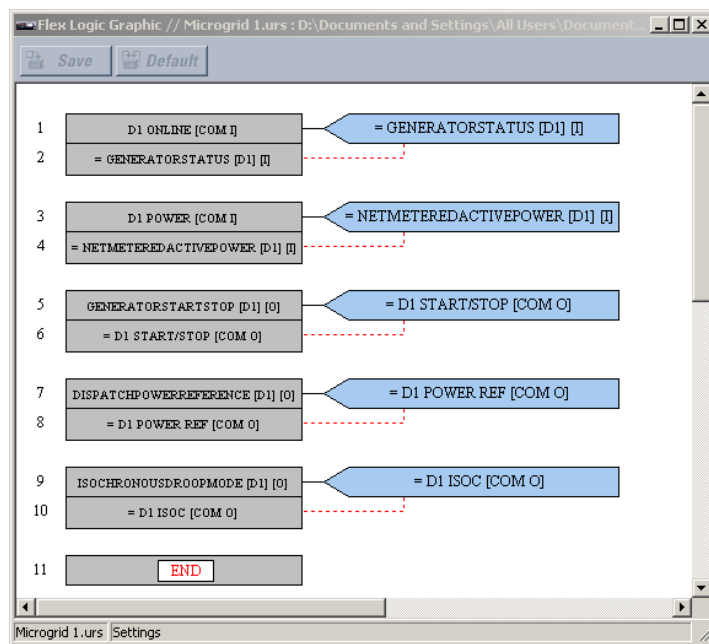
Type

Range: selectable list
Default: End of List

Select the action to perform. See the table.

Table 8: Equation variables

Equation variable	Description
ADD SUB MUL DIV	Performs an arithmetic operation, taking the last two items off the stack and pushing the arithmetic result back onto the top of the stack
NOT	Performs a bitwise NOT operation, taking the last item off the stack and pushing the result of the operation onto the top of the stack
LNOT	Performs a logical NOT operation, taking the last item off the stack and pushing the result of the operation onto the top of the stack
AND NAND OR NOR XOR	Performs a corresponding bitwise logical operation, taking the last two items off the stack and pushing the bitwise logical result onto the top of the stack
SHIFT RIGHT	Uses the last two items on the stack (unsigned integers), shifting item (n-1) right by the value of (n). The results of the shift operation is then pushed onto the top of the stack.
SHIFT LEFT	Uses the last two items on the stack (unsigned integers), shifting item (n-1) left by the value of (n). The result of the shift operation is then pushed onto the top of the stack.
DUPLICATE	Duplicates the last item on the stack
EQUAL GREATER THAN GREATER THAN OR EQUAL LESS THAN LESS THAN OR EQUAL NOT EQUAL	Takes two values off the stack, compares them, and pushes the resulting Boolean value onto the top of the stack
SWAP	Swaps the last two items on the stack
Analog Constant	Pushes a constant floating point value onto the top of the stack
Comms Input	Reads the specified communication device's registers and pushes it onto the top of the stack
Assign Input	
Output	Takes the specified output from the optimizer, and pushes it onto the stack. The set of optimizer outputs available is dependent on the set of assets configured for the installation.
Assign Comms Output	Takes the last value off of the stack and writes it to the specified communication device's registers
Virtual Input	Pushes the specified virtual input onto the top of the stack
Assign Virtual Output	Takes the last value off the stack and assigns it to the specified virtual output
Virtual Analog	Pushes the specified virtual analog onto the stack
Assign Virtual Analog	Takes the last value off the stack and assigns it to the specified virtual analog output
End of List	Marks the last entry in the list

Syntax

Range: selectable list

Default: blank

Select the equation variable. The options selectable reflect the entries in the **Inputs/ Outputs** panels.

System Setup

Configure the microgrid in the software.

Microgrid Operation Modes

Microgrid operation modes differ from optimizer operation modes. For the microgrid, the operation mode refers to isochronous or droop control. For the optimizer, the operation mode determines if the U90^{Plus} performs optimization calculations and communicates with the resources/devices in the microgrid.

To configure microgrid operation modes:

1. Navigate to **Settings > System Setup > Microgrid Operation Modes**.

Figure 62: Configure microgrid operating margins

The following settings are available.

Active Mode

Range: 1, 2, 3, 4

Default: 1

This setting specifies the microgrid operation mode to use. An example of mapping is as follows:

1. Dispatchable isochronous load share (default)
2. Renewable in isochronous
3. Single dispatch in isochronous (CHP)
4. Grid in isochronous

When you have two wind turbines, battery storage, hydro, a backup diesel generator, and a grid connection, all four modes potentially apply. In this case, because the grid connection exists, the grid behaves like an isochronous machine, and hydro in isochronous mode or dispatchable in isochronous mode cannot be selected.

Isoch Margin Plus 1...4, Isoc Margin Minus 1...4

Range: 0 to 100

Default: 0.2

When connected to a grid, the grid compensates for any imbalance between load and generation in the microgrid, behaving like an isochronous machine for the microgrid. However, for islanded microgrids, there is a need for an isochronous machine to maintain load-generation balance and stabilize the microgrid for instantaneous load and renewable generation variations above or below the forecasted values. Such an isochronous machine provides reserve margins in both positive and negative directions

to address the deficit or surplus of power, respectively. These margins are defined as a percent of the total load in the microgrid and need to be defined for both grid-connected and islanded microgrids.

Configure the margins for a microgrid, for both power deficit (the plus margin) and power surplus (the minus margin). The numbers 1 to 4 correspond to the following microgrid operation modes. Configure all values. The higher the variation in power generation, the greater the margin. For example, due to the highly variable nature of solar and wind power, a larger margin can be entered than for a hydro or CHP installation.

1. Dispatchable isochronous load share (default)
2. Renewable in isochronous
3. Single dispatch in isochronous (CHP)
4. Grid in isochronous

Heat Isoch Margin Plus, Heat Isoch Margin Minus

Range: 0 to 100
Default: 0.2

See the explanation for the previous setting.

Configure these settings for a microgrid, for heat deficit (plus margin) and heat surplus (minus margin).

Constraint Mode

Range: Hard, Soft
Default: Hard

Soft constraint means that there are slack variables (in different time steps) in the power-balance constraints of the optimization problem that are penalized in the objective function.

Hard constraint means such slack variables do not exist. These slack variables are defined to insure the feasibility of the optimization problem without significantly compromising/influencing the reserve-margin requirements of the microgrid specified in the same panel.

Power Balance Penalty

Range: $0 to 1000 per kW
Default: $0 per kW

Power balance refers to a match between power generation and demand/load. The power being generated at any one time ideally equals the power being consumed at that time.

This setting specifies a penalty on power balance violation, for both excess power and shortages

Use this setting in conjunction with **Constraint Mode**.

Heat Constraint Mode

Range: Hard, Soft
Default: Hard

Soft constraint means that the microgrid is allowed to violate its heat power balance but at the cost of a penalty in the objective function. Having the possibility of going above or below the heat power balance (soft constraint) helps the feasibility of the optimization.

Hard constraint means that the microgrid is not allowed to go above or below the heat power balance margins specified in the same panel.

Heat Power Balance Penalty

Range: $0 to 1000 per kW

Default: $0 per kW

This setting specifies a penalty on a violation of heat power balance, for both excess heat and heat storage.

Use this setting in conjunction with **Heat Constraint Mode**.

Dispatchables

Add information in the software for each dispatchable resource, such as operating capacity, operating cost, and minimum operating period of a diesel generator.

The number of dispatchable entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel.

Auto-start dispatchable resources are supported, not manually started generators.

To add information for a dispatchable resource:

1. Navigate to **Settings > System Setup > Microgrid Assets > Electrical Assets > Dispatchables**.

Figure 63: Add information for a dispatchable generator

The following settings are available.

Name

Range: up to 20 alphanumeric characters

Default: blank

Enter a name for the resource, such as DIESEL 01 or DISPATCHABLE 1.

Enabled

Range: Disabled, Enabled

Default: Enabled

This setting specifies if the resource is to be included in the microgrid optimization calculations by the U90^{Plus}.

Rated Power

Range: number
Default: 250 kW

This setting specifies the maximum power generation capacity of the dispatchable resource in kW.

Min Power

Range: number
Default: 50 kW

This setting specifies the preferred minimum power, in kW. For example, some generators need to be operated at a minimum of 30 percent of their rated power, expressed in kW.

Efficiency Max

Range: 0 to 1000 kWh/kg
Default: 0.75 kWh/kg

This setting specifies the efficiency at maximum generator power, in kWh per kg of fuel consumed. Calculate the number using the related curves for your generator. If the dispatchable efficiency at maximum power is available in terms of percent, this setting can simply be determined by multiplying the percent value with the higher heating value or energy content of the input fuel in terms of kWh/kg. Higher heating values for different fuel sources can be found in the related handbooks or the Internet.

Efficiency Min

Range: 0 to 1000 kWh/kg
Default: 0.55 kWh/kg

This setting specifies the efficiency at minimum generator power, in kWh per kg of fuel consumed. Generators are usually less efficient when operating at low loads. Calculate the number using the related curves for your generator. If the dispatchable efficiency at minimum power is available in terms of percent, this setting can simply be determined by multiplying the percent value with the higher heating value or energy content of the input fuel in terms of kWh/kg. Higher heating values for different fuel sources can be found in the related handbooks or the Internet.

Start Cost

Range: any number
Default: $10

This setting specifies the cost to power up the resource. Include the costs that you think are important based on your experience with the microgrid.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Stop Cost

Range: any number
Default: $10

This setting specifies the cost to power down the resource.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Fuel Cost

Range: $0 to 100 per liter
Default: $1.00 per liter

This setting specifies the cost of fuel that operates the dispatchable generator, in dollars per liter. For example, enter the price for a liter of diesel fuel or gasoline.

The volume of gaseous fuels are usually expressed in terms of Normal cubic meter (Nm^3). Therefore, **Fuel Cost** of dispatchable generation resources running on gaseous fuels can also be expressed in terms of dollars per Nm^3; however, in this case, **Fuel Density** also needs to be in terms of kg per Nm^3.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Fuel Density

Range: 0 to 1000 kg/L
Default: 0.85 kg/L

This setting specifies the specific gravity of fuel in kg per liter. Values differ based on the fuel type, such as natural gas and diesel. Use reference books or the Internet to determine this value. Examples are 0.832 kg/L for diesel, 0.745 kg/L for ethanol-free gasoline, 0.71 to 0.77 kg/L for gasoline, and 0.41 to 0.5 kg/L for liquefied natural gas (LNG).

Fuel Density can also be expressed in terms of kg/Nm^3, which is common for gaseous fuels. In this case, **Fuel Cost** also needs to be expressed in terms of $\$/Nm^3$. The unit of volume in both **Fuel Cost** and **Fuel Density** settings need to be the same.

Constraint Mode

Range: Off, On
Default: Off

On selects soft constraint, which means that the generator is allowed to violate its minimum power generation level but at the cost of a penalty in the objective function. Having the possibility of going below the minimum power (soft constraint) can positively affect the feasibility of the microgrid optimization problem.

Off selects hard constraint, which means that the generator is not allowed to go below its minimum power generation level.

Use this setting in conjunction with **Min Power Penalty**.

Min Power Penalty

Range: $0 to 1000 per kWh
Default: $0 per kWh

Use this setting in conjunction with **Constraint Mode**. This setting puts a numerical value on the minimum power violation. When the violation from minimum power is critical, set a high value here.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Isoch Operation Mode

Range: Droop, Isoch
Default: Droop

This setting specifies if isochronous or droop (non-isoch) mode is to be used for the dispatchable resources in each of the microgrid operation modes.

The numbers 1 to 4 for this setting refer to operation modes for the microgrid. Depending on the type of isochronous machine and how the reserve margins are provided, four different operation modes can be considered for the microgrid. The following modes are some examples that can be used:

1. Dispatchable/CHP isoch load sharing
2. Hydro in isoch
3. Single dispatchable/CHP in isoch
4. Grid in isoch

For example, assume in a particular microgrid, one big dispatchable generator can operate in isochronous mode. This corresponds to Operation Mode 3; however, any of the four operation modes can be assigned to a single dispatchable in isoch. If the operator follows the suggested operation-mode assignment (that is, Operation Mode 3 is single dispatchable in isoch) and Dispatchable 1 is supposed to be the isoch machine, the following are set for this machine:

Operation Mode 1 = Droop
 Operation Mode 2 = Droop
 Operation Mode 3 = Isoch
 Operation Mode 4 = Droop

This way, if you select the third mode to be the active mode for the microgrid, then Dispatchable 1 can run in isoch mode by receiving the isoch command from U90^{Plus}. For the other microgrid operation modes, Dispatchable 1 is in non-isochronous mode (as set by zero values). These operation modes are explained later in the Microgrid Operation Modes section.

The following fields indicate status and are read-only.

Online

This field indicates if the resource is online or offline. It is not necessarily the same as being available for use in the U90^{Plus} optimization calculations.

Input Isoch Mode

This field indicates if the resource is to be in droop or isochronous mode.

There is an input and output isoch mode. The input isoch mode is advice produced by the optimizer and issued to the dispatchable asset. The output isoch mode is the actual operating mode of the dispatchable asset. Assuming that the dispatchable resource follows the advice of the optimizer, the modes are usually the same.

Availability

Availability is declared by the generator. This field indicates if the generator can be controlled by the U90^{Plus} and included in the optimization problem solved by the U90^{Plus}. An online generator is not necessarily an available generator. The availability signal is built by the generator's local controller based on some parameters and is read by the U90^{Plus}.

Net Meter Power

This field indicates the power generation values in kW read from different dispatchable generators in the system.

Start

Start/stop is a command. When the U90^{Plus} sends the start command, the generator comes online after some time.

Output Isoch Mode

This field indicates if the resource is in droop or isochronous mode.

There is an input and output isoch mode. The input isoch mode is advice produced by the optimizer and issued to the dispatchable asset. The output isoch mode is the actual operating mode of the dispatchable asset. Assuming that the dispatchable resource follows the advice of the optimizer, the modes are usually the same.

Power Ref

This field refers to the power reference points of dispatchable generators, in kW. Their values are computed by the U90^{Plus} dispatch algorithm.

Renewables   Add information in the software for each renewable resource, such as power generating capacity and operating cost of a photovoltaic array.

The number of renewable entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel. Recall that renewable resources of the same type that are co-located are considered one device.

To add information for a renewable resource:

1.   Navigate to **Settings > System Setup > Microgrid Assets > Electrical Assets > Renewables**.

Figure 64: Add information for a renewable generator
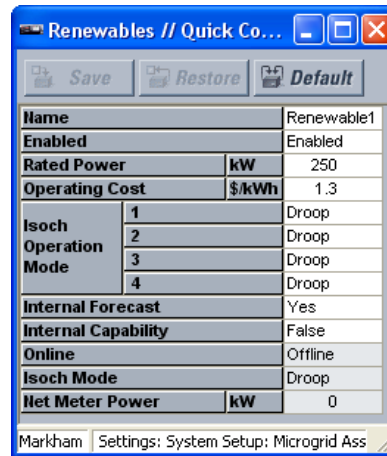
The following settings are available.

Name
Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the resource, such as PV-1, TURBINE 01, or OFFICE PV 2.

Enabled
Range: Disabled, Enabled
Default: Enabled

This setting specifies if the resource is to be included in the microgrid optimization calculations by the U90^{Plus}.

Rated Power
Range: number
Default: 250 kW

This setting specifies the maximum power generation capacity in kW depending on the availability of the renewable resource.

Operating Cost
Range: number
Default: $0 per kWh

This setting specifies the operating cost of the equipment in dollars per kWh. Include operations, maintenance, and (any) fuel costs.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Isoch Operation Mode

Range: Droop, Isoch
Default: Droop

This setting specifies if isochronous or droop (non-isoch) mode is to be used for the renewable resources in each of the microgrid operation modes.

The numbers 1 to 4 for this setting refer to operation modes for the microgrid. Depending on the type of isochronous machine and how the reserve margins are provided, four different operation modes can be considered for the microgrid. The following modes are some examples that can be used:

1. Dispatchable/CHP isoch load sharing
2. Hydro in isoch
3. Single dispatchable/CHP in isoch
4. Grid in isoch

For example, assume in a particular microgrid, one big hydro generator (such as a run-of-the-rive hydro unit with a reservoir) can operate in isochronous mode. This corresponds to Operation Mode 2; however, any of the four operation modes can be assigned to a single hydro unit in isoch. If the operator follows the suggested operation-mode assignment (that is, Operation Mode 2 is hydro in isoch) and Hydro 1 is supposed to be the isoch machine, the following are set for this machine:

Operation Mode 1 = Droop
Operation Mode 2 = Isoch
Operation Mode 3 = Droop
Operation Mode 4 = Droop

This way, if you select the second mode to be the active mode for the microgrid, then Hydro 1 can run in isoch mode by receiving the isoch command from U90^{Plus}. For the other microgrid operation modes, Hydro 1 is in non-isochronous mode (as set by zero values). These operation modes are explained later in the Microgrid Operation Modes section.

Internal Forecast

Range: No, Yes
Default: No

This setting specifies if the forecast calculated by the U90^{Plus} (internal) or another forecast is to be used (external).

There are two options available for updating the renewable forecast information. The first option is to use the internal forecast algorithm of the U90^{Plus}. Second, an external device can perform the forecast and communicate the forecasted data to the U90^{Plus}. In this case, for each renewable resource, there are 240 registers available in the U90^{Plus}.

Internal Capability

Range: False, True
Default: False

This setting is defined for hydro machines operating in isochronous mode. Support of isochronous operation of renewable resources (such as a run-of-the-river hydro unit with reservoir) is made possible by defining Renewable Capability over the prediction horizon that represents a fraction (0 to 1) from the generator rated power. Internal Capability enables the user to use the "internal" update of this fraction (using accumulated measurements to build the forecasted values) or to rely on updates from an "external" device.

The following fields indicate status and are read-only.

Online

This field indicates if the renewable resource is online or offline.

Isoc Mode

This field indicates if the resource is in droop or isochronous mode.

Net Meter Power

This field indicates the power generation values in kW read from different renewable generators in the system.

Storage Devices

Add information in the software for each electrical storage installation, such as capacity and cost.

The number of storage entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel. Recall that several storage devices of the same type that are co-located are considered one storage device.

To add information for a storage device:

1. Navigate to **Settings > System Setup > Microgrid Assets > Electrical Assets > Storage Devices**.

Figure 65: Add information for a storage device

The following settings are available.

Name

Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the resource, such as S1 or BATTERY 01.

Input Enabled

Range: Disabled, Enabled
Default: Enabled

This setting indicates if the storage input/charging is set to be included in the microgrid optimization calculations by the U90^{Plus}. When storage input is offline and the optimal dispatch result indicates storage input usage above the minimum storage input for

equal to or longer than the **Charging Min Up Time**, then the storage input is started. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, enabling the input translates to enabling the electrolyzer.

Output Enabled

Range: Disabled, Enabled

Default: Enabled

This setting indicates if the storage output/discharge is set to be included in the microgrid optimization calculations by the U90^{Plus}. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, enabling the output translates to enabling the fuel cell.

Type

Range: Hydrogen, Battery

Default: Battery

Specify if the storage is batteries or a hydrogen-based system, such as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell.

Max Discharging Power

Range: number

Default: 50 kW

This setting specifies the maximum electrical power in kW that the storage unit can discharge to the microgrid. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, this setting refers to the rated power of a fuel cell.

Min Discharging Power

Range: number

Default: 25 kW

This setting specifies the minimum electrical power in kW that the storage unit is to discharge to the microgrid. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, this setting refers to the minimum fuel cell output power.

Max Charging Power

Range: number

Default: 50 kW

This setting specifies the maximum input/charging power of the storage unit in kW. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, this setting refers to the rated power of the electrolyzer.

Min Charging Power

Range: number

Default: 25 kW

Charging power for a storage device cannot be below a certain level, so this setting specifies the minimum input/charging power of the storage unit. This power level is related to the technology and specifications of the storage device itself and it does not depend on other dispatchable or renewable devices in the system. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, this setting refers to the minimum input power of the electrolyzer. For example, for a 300-kW alkaline electrolyzer, this setting can be in the range of 120 to 130 kW.

Charging Efficiency

Range: 0 to 100 percent
Default: 50 percent

This setting describes how efficient the input or charging power over time contributes in increasing the state of charge. Charging efficiency depends on the input/charging power and storage state of charge. However, it is assumed here to be a fixed setting, which is acceptable in most applications. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, this setting refers to the electrolyzer efficiency. (The charging efficiency of the storage cylinders is close to unity.)

Discharging Efficiency

Range: 0 to 100 percent
Default: 55 percent

This setting describes how efficient the stored energy is converted back to the microgrid. Discharging efficiency depends on the output/discharging power and storage state of charge. However, it is assumed here to be a fixed setting, which is acceptable in most applications. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, this setting refers to the fuel cell efficiency. (The discharging efficiency of the storage cylinders is close to unity.)

SOC Max

Range: number
Default: 300 kWh

This setting is the maximum capacity of the storage device. It specifies the maximum level of storage state of charge (SOC), in kWh.

SOC Min

Range: number
Default: 50 kWh

This setting specifies the minimum level of storage state of charge, in kWh. Due to lifetime considerations, SOC cannot usually go below a certain limit. This is referred to as maximum depth of discharge (DOD). For example, for a 100-kWh storage device with 80% DOD, SOC Min is set to 20 kWh.

UB Store Dev1

Range: 0 to 1
Default: 0

Storage state of charge needs to be always above **SOC Min** and below **SOC Max**. However, a variety of practical complexities, such as storage standby loss, delay in issuing the charging/discharging commands, measurements errors, and startup or environmental conditions, lead to the violation of these limits and can render the real-time microgrid optimization problem infeasible. Apart from the infeasibility of the optimization problem, there is also a chance of an undesired phenomenon occurring, which is frequent charging and discharging (cycling) of storage devices. These undesired outcomes (that is, infeasibility and cycling) are avoided in the U90^Plus by having some pre and post processing units outside of the optimization core to modify the commands issued by the controller, such as storage stop/start, or to change some input readings, such as SOC. This also requires defining some small regions around **SOC Max** and **SOC Min**. Thus, two regions below **SOC Max**, and two regions on either side of **SOC Min** are defined as shown in the following figure. If SOC is located in region E, no action is required; however, if SOC is within any of four regions A to D, its measured value is appropriately changed together with issuing some necessary charging/discharging commands.

UB Store Dev1 is the upper boundary of the maximum acceptable charging level. Configure it to be within a few percent of storage maximum capacity (**SOC Max**), for example one to five percent (that is, 0.01 to 0.05).

Figure 66: Demonstration of storage SOC and margins
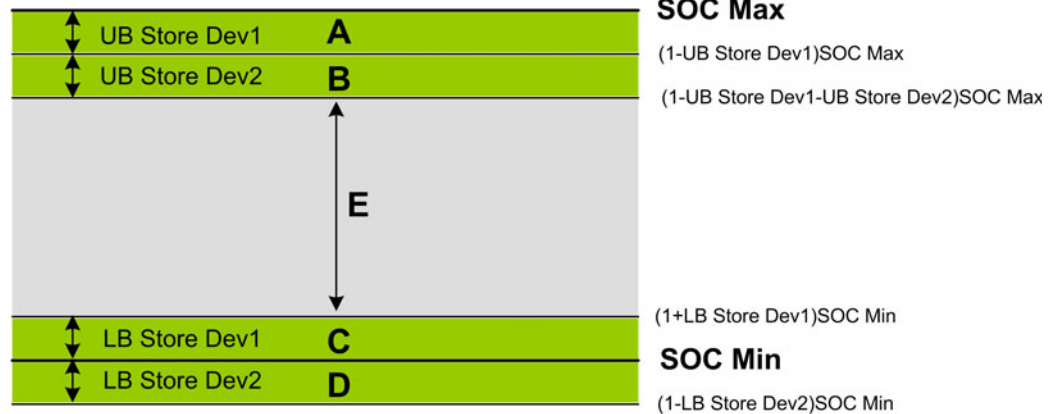
UB Store Dev2
Range: 0 to 1
Default: 0

This setting is the lower boundary of the maximum acceptable charging level. Configure it to be within a few percent of storage maximum capacity (**SOC Max**), for example one to five percent (that is, 0.01 to 0.05).

LB Store Dev1
Range: 0 to 1
Default: 0

This setting is the upper boundary of the minimum acceptable charging level. Configure it to be within a few percent of storage minimum capacity (**SOC Min**), for example one to five percent (that is, 0.01 to 0.05).

LB Store Dev2
Range: 0 to 1
Default: 0

This setting is the lower boundary of the minimum acceptable charging level. Configure it to be within a few percent of storage minimum capacity (**SOC Min**), for example one to five percent (that is, 0.01 to 0.05).

Constraint Mode
Range: Hard, Soft
Default: Hard

Soft constraint means that the storage device is allowed to violate its minimum capacity (**SOC Min**) but at the cost of a penalty in the objective function. Having the possibility of going below the minimum capacity (soft constraint) can positively affect the feasibility of the microgrid optimization problem but can also result in charge/discharge cycling.

Hard constraint means that the storage is not allowed to go below its minimum capacity (SOC Min).

Use this setting in conjunction with **SOC Penalty**, **SOC Incentive**, and **SOC Min Penalty**.

Charging Cost

Range: $0 to 1000 per kWh
Default: $10 per kWh

This setting is the cost to charge the storage device in dollars per kWh. Determine the cost based on your knowledge of the microgrid or initial simulation studies. Including such costs helps to prevent simultaneous charging and discharging and helps to limit charge/discharge cycling.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Discharging Cost

Range: $0 to 1000 per kWh
Default: $5 per KWh

This setting is the cost to discharge power from the storage unit in dollars per kWh. Determine the cost based on your knowledge of the microgrid or initial simulation studies. Including such costs helps to prevent simultaneous charging and discharging and helps to limit charge/discharge cycling.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Charging Incentive

Range: $0 to 1000 per kWh
Default: $0 per kWh

This setting is the financial incentive to charge storage, in dollars per kWh. In some jurisdictions, utilities are required to store a percent of energy and incentives can be available for such a program. The incentive can be used to set this parameter for grid-connected microgrid configurations. In the absence of such an incentive program, some simulation studies can be needed to fine-tune this setting given the requirement to prevent simultaneous charging and discharging and the need to limit storage cycling.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Discharging Incentive

Range: $0 to 1000 per kWh
Default: $0 per kWh

This setting is the financial incentive to discharge storage, in dollars per kWh. In the absence of incentive programs for grid-connected microgrids, some simulation studies can be needed to fine-tune this setting given the requirement to prevent simultaneous charging and discharging and the need to limit storage cycling.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

SOC Penalty

Range: $0 to 1000 per kWh^2
Default: $0 per kWh^2

This setting promotes discharging and lower values of SOC.

Both **SOC Penalty** and **SOC Incentive** settings are provided to allow you more freedom to configure the system based on your operational knowledge.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

SOC Incentive

Range: $0 to 1000 per kWh^2
Default: $0 per kWh^2

This incentive promotes more charging and higher values of SOC.

Both **SOC Penalty** and **SOC Incentive** settings are provided to allow you more freedom to configure the system based on your operational knowledge.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

SOC Min Penalty

Range: $0 to 1000 per kWh^2

Default: $0 per kWh^2

The setting is the penalty when storage is allowed to violate its minimum level (that is, soft constraint is set for **Constraint Mode**). The greater the violation from **SOC Min**, the greater the penalty cost in the objective function.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Hysteresis

Range: Off, On

Default: Off

The U90^{Plus} supports input up-time, down-time, and cycle-per-day hysteresis. When **Hysteresis** is On, a set of appropriate parameters is in place to prevent excessive switching and cycling. Support for hysteresis is required for storage input to overcome high-frequency on/off cycling of the electrolyzer because it lowers performance and decreases the life of the device. The hysteresis mostly targets the electrolyzer (hydrogen-based storage), but it is available for all storage devices.

Charging Min Up Time

Range: 0 to 720 min

Default: 0 min

When the **Hysteresis** field is set to On, this is the minimum running time of the electrolyzer, in minutes. If the electrolyzer is turned on, it runs for at least this length of time. When storage input is offline and the optimal dispatch result indicates storage input usage above the minimum storage input (**Min Charging Power**) for equal to or longer than the **Charging Min Up Time**, then the storage input is started with the calculated setpoint.

Charging Min Down Time

Range: 0 to 720 min

Default: 0 min

When the **Hysteresis** field is set to On, this is the minimum off time of the electrolyzer, in minutes. When the electrolyzer is on and receives an off command, it turns off and stays off for at least this length of time.

Charging Limit Feedback

Range: No, Yes

Default: No

Yes means that the storage local controller provides the maximum value of discharging power for the U90^{Plus} to read. No means that the value read by the U90^{Plus} is disregarded.

For storage devices we have maximum charging power and maximum discharging power; these are settings and fixed values. However, for particular storage technologies, these maximum powers are not fixed; they depend on the state of charge (SOC). For example, we have a setting of 100 kW for maximum discharging power but if SOC is below a certain limit we cannot approach this maximum 100-kW limit. For these particular storage devices, the maximum charging or discharging powers are declared by their local controllers; they have mathematical functions that calculate the maximum power depending on the value of SOC; these values are published so that an external device like the U90^{Plus} can read them.

Given this, the U90^{Plus} has two related settings for storage devices: Charging Limit Feedback and Discharging Limit Feedback. For example, when the Charging Limit Feedback is Yes, it means that the storage local controller provides the maximum value of charging power (this is read by the U90^{Plus} and used in the optimization calculation). In this case, the value read by the U90^{Plus} is replaced with the maximum value already set by the user. In other words, setting value for maximum charging power is overwritten based on the value provided by the storage local controller and read by the U90^{Plus}. When the Charging Limit Feedback is set to No, then the value read by the U90^{Plus} is disregarded.

Discharging Limit Feedback

Range: No, Yes
Default: No

See the explanation in the previous field.

Used By UC 1...4

Range: No, Yes
Default: No

Select yes to have storage contribution considered in the Unit Commitment (UC) routine of the optimization problem. The Unit Commitment problem is the task of determining a combination of power generation units each with a certain capacity and operation cost so as to minimize the total operation costs while satisfying the electricity-demand requirement of the microgrid in each time period.

The numbers 1 to 4 specify whether or not to consider the contribution of storage devices in the Unit Commitment (UC) routine in each of the four microgrid operation modes.

Charge Dissipation

Range: 0 to 1000 kWh/h
Default: 0 kWh/h

This setting represents energy loss from the storage device over time. It specifies the rate of charge dissipation, or standby loss of the storage, in kWh/h. You set this value based on your knowledge of the storage technology used in the microgrid. For example, some storage technologies, such as hydrogen, have low standby losses while battery storage systems have relatively high dissipation.

The following fields indicate status and are read-only.

Input Online

This field indicates if the storage input is online or offline. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Input Online** represents the offline/online status of the electrolyzer.

Being online is not necessarily the same as being available for use in the U90^{Plus} optimization calculations.

Output Online

This field indicates if the storage output is online or offline. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Output Online** represents the offline/online status of the fuel cell.

Being online is not necessarily the same as being available for use in the U90^{Plus} optimization calculations.

Input Availability

Input availability is declared by the storage device. It indicates if the storage input can be controlled by the U90^{Plus} and included in the optimization problem solved by the U90^{Plus}. The availability signal is built into the storage local controller based on some

parameters and is read by the U90^{Plus}. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Input Availability** represents the availability of the electrolyzer.

An online storage resource is not necessarily an available storage resource.

Output Availability

Output availability is declared by the storage device. It indicates if the storage output can be controlled by the U90^{Plus} and included in the optimization problem solved by the U90^{Plus}. The availability signal is built into the storage local controller based on some parameters and is read by the U90^{Plus}. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Output Availability** represents the availability of the fuel cell.

An online storage resource is not necessarily an available storage resource.

Net Meter Power In

This is the net metered input power, in kW. It indicates the input/charging power value read from the storage device. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Net Meter Power In** represents the measured value of the electrolyzer input/charging power.

Net Meter Power Out

This is the net metered output power, in kW. This field indicates the output/discharging power value read from the storage device. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Net Meter Power Out** represents the measured value of the fuel cell output/discharging power.

SOC

This field indicates storage state of charge, in kWh.

Input Start

This field represents the start command for storage charging. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Input Start** corresponds to the electrolyzer start command.

Output Start

This field represents the start command for storage discharging. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Output Start** corresponds to the fuel cell start command.

Power Ref In

This field reflects the reference input power of the storage device. It is the value decided by the U90^{Plus} for the storage charging power. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Power Ref In** represents the command for electrolyzer input/charging power.

Power Ref Out

This field reflects the reference output power of the storage device. It is the value decided by the U90^{Plus} for the storage discharging power. For hydrogen storage, which is interpreted as the combination of electrolyzer, high-pressure storage cylinders, and fuel cell, **Power Ref Out** represents the command for fuel cell output/discharging power.

Grid   Add information to the software regarding the grid, such as the amount of power to import.

One grid is allowed, as set in the **Settings > Product Setup > Installation** panel.

To add information for a grid:

1.   Navigate to **Settings > System Setup > Microgrid Assets > Electrical Assets > Grid**.

Figure 67: Add information for a grid

The following settings are available.

Name

Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the grid, such as GRID TIE-1, 29 PALMS GRID, or PAOLO HYDRO GRID.

Import Enabled

Range: Disabled, Enabled
Default: Enabled

This setting specifies if importing from the grid to the microgrid is enabled.

This setting takes the grid contribution into the microgrid optimization calculations but only import power from the grid is allowed. If both **Import Enabled** and **Export Enabled** are set to Enabled, optimization calculations decide whether import power from the grid or export power to the grid happens depending upon the optimal contribution of generation/storage devices in the microgrid. For off-grid or autonomous microgrids, set both **Import Enabled** and **Export Enabled** to Disabled.

Export Enabled

Range: Disabled, Enabled
Default: Enabled

This setting specifies if exporting from the microgrid to the grid is enabled.

This setting takes the grid contribution into the microgrid optimization calculations but only export power to the grid is allowed. If both **Import Enabled** and **Export Enabled** are set to Enabled, optimization calculations decide whether import power from the grid or export power to the grid happens depending upon the optimal contribution of generation/storage devices in the microgrid. For off-grid or autonomous microgrids, set both **Import Enabled** and **Export Enabled** to Disabled.

Max Import Power, Min Import Power

Range: number
Default: 1,000 kW maximum, 50 kW minimum

Maximum and minimum amounts of electricity to import from the grid to the microgrid, in kW.

Max Export Power, Min Export Power

Range: number
Default: 1,000 kW maximum, 0 kW minimum

Maximum and minimum amounts of electricity to export to the grid from the microgrid, in kW.

Power Resolution

Range: number
Default: 10 kW

While power that can be supplied by a grid is a continuous quantity, the U90[Plus] allows partitioning of the load requirement into discrete values. That is, the U90[Plus] allows the grid to supply a combination of a finite set of power values. This is useful because the U90[Plus] typically has several power sources in the microgrid with which to optimize, including any grid.

This setting is power in terms of kW. It is the resolution of the discrete values for power grid supply. The lower the number, the more flexibility provided for optimization.

The following fields indicate status and are read-only.

Online

This field indicates if the resource is online or offline. The status of being online can also translate to having grid connection.

Net Meter Power

This field indicates the import/export power value, in kW.

Importing

This field indicates whether the grid is importing or exporting power.

Loads   Add information to the software regarding use of the electricity, such as which forecast to use.

The number of load entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel.

To add information for a load:

1.   Navigate to **Settings > System Setup > Microgrid Assets > Electrical Assets > Loads**.

Figure 68: Add information about loads
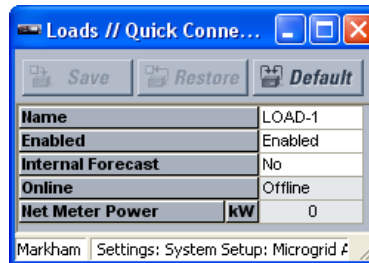
The following settings are available.

Name

Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the load, such as LOAD-1, RESIDENTIAL, or PINGNAN FACTORY.

Enabled

Range: Disabled, Enabled
Default: Enabled

This setting specifies if the load is to be included in the microgrid optimization calculations by the U90[Plus]. For example, if there are two loads in the microgrid, disabling Load 2 disregards the demand of the second load in the microgrid unit commitment and optimal dispatch problems.

Internal Forecast

Range: No, Yes
Default: No

This setting specifies if the forecast calculated by the U90^{Plus}or another forecast is to be used.

There are two options available for updating the load forecast information. The first option is to use the internal forecast algorithm of the U90^{Plus}. Second, an external device can perform the forecast and communicate the forecasted data to the U90^{Plus}. In this case, for each load, there are 240 registers available in the U90^{Plus}.

The following fields indicate status and are read-only.

Online

This field indicates if the load is online or offline, meaning consuming electricity or not.

Net Meter Power

This field indicates the values of demanding powers in kW read from different loads in the system.

CHP   Add information to the software regarding any combined heat and power (CHP) generation devices.

The number of CHP entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel.

To add information for a cogenerator:

1.   Navigate to **Settings > System Setup > Microgrid Assets > Thermal Assets > CHP**.

Figure 69: Add information about a cogenerator
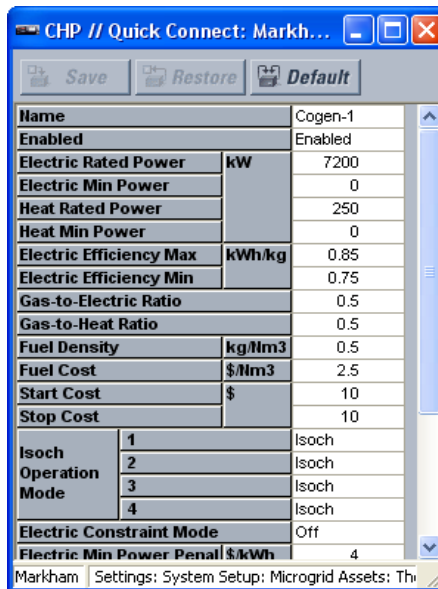
The following settings are available.

Name

Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the cogenerator, such as COGEN-1 or CHP 1.

Enabled

Range: Disabled, Enabled

Default: Enabled

This setting specifies if the cogenerator is to be included in the microgrid optimization calculations by the U90[Plus].

Electric Rated Power

Range: number

Default: 250 kW

This setting specifies the maximum electric power generation capacity of the cogenerator in kW. It is the maximum potential power contribution of the cogenerator in the microgrid.

Electric Min Power

Range: number

Default: 50 kW

This setting specifies the preferred minimum electric power in kW that the cogenerator is to generate.

Heat Rated Power

Range: number

Default: 250 kW

This setting specifies the heating capacity of the cogenerator in kW. It is the maximum heat supply that the cogenerator can generate.

Heat Min Power

Range: number

Default: 50 kW

This setting specifies the preferred minimum heat supply in kW that the cogenerator is to generate.

Electric Efficiency Max

Range: 0 to 1000 kWh/kg

Default: 5.25 kWh/kg

This setting specifies the efficiency of the cogenerator at maximum generator load, in kWh/kg of consumed natural gas. If the cogenerator efficiency at maximum power is available in terms of percent, this setting can simply be determined by multiplying the percent value with the higher heating value or energy content of the input fuel in terms of kWh/kg. Higher heating values for different fuel sources can be found in the related handbooks or the Internet.

Electric Efficiency Min

Range: 0 to 1000 kWh/kg

Default: 4.2 kWh/kg

This setting specifies the efficiency of the cogenerator at minimum generator load, in kWh/kg of consumed natural gas. If the cogenerator efficiency at minimum power is available in terms of percent, this setting can simply be determined by multiplying the percent value with the higher heating value or energy content of the input fuel in terms of kWh/kg. Higher heating values for different fuel sources can be found in the related handbooks or the Internet.

Gas-to-Electric Ratio

Range: 0 to 1

Default: 0.35

This setting specifies the gas-to-electricity conversion ratio of the cogenerator. For example, a ratio of 0.35 means that 35% of the energy content of natural gas is converted to electricity and the remainder is in the form of heat that cannot be

recovered completely. To illustrate, if there are100 units natural gas (input), we get 35 units as electricity. The remaining part (that is, 65 units) is heat but all of that cannot be recovered. We can recover about 45 units. Therefore, there are 20 units of parasitic loss (not recoverable).

A typical value for this setting is 0.35.

Gas-to-Heat Ratio

Range: 0 to 1
Default: 0.45

This setting specifies the gas-to-heat conversion ratio of the cogenerator. For example, a ratio of 0.45 means that 45% of the energy content of natural gas is converted to recoverable heat. It is the head that can cover all or part of the heat-demand requirements of the microgrid. A typical value for this setting is 0.45.

Fuel Density

Range: 0 to 5 kg/Nm^3
Default: 0.8 kg/Nm^3

This setting specifies the density of the fuel of the cogenerator in terms of kg per normal cubic meter (Nm^3), which is a typical unit for gaseous fuels such as natural gas. Any fuel source has its own density; search the related handbooks or the Internet for the appropriate value.

Fuel Cost

Range: $0 to $100 per Nm^3
Default: $0.35 per Nm^3

This setting specifies the cost of fuel that operates the cogenerator, in dollars per normal cubic meter (Nm^3). For example, enter the price of the natural gas. The default value of $0.35 per Nm^3 is almost equal to $1 per Therm or $10 per thousand cubic feet of natural gas.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Start Cost

Range: number
Default: $10

This setting specifies the cost in dollars to power up the cogenerator. Include the cost(s) that you think are important based on your experience with the generation resource and the microgrid.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Stop Cost

Range: number
Default: $10

This setting specifies the cost in dollars to power down the cogenerator.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Isoch Operation Mode

Range: Droop, Isoch
Default: Droop

This setting specifies if isochronous or droop (non-isoch) mode is to be used for the cogenerators in each of the microgrid operation modes.

The numbers 1 to 4 for this setting refer to operation modes for the microgrid. Depending on the type of isochronous machine and how the reserve margins are provided, four different operation modes can be considered for the microgrid. The following modes are some examples that can be used:

1. Dispatchable/CHP isoch load sharing
 2. Hydro in isoch
 3. Single dispatchable/CHP in isoch
 4. Grid in isoch

For example, assume in a particular microgrid, one big cogenerator can operate in isochronous mode. This corresponds to Operation Mode 3; however, any of the four operation modes can be assigned to a single cogenerator in isoch. If the operator follows the suggested operation-mode assignment (that is, Operation Mode 3 is single dispatchable/CHP in isoch) and Cogenerator 1 is supposed to be the isoch machine, the following are set for this machine:

Operation Mode 1 = Droop
 Operation Mode 2 = Droop
 Operation Mode 3 = Isoch
 Operation Mode 4 = Droop

This way, if you select the third mode to be the active mode for the microgrid, then Cogenerator 1 can run in isoch mode by receiving the isoch command from U90^{Plus}. For the other microgrid operation modes, Cogenerator 1 is in non-isochronous mode (as set by zero values). These operation modes are explained later in the Microgrid Operation Modes section.

Electric Constraint Mode

Range: Off, On
Default: Off

On selects soft constraint, which means that the cogenerator is allowed to violate its minimum power generation level but at the cost of a penalty in the objective function. Having the possibility of going below the minimum power (soft constraint) can positively affect the feasibility of the microgrid optimization problem.

Off selects hard constraint, which means that the cogenerator is not allowed to go below its minimum power generation level.

Use this setting in conjunction with **Electric Min Power Penalty**.

Electric Min Power Penalty

Range: $0 to 1000 per kWh
Default: $0 per kWh

Use this setting in conjunction with **Electric Constraint Mode**. This setting puts a numerical value on the minimum power violation. When the violation from minimum power is critical, set a high value here.

The following fields indicate status and are read-only.

Net Electric Meter Power

This field indicates the electric power generation values in kW read from different cogenerators in the system.

Net Heat Meter Power

This field indicates the heat power generation values in kW read from different cogenerators in the system.

Electric Online

This field indicates if the cogenerator is online or offline for electricity production. It is not necessarily the same as being available for use in the U90^{Plus} optimization calculations.

Heat Online

This field indicates if the cogenerator is online or offline for heat production. It is not necessarily the same as being available for use in the U90^{Plus} optimization calculations.

Electric Isoch Mode

This field indicates if the electricity-generating function of the cogenerator is in isochronous or droop mode.

Electric Availablity

Availability is declared by the cogenerator. This field indicates if the cogenerator can be controlled by the U90^{Plus} for electricity production and included in the optimization problem solved by the U90^{Plus}. An online cogenerator is not necessarily an available cogenerator. The availability signal is built into the cogenerator's local controller based on some parameters and is read by the U90^{Plus}.

Electric Power Ref

This field refers to the electric power reference points of cogenerators, in kW. Their values are computed by the U90^{Plus} dispatch algorithm.

Boiler

Add information to the software regarding any boilers that generate heat within the microgrid.

The number of boiler entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel.

To add information for a cogenerator:

1. Navigate to **Settings > System Setup > Microgrid Assets > Thermal Assets > Boiler**.

Figure 70: Add information about a boiler

The following settings are available.

Name

Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the boiler such as BOILER-1 or SOUTH BOILER.

Enabled

Range: Disabled, Enabled

Default: Enabled

This setting specifies if the boiler is to be included in the microgrid optimization calculations by the U90^{Plus}.

Rated Power

Range: number

Default: 250 kW

This setting specifies the maximum heat generation capacity of the boiler in kW. Some manufacturers provide the rating in kW and otherwise use the related handbooks or Internet to find an appropriate conversion procedure.

Min Power

Range: number

Default: 50 kW

This setting specifies the preferred minimum heat power in kW that the boiler is to generate.

Fuel Cost

Range: $0 to $1000 per Nm^3

Default: $0.35 per Nm^3

This setting specifies the cost of fuel that operates the boiler, in dollars per normal cubic meter (Nm^3). For example, enter the price of the natural gas. The default value of $0.35 per Nm^3 is almost equal to $1 per Therm or $10 per thousand cubic feet of natural gas.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Fuel Density

Range: 0 to 1000 kg/Nm^3

Default: 0.8 kg/Nm^3

This setting specifies the density of the fuel of the boiler in terms of kg per normal cubic meter (Nm^3), which is a typical unit for gaseous fuels such as natural gas. Any fuel source has its own density; search the related handbooks or Internet for the appropriate value.

Start Cost

Range: $0 to 1000

Default: $50

This setting specifies the cost in dollars to power up the boiler. Include the cost(s) that you think are important based on your experience with the heat generation resource and the microgrid.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Stop Cost

Range: $0 to 1000

Default: $50

This setting specifies the cost in dollars to power down the boiler.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

Efficiency

Range: 0 to 1000 kWh/kg

Default: 13.5 kWh/kg

This setting specifies the efficiency of the boiler to produce heat, expressed in terms of kWh heat generated per kg of fuel consumed. Assuming the fuel to be natural gas, the default value of 13.5 kWh/kg translates to almost 90% efficiency considering the energy content of natural gas. Calculate the number using the related curves for your boiler. If the boiler efficiency is available in terms of percent, this setting can simply be determined by multiplying the percent value with the higher heating value or energy content of the input fuel in terms of kWh/kg. Higher heating values for different fuel sources can be found in the related handbooks or the Internet.

Constraint Mode

Range: Off, On

Default: Off

On selects soft constraint, which means that the boiler is allowed to violate its minimum heat generation level but at the cost of a penalty in the objective function. Having the possibility of going below the minimum heat (soft constraint) can positively affect the feasibility of the microgrid optimization problem.

Off selects hard constraint, which means that the boiler is not allowed to go below its minimum heat generation level.

Min Power Penalty

Range: $0 to 1000 per kWh

Default: $10 per kWh

Use this setting in conjunction with **Constraint Mode**. This setting puts a penalty value on the violation from the minimum heat power. When violation from the minimum heat power is critical, set a high value here.

The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency.

The following fields indicate status and are read-only.

Net Meter Power

This field indicates the heat power generation values in kW read from different boilers in the system.

Online

This field indicates if the boiler is online or offline. It is not necessarily the same as being available for use in the U90^{Plus} optimization calculations.

Input Isoch Mode

This field indicates if the boiler is in isochronous or droop mode, as read from the boiler by the U90^{Plus}.

Availablity

Availability is declared by the boiler. This field indicates if the boiler can be controlled by the U90^{Plus} and included in the optimization problem solved by the U90^{Plus}. An online boiler is not necessarily an available boiler. The availability signal is built into the boiler's local controller based on some parameters and is read by the U90^{Plus}.

Power Ref

This field refers to the heat power reference points of boilers, in kW. Their values are computed by the U90^{Plus} dispatch algorithm.

Start

Start/stop is a command. When the U90^{Plus} sends the start command, the boiler comes online after some time.

Output Isoch Mode

This field indicates if the boiler is to be in isochronous or droop mode, as sent to the boiler from the U90^{Plus}.

Heat Loads   Add information to the software regarding use of the heat, such as which forecast to use.

The number of heat load entries displayed reflects the number entered in the **Settings > Product Setup > Installation** panel.

To add information for a heat load:

1.   Navigate to **Settings > System Setup > Microgrid Assets > Thermal Assets > Heat Loads**.

Figure 71: Add information about heat loads
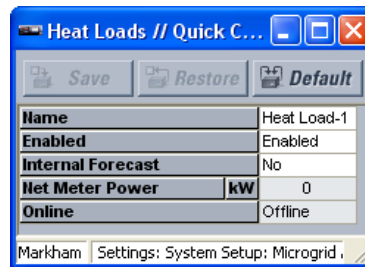
The following settings are available.

Name

Range: up to 20 alphanumeric characters
Default: blank

Enter a name for the heat load, such as HEAT LOAD-1 or INDSTRIAL HEAT.

Enabled

Range: Disabled, Enabled
Default: Enabled

This setting specifies if the heat load is to be included in the microgrid optimization calculations by the U90^{Plus}. For example, if there are two heat loads in the microgrid, disabling Heat Load 2 disregards the demand of the second heat load in the microgrid unit commitment and optimal dispatch problems.

Internal Forecast

Range: No, Yes
Default: No

Select Yes to use the forecast calculated by the U90^{Plus}. Select No to use an external forecast.

There are two options available for updating the heat load forecast information. The first option is to use the internal forecast algorithm of the U90^{Plus}. Second, an external device can perform the forecast and communicate the forecasted data to the U90^{Plus}. In this case, for each heat load, there are 240 registers available in the U90^{Plus}.

The following fields indicate status and are read-only.

Net Meter Power

This field indicates the values of demanding heat powers in kW read from different heat loads in the system.

Online

> This field indicates if the heat load is online or offline, meaning consuming heat or not.

Economic Dispatch Setup

Economic dispatch setup specifies the length of time for prediction (**Prediction Horizon**) and the optimization resolution (**Dispatch Time**), both of which determine the size of forecast parameters as well as decision variables for the microgrid optimization problem. For each renewable, grid, load, and heat load forecasts, there are 240 registers available in the U90^{Plus} and up to 48 hours is possible as the Prediction Horizon. The Dispatch Time needs to be set in conjunction with the Prediction Horizon so that the number of forecast values is not more than 240.

To set the forecasting time periods:

1. Navigate to **Settings > Economic Dispatch Setup**.

The following settings are available.

Figure 72: Set the forecast length and optimization calculation interval
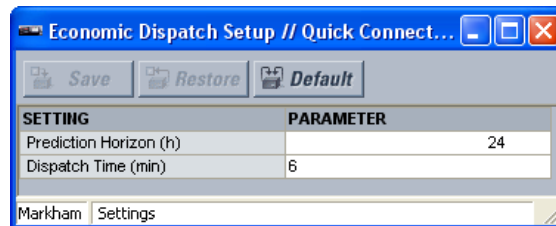
Prediction Horizon

> *Range: 1 to 48 hours*
>
> *Default: 24 hours*

This setting specifies the length of time for U90^{Plus} prediction. For example, a Prediction Horizon of 24 hours sets the U90^{Plus} to predict the optimal operation of the microgrid for the next 24 hours based on the 24-hour forecasts values for loads, renewables, and grid prices. Select a value for **Prediction Horizon** that ensures no more than 240 points are generated based on the **Dispatch Time** interval. For example, for a six-minute Dispatch Time, the maximum value that can be set for Prediction Horizon is 24 hours (that is, 24 h / 6 min = 240).

Dispatch Time

> *Range: 6, 12, 18, 24, 30, 36, 42, 48, 54, 60 minutes*
>
> *Default: 12 minutes*

This setting is the optimization time resolution. It specifies the frequency at which the U90^{Plus} generates a data file based on the collected information from the microgrid, solves the optimization problem, and update commands for the resources in the microgrid. Select a value that ensures no more than 240 points are generated based on the **Prediction Horizon**. For example, for a 48-hour Prediction Horizon, the minimum value that can be set for **Dispatch Time** is 12 min (that is, 48 h / 12 min = 240).

The HMI panel reflects this setting as the **Time to Next Command Update**.

The U90^{Plus} is designed to conclude the microgrid optimal solution within two minutes. Depending on the number of assets in the microgrid, inappropriate setting of **Prediction Horizon** and **Dispatch Time** can lead to the violation of this two-minute time limit, which initiates an alarm. For microgrids with a relatively large number of assets, reduce the **Prediction Horizon** and/or increase the **Dispatch Time** from the default values. As an example, for a microgrid with eight dispatchables, two renewables, and one hydrogen

storage (including electrolyzer, high-pressure storage cylinders, and fuel cell), the optimal solution is found in less than 80 seconds based on the default values for **Prediction Horizon** (24 h) and **Dispatch Time** (12 min).

Command Scheduler Setup

This section outlines the panels under **Settings > Command Scheduler Setup**.

Dispatchable Units / Storage Units

For dispatchable and storage resources, configure the software for startup and shutdown time intervals. The purpose is to apply optimal dispatch advice with a sequence that does not endanger the microgrid stability and which has low impact on the microgrid voltage and frequency profile.

To set dispatchable and storage startup and shutdown intervals:

1. Navigate to **Settings > Command Scheduler Setup > Dispatchable Units** or **Storage Units**.

Figure 73: Set startup and shutdown intervals for dispatchable resources
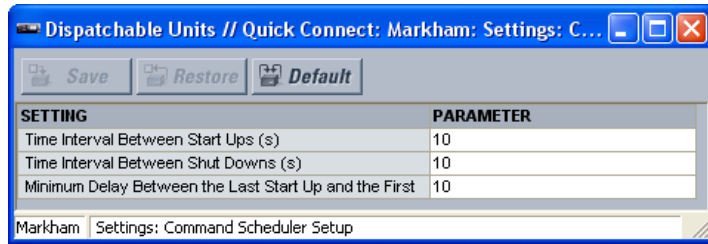
Figure 74: Set startup and shutdown intervals for storage
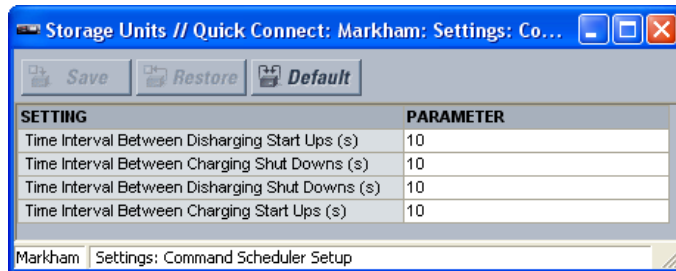
The following settings are available (vary with selection).

Time Interval Between Start Ups

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between starting dispatchable units. This action always starts from the largest unit to the smallest unit.

Time Interval Between Shut Downs

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between stopping dispatchable units. This action always starts from the largest unit to the smallest unit.

Minimum Delay Between the Last Start Up and the First Shut Down

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between last starting and the first stopping of dispatchable units.

Time Interval Between Discharging Start Ups

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between starting discharging storage units.

Time Interval Between Charging Shut Downs

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between stopping charging storage units.

Time Interval Between Discharging Shut Downs

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between stopping discharging storage units.

Time Interval Between Charging Start Ups

Range: 0, 10, 20, 30, 40, 50, 60 seconds

Default: 10 seconds

This setting is the minimum delay between starting charging storage units.

Isoch Check

The U90^{Plus} sends commands to resources when they need to run in isochronous mode. The command is referred to as the isoch command. The setting in this panel specifies how long the U90^{Plus} waits before it checks if the isoch command has been implemented.

To set the interval:

1. Navigate to **Settings > Command Scheduler Setup > Isoch Check**.

Figure 75: Set the isoch check interval
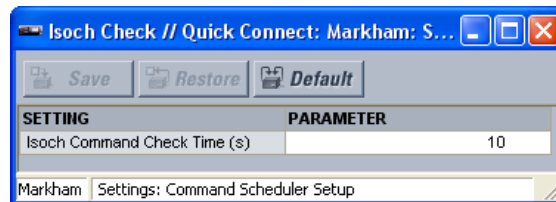
The following setting is available.

Isoch Command Check Time

Range: 10 to 720 seconds

Default: 10 seconds

This setting is the time that the U90^{Plus} waits after sending the isoch command to check if the command has been implemented or not.

Send Setup to Device

Clicking the **Save** button in the software saves any change in the software only. You also need to send the changes to the U90^{Plus}. Exceptions are the Commands panels and user account management, which are sent immediately to the unit.

To send the configuration settings to the unit:

1. When working online, in the **Online Window** area of the EnerVista software, navigate to **Settings > Send Setup to Device**. When working offline, in the **Offline Window** area, right-click and select **Write to Device**.

2. Confirm the configuration at the prompt.

   When successful, the system creates two XML configuration files and sends them to

the unit using the trivial file transfer protocol (TFTP). A message indicates success and that the unit is restarting.

When an error message displays that the unit failed to send the configuration files to the device, turn on the U90^Plus and also check in the **Device** drop-down list of the software that you are accessing the right U90^Plus.

The two files created are as follows:

*   **MGC.XML** — Main configuration file, including Modbus device configuration, equation logic, control settings, alarms, and input/output declarations
*   **CNFGANC.XML** — The annunciator configuration file that defines configured alarms and defines how the alarms display in the annunciator panel

You can view when information was last sent.

To view the configuration date:

1.   Navigate to **Settings > Installation** and view the **Config Date** field.

NOTE

The settings in the **Online Window** and **Offline Window** areas of the software are not synchronized. If you change the settings online, then send settings to the device from the offline settings area, you overwrite the online changes.

Actual Values

Data is viewable in the software and on the front panel. See the Front Panel Interface section for information on the latter.

To view data in the software:

1.   In the **Online Window** area, navigate to **Actual Values** and select a panel.

In the example shown for storage, the data can be interpreted as follows. Storage charging and discharging are both Enabled, which means that user has set both to be included in the U90^Plus optimization calculations. If storage is of hydrogen type, Enabled charging and discharging means that both fuel cell and electrolyzer are set by user to be present in the optimization problem. The input and output of the device are both available for use according to the signal sent from the storage local controller (Availability). In this case, both storage charging (that is, electrolyzer) and storage discharging (that is, fuel cell) are taken into account for optimization calculations and hence, they can be both controlled by the U90^Plus. There is a Start command for storage output with a 100-kW discharging advice. The actual readings from storage input (charging) and storage output (discharging) are 0 and 100 kW, respectively. Also, the storage state-of-charge is measured to be 1500 kWh.

Figure 76: Viewing information about a storage resource

Data Recorder

All input and output variables as well as the optimization internal variables for the next 24 hours can be checked in the Data Recorder. They are saved as common format for transient data exchange (COMTRADE) files. The following four files are generated:

- Header (.HDR)
- Configuration (.CFG)
- Data (.DAT)
- Information (.INF)

For compatibility with UR and UR^{Plus} platforms, these files are named with the generic suffix "osc."

Figure 77: Viewing trends over 24 hours in the Data Recorder panel
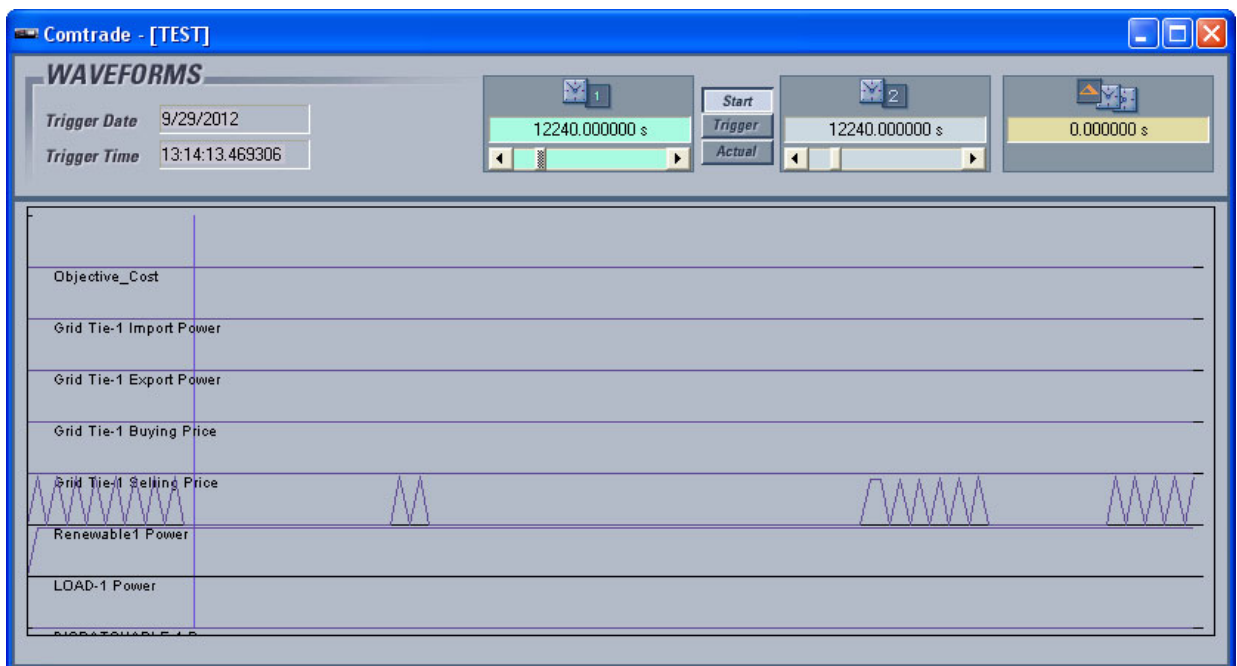
Another option is to obtain files under **Maintenance > Retrieve File**; see the Retrieve Files section.

To view data records:

1.   In the **Online Window** area, navigate to **Actual Values > Data Recorder**. When no files exist, no graph displays and a message displays that no COMTRADE file is available.

Commands

This section outlines panels in the **Commands** category of the software.

Commands are issued immediately to the device, using the trivial file transfer protocol (TFTP) and Modbus. The following commands use Modbus: Security, Forecasts, and Set Date and Time. All other commands use XML over TFTP.

If a password is set, the commands password needs to be entered to save any changes made. The password is set under **Settings > Product Setup > Security**. Once set, the password entry requirement cannot be removed.

Optimizer Operation Mode

The U90^{Plus} can run in different modes in terms of optimization. The mode determines whether optimization is on or off. Set it as follows:

*   **Legacy (Off)** — Off — No optimization takes place and no communication occurs with the resources and assets in the microgrid. When you select this mode, the microgrid continues to operate using the last configuration. For example, when a diesel generator is on, and you activate Legacy (Off) mode, the diesel generator continues to operate.

*   **Auto** — On — Optimization occurs and the optimal solution is communicated with the resources and assets

*   **Advisory** — On — Optimization occurs but the optimal solution is not communicated with the resources and assets. When there is a problem in the microgrid, the unit automatically switches to this mode to prevent commands from being sent to devices. To fix this issue, inspect the system, including generation and storage devices, local controllers, and communication links.

*   **Test** — Test mode — Provides control over inputs and outputs of the device. Use it to validate the interfaces with various assets and platforms in the microgrid. When in a production environment, use this mode only with guidance from GE staff. See the next section for details.

Note that there are some delays in transitioning between modes. Also, the mode cannot be abruptly changed from off to Auto; it first switches to Advisory mode, and if the optimization problem is feasible, and an optimal solution is found, the operation mode changes from Advisory to Auto at the end of the problem-solving phase. This transition is indicated by "Running Optimal Dispatch" on the main HMI panel.

Figure 78: Set U90^Plus operation mode
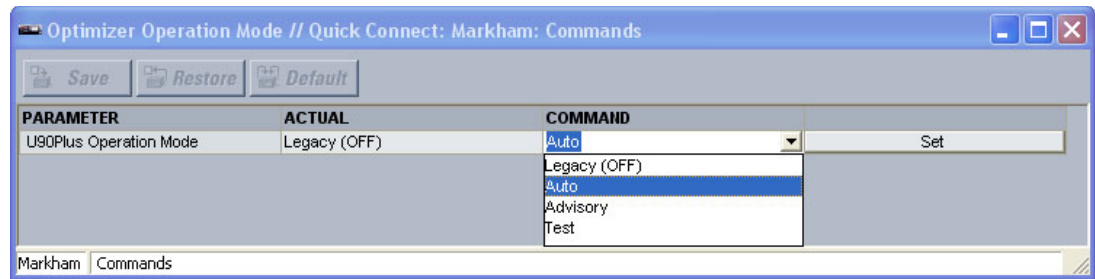
To set optimizer mode:

1. In the software, navigate to **Commands > Optimizer Operation Mode**.

2. Select the mode from the **Command** drop-down list.

3. Click the **Set** button. A message displays upon success. The function is equivalent to writing 0 (Legacy/Off), 1 (Auto), or 2 (Advisory) to Modbus address 0x1064. When set, the main HMI panel on the unit reflects the mode in the **U90Plus Operation Mode** field; it can take a few minutes to update the display.

Figure 79: Operation mode displayed on front panel
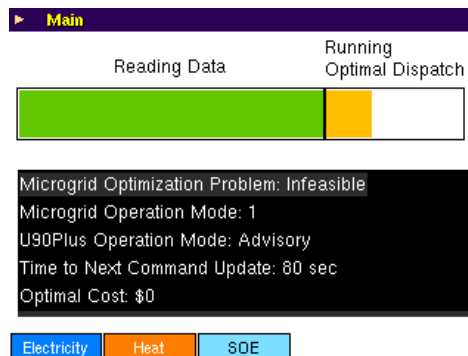
Test mode   Test mode provides control over inputs and outputs of the device. Use it to validate the interfaces with various resources and platforms in the microgrid. This section outlines the inputs and outputs that can be tested. If you need to know the registers to which the inputs and outputs map, access the register map in the **File > Register Map Editor** menu.

In a production environment, use test mode only under the guidance of GE staff.

To set test mode:

1. In the software, navigate to **Commands > Optimizer Operation Mode**.

2. Select the **Test** option from the **Command** drop-down list.

3. Click the **Set** button. It can take a few seconds before the **Actual** field refreshes to Test mode.

The following figures show the input and output mappings that can be validated using test mode.

Figure 80: Dispatchable resource type
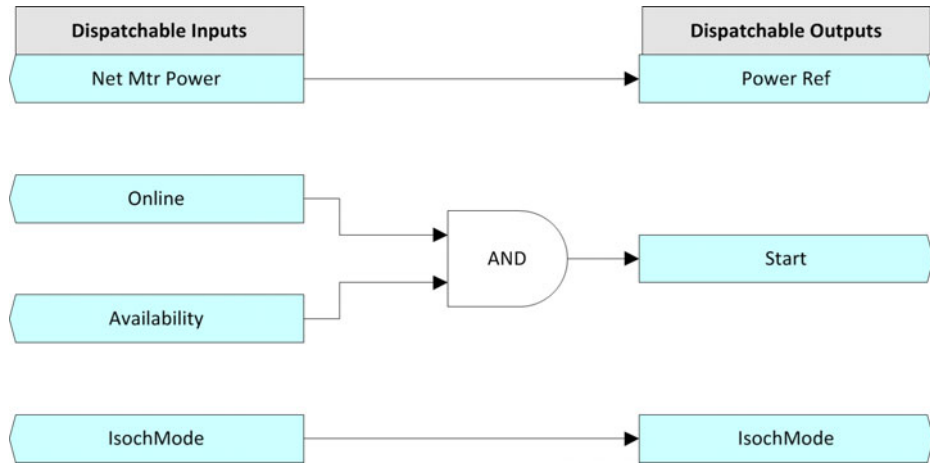
Figure 81: Electric storage resource type
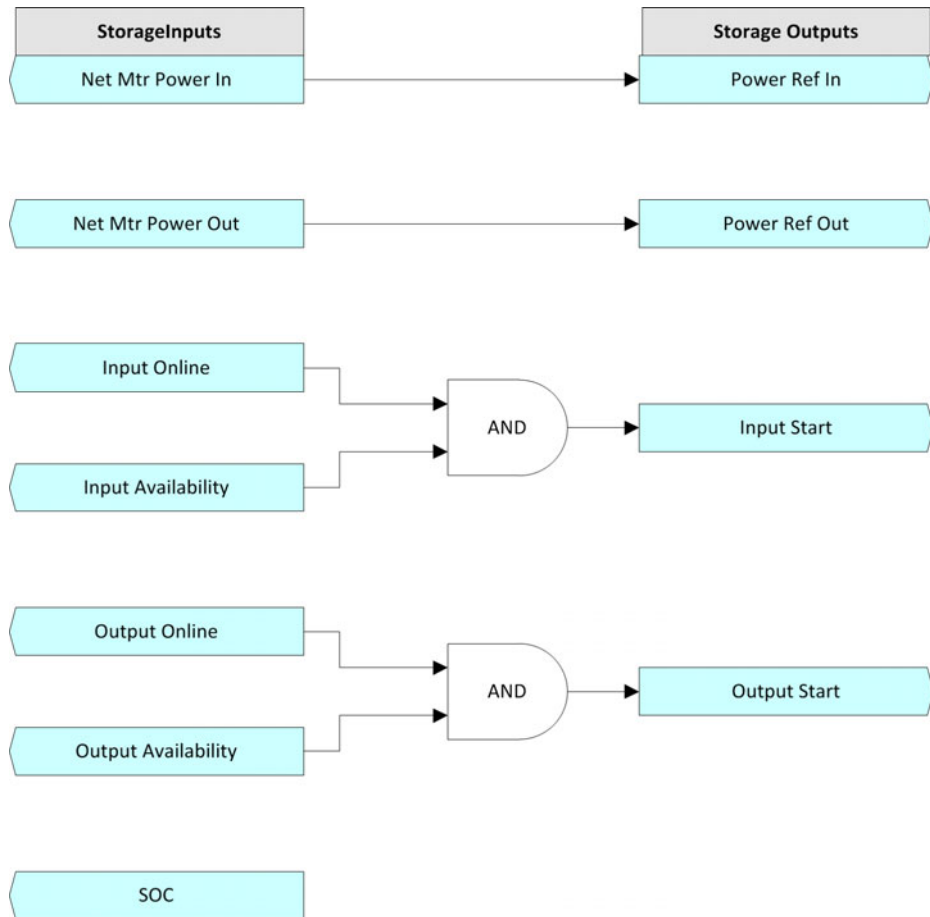
For the electric storage resources, the state-of-charge (SOC) input can be tested/validated by reading the corresponding actual with the EnerVista software, by reading the corresponding Modbus register through a modbus client, or by reading the SOC within the COMTRADE record.

Figure 82: Renewable resource type
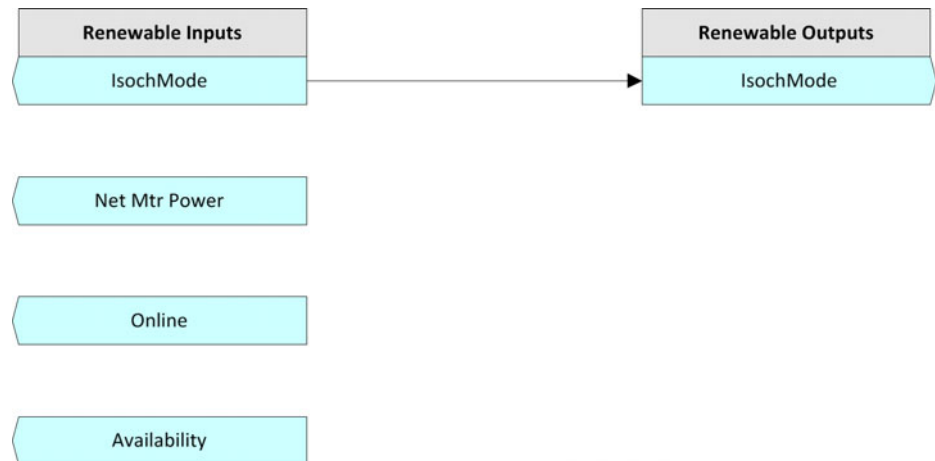
For the renewable resource type, the net metered power and the online and availability status inputs can be tested/validated by reading the corresponding actuals with the EnerVista software, by reading the corresponding Modbus registers through a modbus client, or by reading them within the COMTRADE record.

Figure 83: Grid type
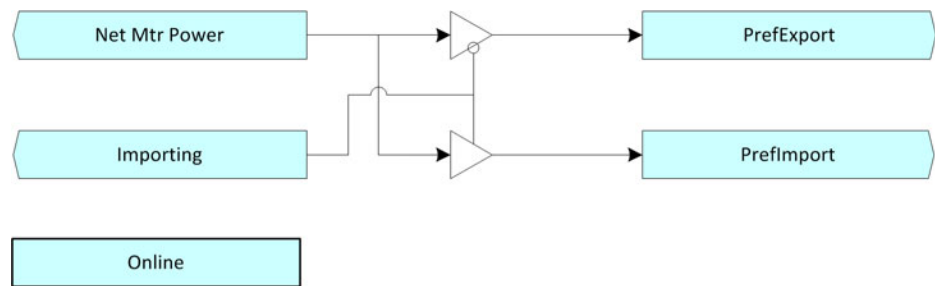
Figure 84: Combined heat and power (CHP) type
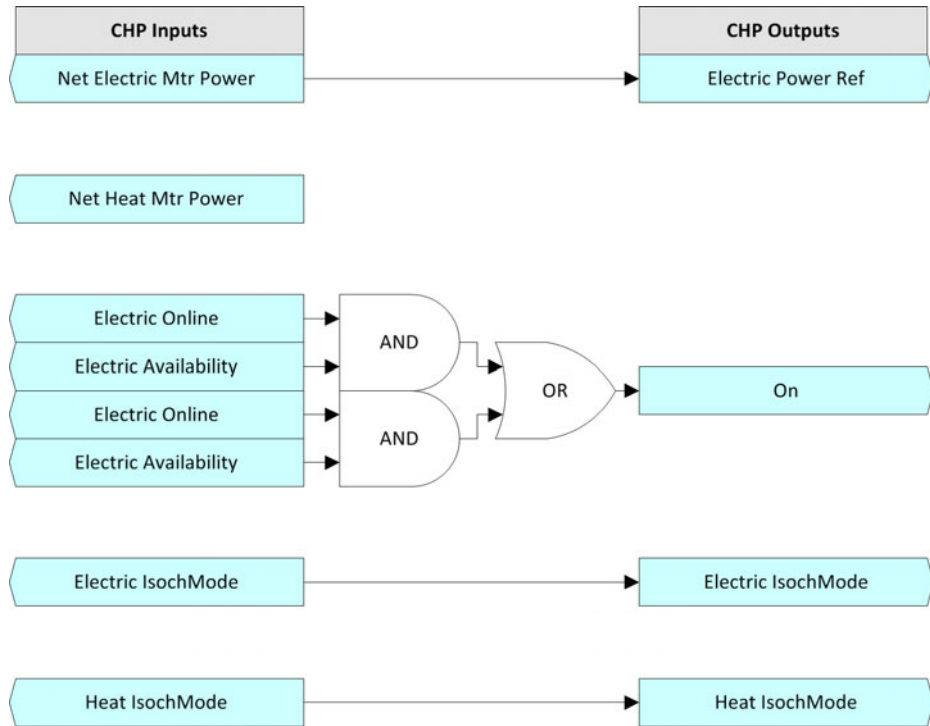
For CHP, the net heat metered power input corresponding to the thermic portion of the CHP unit can be tested/validated by reading the corresponding actual with the EnerVista software, by reading the corresponding Modbus register through a modbus client, or by reading it within the COMTRADE record.

Figure 85: Boiler resource type
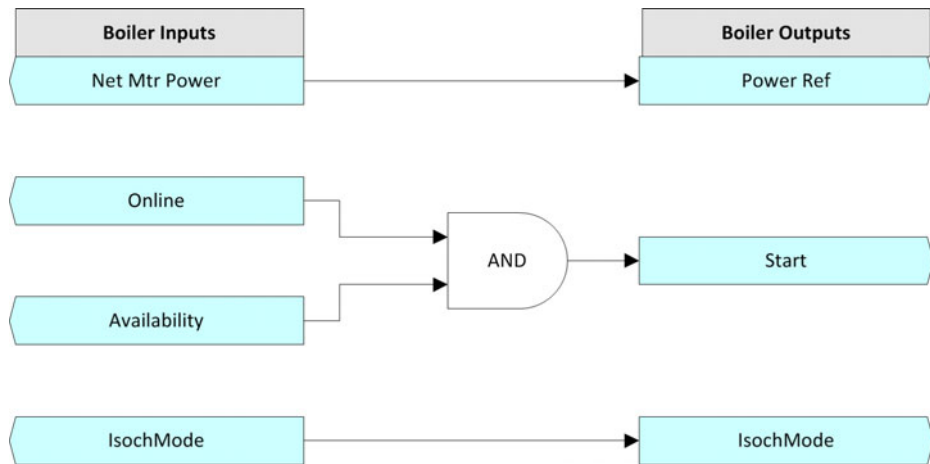
Figure 86: Electric load resource type

For electric load, because the load is not controlled by the U90^{Plus}, none of inputs corresponding to this asset type has a corresponding one into the output layer. The inputs (the net metered power and the online and availability status inputs) can be tested/validated by reading the corresponding actuals with the EnerVista software, by reading the corresponding Modbus registers through a modbus client, or by reading them within the COMTRADE record.

Figure 87: Heat load resource type

The information for electric load also applies to heat load.

Forecasts

This section outlines how to provide forecast values for load and renewable power, and grid buy and sell prices.

Renewable   This panel allows you to provide power forecasts of renewable resources in kW. It allows you to account for daily variation, such as sun during the day and not at night, for use in forecasts.

The values are based on experience or can be estimated using sites on the Internet that account for location, angle, and month, for example.

Consider adjusting the values seasonally. For example, wind turbine output can be lowest in summer when demand is highest, making entry of such data crucial.

This panel documents forecasted output power. Potential output is entered in the **Renewable Capability** panel.

To configure expected output of renewable resources:

1.   In the software, navigate to **Commands > Forecasts > Renewable**.

2.   Select the resource from the **Renewable** drop-down list. The number of renewable resources selectable from the drop-down list is set under **Settings > Product Setup > Installation**.

3. From the **Resolution** drop-down list, select the time period to use, from 1 hour (60 minutes) to 6 hours (360 minutes). This determines which hours display in the panel.

4. Enter the power output expected at each time, for example 200 for 200 kW.

5. Click the **Save** button. The data is sent to the U90^Plus. A message displays upon success.

6. Repeat the procedure for each renewable resource in the first drop-down list.

Figure 88: Entering hourly output estimates for renewables

The following settings are available.

Renewable

Range: selectable from drop-down list

Default: blank

Select the renewable resource from the drop-down list. This setting is blank when no renewable resources have been specified in the **Settings > Product Setup > Installation** panel or when not configured with a name.

Resolution

Range: 60, 120, 180, 240, 300, 360 minutes

Default: 120 minutes

This setting determines how many time labels to display in the panel. When set to 60 minutes, 24 time labels display. When set to 360 minutes, there are five times displayed, for example 00:00, 06:00, 12:00, 18:00, and 24:00.

Note that **Prediction Horizon** and **Dispatch Time** settings specify the total number of required forecast values. For example, 120 forecast values are required based on a Prediction Horizon of 24 hours and Dispatch Time of 12 minutes. If **Resolution** is set to 60 minutes, only 25 forecast values can be provided by the user corresponding to each hour from 00:00 to 24:00. In order to cover the forecast requirements for the whole Prediction Horizon, the U90^{Plus} interpolates the required 120 forecast values based on the 25 values provided by the user.

Offset
Range: number
Default: 0 minutes

This setting specifies the time stamp of the first value with respect to the U90^{Plus} reference time, which is assumed to be 12:00 AM. Use

(Present Time – 00:00) * 60

to set the offset, and generate appropriate time labels for the forecast values. For example, if the **Resolution** is 120 minutes, and the present time when forecast values are sent to the U90^{Plus} is 06:00, enter 360 minutes to display the time labels as 06:00, 08:00, 10:00, and so on.

If you change this value, the U90^{Plus} interpolates the forecasted data the first time to fill the time gap created by the offset.

Forecast
Range: number
Default: 1.000000 kW

This setting is the forecasted power output. For example, enter 200 for 200 kW.

The number of entries depends on the **Resolution** selected.

Load   This panel allows you to provide load forecasts in kW.

To set values for load forecasts:

1. In the software, navigate to **Commands > Forecasts > Load**.
2. Select the resource from the **Load** drop-down list. The number of loads selectable from the drop-down list is set under **Settings > Product Setup > Installation**.
3. From the **Resolution** drop-down list, select the time period to use, from 1 hour (60 minutes) to 6 hours (360 minutes). This determines which hours display in the panel.
4. Enter the load expected for each time, for example 900 for 900 kW of electricity.
5. Click the **Save** button. The data is sent to the U90^{Plus}. A message displays upon success.
6. Repeat the procedure for each load in the first drop-down list.

See the previous section for a description of the fields.

Grid Buy Price   This panel allows you to provide grid buy price forecasts in $/kWh.

If you select one of the importing or exporting options, there is no limitation and the unit is enable to either import or export over the prediction horizon based on your setting.

There are two options for entering the prices to be used in forecasts: add them in the EnerVista software, or use an external source.

To set electricity buy prices in the EnerVista software:

1. Navigate to **Commands > Forecasts > Grid Buy Price**.
2. Select the grid from the **Grid Buy** drop-down list. This is the grid from which the microgrid imports.

3. From the **Resolution** drop-down list, select the time period to use, from 1 hour (60 minutes) to 6 hours (360 minutes). This determines which time labels display in the panel.

4. Enter the price for each period, for example enter 0.1 for $0.1 per kWh. The cost is in dollars; for other currencies simply enter that value and be consistent in all fields involving the currency. These are the prices at which the microgrid purchases the electricity.

5. Click the **Save** button. The data is sent to the U90^Plus. A message displays upon success.

See the Renewable section for a description of the fields.

Using the following figure, note the difference between the generated time labels for Grid Buy Price with those of generated for Load and Renewable. With the Grid Buy Price, a time period is given instead of a discrete time.

Figure 89: Set the price for purchase from grid
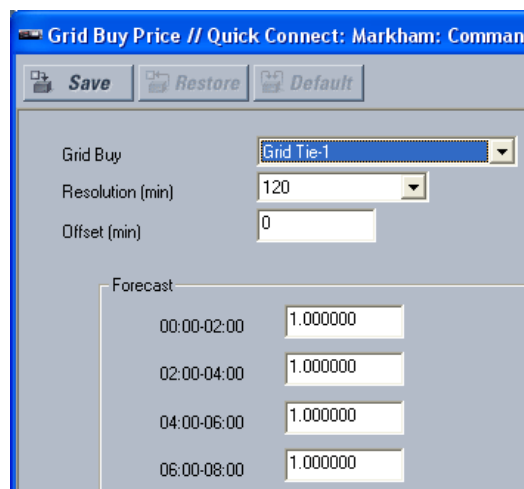
Grid Sell Price

Set the sell price of electricity in this panel, meaning the prices at which the grid purchases from the microgrid. The information is similar to the previous section. The **Grid Sell** field specifies the grid to which the microgrid exports.

Renewable Capability

This panel allows for variation in renewable output. Depending on geographical location, some renewable resources, such as a run-of-the-river hydro unit with reservoir, can provide relatively reliable and stable output power in certain periods. This qualifies them to operate as an isochronous machine in the microgrid. However, in order to support such a feature in the microgrid optimization framework, a parameter titled **Renewable Capability** is provided over the prediction horizon. This parameter, which is only applicable to renewable resources operating as isochronous machines, indicates potential output power as a coefficient between 0 and 1. When no Renewable Capability forecast is provided by the user, a default value of 1 is used by the U90^Plus.

Similar to load, renewable and grid price forecasts, **Prediction Horizon** and **Dispatch Time** specify the total number of Renewable Capability values to be provided. However, the user can provide only a few of them in particular hours, and in the U90^Plus appropriate values for all the required renewable capabilities are interpolated.

This panel documents potential output. Expected output is entered in the **Renewable** panel.

To configure Renewable Capability coefficients for renewable resources:

1. In the software, navigate to **Commands > Forecasts > Renewable Capability**.

2. Select the resource from the **Renewable** drop-down list. The number of renewable resources selectable from the drop-down list is set under **Settings > Product Setup > Installation**.

3. From the **Resolution** drop-down list, select the time period to use, from 1 hour (60 minutes) to 6 hours (360 minutes). This determines which time labels display in the panel.

4. Enter the coefficient for each time.

5. Click the **Save** button. The data is sent to the U90^{Plus}. A message displays upon success.

6. Repeat the procedure for each renewable resource in the first drop-down list.

Figure 90: Entering hourly coefficients for renewables

The following settings are available.

Renewable

Range: selectable from drop-down list
Default: blank

Select the renewable resource from the drop-down list. This setting is blank when no renewable resources have been specified in the **Settings > System Setup > Microgrid Assets > Renewables** panel to run in isochronous mode.

Resolution

Range: 60, 120, 180, 240, 300, 360 minutes

Default: 120 minutes

This setting determines how many time labels to display in the panel. When set to 60 minutes, 24 time labels display. When set to 360 minutes, there are five times displayed, for example 00:00, 06:00, 12:00, 18:00, and 24:00.

Offset

Range: number

Default: 0 minutes

This setting specifies the time stamp of the first value with respect to the U90^{Plus} reference time, which is assumed to be 12:00 AM. Use

(Present Time - 00:00)*60

to set the offset, and generate appropriate time labels for the forecast values. For example, if the **Resolution** is 120 minutes, and the present time when forecast values are sent to U90^{Plus} is 06:00, enter 360 minutes to display the time labels as 06:00, 08:00, 10:00, and so on.

If you change this value, the U90^{Plus} interpolates the forecasted data the first time to fill the time gap created by the offset.

Forecast

Range: 0 to 1

Default: 1.000000

This setting is the Renewable Capability coefficients. For example, when renewable output capability is 30 percent of the maximum capacity, enter 0.30.

The number of entries depends on the **Resolution** selected.

Heat Load   Set the expected demand for heat in this panel, for use in forecasts. The information is similar to the Load section earlier.

Virtual Inputs

This panel displays the current value of configured virtual inputs and allows you to update their values.

To set the value of virtual inputs:

1.   Navigate to **Commands > Virtual Inputs**. The window that displays is empty when no virtual inputs are configured under **Settings > Inputs/Outputs > Virtual Inputs**.

2.   In the **Actual Value** field, select a value from the drop-down list.

3.   Click the **Save** button.

Virtual Analog Inputs

This panel displays the current value of configured virtual analog inputs and allows you to update their values.

To set the value of virtual analog inputs:

1.   Navigate to **Commands > Virtual Analog Inputs**. The window that displays is empty when no virtual inputs are configured under **Settings > Inputs/Outputs > Virtual Analogs**.

2.   In the **Actual Value** field, select a value from the drop-down list.

3.   Click the **Save** button.

Set Date and Time

There are two options for setting the timestamp: IRIG-B and the EnerVista software. See the Real Time Clock section earlier.

U90^{Plus} Microgrid Generation Optimization

Chapter 6: Security

This chapter outlines security features.

Security options

Security measures include the following:

- Use of a password to change the Commands panels (**Settings > Product Setup > Security**; see the Security section earlier)
- Logins recorded in the event record (**Security > Event Log > View**; see the View Event Log section later)
- Security-related event log for the EnerVista software downloaded as a file (**Maintenance > Retrieve File**; see the Retrieve Files section later)

U90^{Plus} Microgrid Generation Optimization

Chapter 7: Maintenance

This chapter outlines how to view alarms, events, basic product information, update hardware and software, and replace modules.

View and turn off alarms

You manually check the alarms, either on the unit or in the software. To be automatically notified of alarms, use control software, such as GE CIMPLICITY or third-party software.

On the front panel, alarms are organized in a table and numbered from left to right and then top to bottom. The first location in the top left corner of the first page is denoted as indicator 1 by the EnerVista software. The top left location of the next page is the bottom right location's indicator number on the previous page plus one.

Alarms need to be configured under **Settings > Product Setup > Annunciator**. See the Annunciator (alarms) section earlier. Alarms are explained in that section.

The following two procedures are outlined:

* View and turn off alarms on the unit
* View and turn off alarms in the software

To view and turn off alarms on the unit:

1. View them on the annunciator panel on the left. Use the following control buttons at the bottom of the display:

* The **Ack** button acknowledges the selected alarm. This turns off the alarm.
* The **Next Alarm** button cycles through the active alarms, paging as required
* The **Next Page** button cycles through the pages of indicators and to the information pages

In the software, the table displays the alarm ID, its operator specified name, and a button. The default text is white on a black background, but changes to the configured color if the alarm is active. The action button becomes enabled when the alarm is active.

To view and turn off alarms in the software:

EVENT AND DATA RECORDS

1. Navigate to **Actual Values > Annunciator Panel**. Alarm conditions display in the color configured, for example red. Otherwise, when an alarm has not been triggered, the color is black.

2. To turn off any alarm condition, click its **Acknowledge** button.

Figure 91: Alarm panels
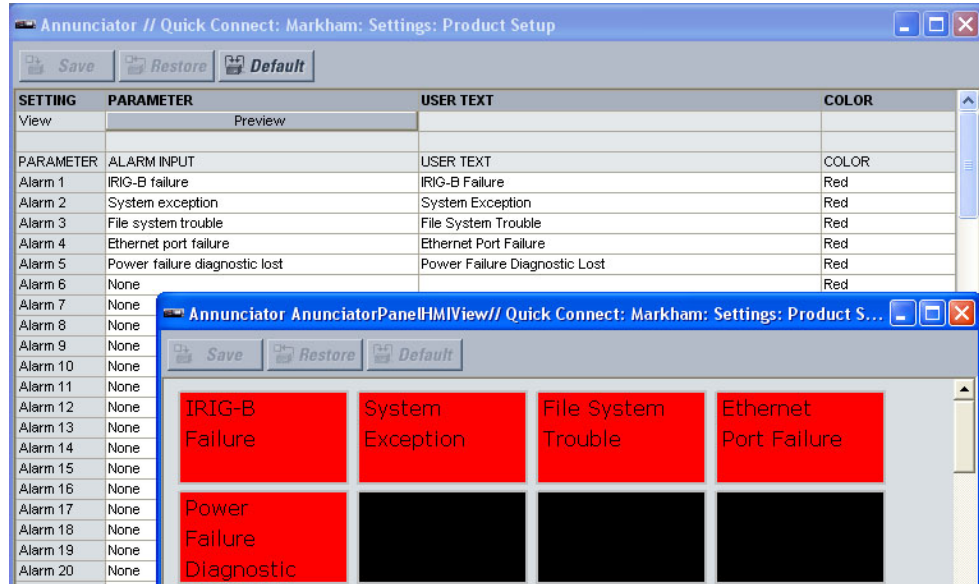
Event and data records

The U90^{Plus} stores three types of event and data records:

- **Event records** — Operational events, such as alarms
- **Event log** — System-level events, such as when the EnerVista software was started and the addition of a user account
- **Data records** — Actual values (inputs) and commands (outputs)

The event recorder provides a time-stamped record of predefined events, such as alarms. The U90^{Plus} stores up to 8,192 events in non-volatile memory. The recording of events is enabled on a per-element basis. When the memory is full, the oldest events are overwritten. The events are time-stamped with an accuracy of 1 ms.

View event records

The event records are viewable on the U90^{Plus} front panel and in the EnerVista software. Two cursors also are provided for measurement of the time difference between events.

Figure 92: Event records on the HMI panel

To view event records on the U90^{Plus} front panel:

1. Press the **SOE** button below the HMI display.
2. Navigate through the list using the **Up** and **Down** buttons.
    To go back in the menu, press the round **Back** button on the front of the unit.
    Or press the **more** button, then one of the following buttons:
    –   **Page Up** — Displays newer records
    –   **Page Down** — Displays older records
    –   **Last Event** — Displays latest record
    –   **First Event** — Displays oldest record

To view the time difference using the lock cursor feature on the U90^{Plus} front panel:

1. Navigate to place the cursor on a record entry.
2. Press the **Lock Cursor** button.
3. Navigate to place the cursor on a second record entry. The Delta line at the top of the window displays the time difference between the two records in days, hours, minutes, seconds, and fractions of seconds.
4. Press the **Lock Cursor** button a second time to unlock.

To view event records in the EnerVista software:

1. In the **Online Window** area, navigate to **Actual Values > Records > Event Record**.

To view time difference using the lock cursor feature in the EnerVista software:

1. In the **Online Window** area of the software, navigate to **Actual Values > Records> Event Record**.
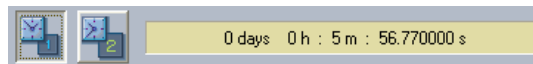
2. Click the 1 clock button, then click the first required record entry.
3. Click the 2 clock button, then click the second required record entry.
4. The yellow window beside the buttons displays the time difference between the two records in days, hours, minutes, and seconds.
5. To sort the list, double-click a column heading.

View event log
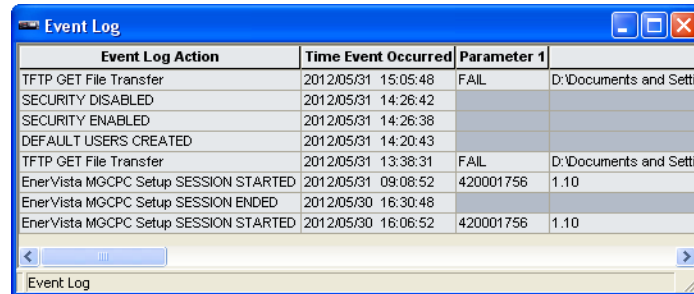
The event log displays system-level events, such as the time that the EnerVista software was started and the addition of a user account.

The event log can also be downloaded under **Maintenance > Retrieve File**; see the Retrieve Files section.

To view the event log:

1.   In the EnerVista software, select the **Security > Event Log > View** menu option at the top of the window. The event log displays.

Figure 93: Event log showing software startup time and user account addition

Clear event records and logs

Event records and logs can be cleared.

To clear event records using the EnerVista software:

1.   In the **Online Window** area, navigate to **Commands > Clear Records**.
2.   Confirm the action at the prompt.

To clear the event log:

1.   Select the **Security > Event Log > Clear** menu option at the top of the window.
2.   Confirm the action at the prompt.

View serial number

There are two ways to view the serial number: on the back of the unit and in the EnerVista software.

To view the serial number on the unit:

1.   Look for the bar code sticker on the back of the unit.

To view the serial number in the EnerVista software:

1.   In the **Online Window** area, navigate to **Actual Values > Product Info > Model Information**.

View order code

The order code is useful for ordering, licensing, and to know which product options apply. An example is U90P-HE-FX01XXX-XHXXXXXXXX.

To view the order code in the EnerVista software:

1. In the **Online Window** area, navigate to **Actual Values > Product Info > Model Information**.

See the Order Code section for an explanation of the code.

View firmware and software versions

The version numbers of the firmware and software are viewable. The information is useful to determine when updating is possible.

There are two ways to view firmware version: on the annunciator display and in the EnerVista software.

There is one way to view the software version number: in the EnerVista software. The system does not check automatically for available software updates.

Figure 94: View firmware version in software
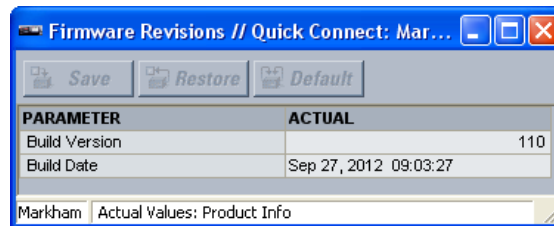
To view the firmware version on the unit:

1. Page down on the annunciator display to the Product Information page. An example of the **Firmware** number is 1.10.

To view the firmware version in the EnerVista software:

1. In the **Online Window** area, navigate to **Device Definition**. The firmware version number displays as the **Version** item, for example 1.1x. Or navigate to **Actual Values > Product Info > Firmware Revisions**. The build version and its date display (see figure), where 110 means version 1.10.

To view the software version number:

1. Click the **Help > About EnerVista U90Plus Setup** menu option at the top of the window. The version and its date display.
2. Click the **+** to view more version numbers.

Figure 95: Software version number
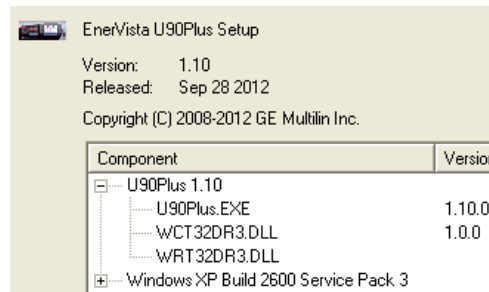
Update firmware and software

The firmware of a U90^Plus unit can be upgraded remotely over Ethernet using the EnerVista U90^Plus Setup software. You download the update, save existing settings, update, then apply the saved settings.

The EnerVista software can also be updated. The system does not check for updates automatically.

NOTE

Updating the firmware deletes device settings and event records. To save device settings, follow the next procedure.

To update the hardware firmware:

1. Download the firmware update file from the GE website at
    http://www.gedigitalenergy.com/multilin/software/index.htm
    The file is a ZIP file that is password-protected. Do not unzip it.

2. Remove the U90^Plus unit from service, for example set the operating mode to Legacy (Off) under **Commands > Optimizer Operation Mode**. Leave the unit on.

3. Save existing settings as follows. In the **Online Window** area of the EnerVista software, right-click the U90^Plus device and select **Read Device Settings**. In the window that displays, select an existing file to overwrite, or specify a location and name for a new file. Click **Receive** to start the backup. This function saves a URS file that is usable only by the U90^Plus. It is not the same as exporting the settings to as a CSV file (**Export Settings to File**).

Figure 96: Select the zip file to update firmware
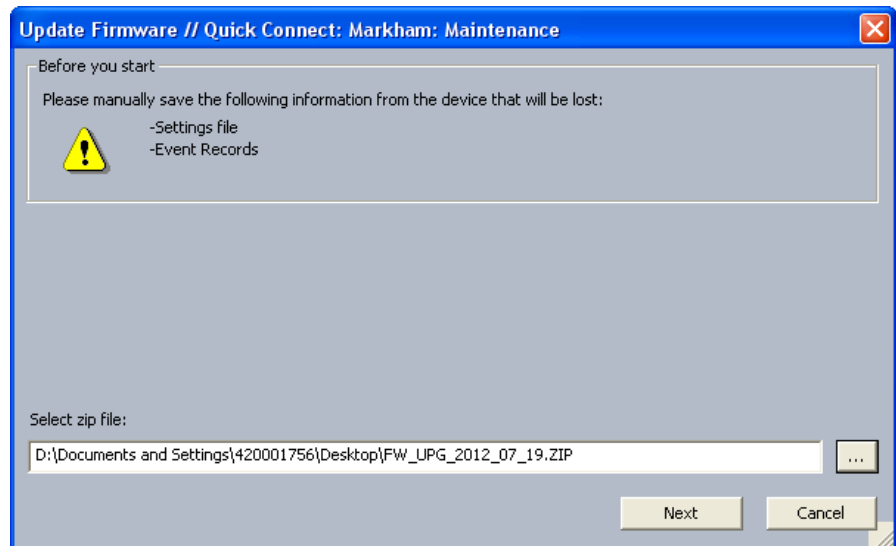
4. To start the update, in the **Online Window** area, navigate to **Maintenance > Update Firmware**. Select the firmware update file, click **Next**, and continue with the prompts to start the update. Progress displays, as shown in the following figure. Ensure power to the device remains on during the update and wait for the unit to restart itself before continuing.

NOTICE   Interruption of communication during the update can result in corrupted firmware. If this occurs, consult the factory for recovery instructions.

Figure 97: Firmware update completion
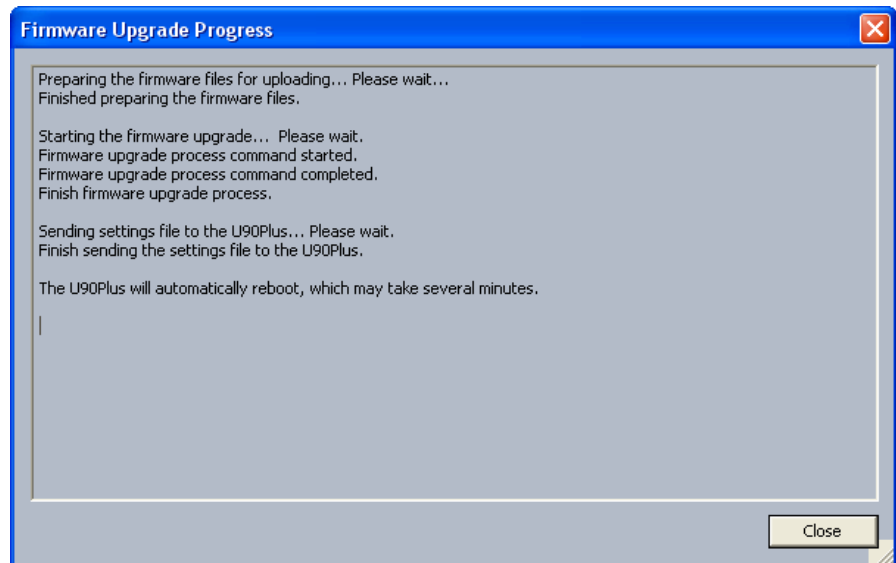
5. To apply your saved settings, right-click the saved settings file in the **Offline Window** area and select **Write to Device**. If you see an error message and cannot connect to the unit, wait for the unit to finish restarting and try again.

6. Return the unit to service, for example by changing the operating mode under **Commands > Optimizer Operation Mode**. Confirm the messages that appear. If you see an error message, wait for the unit to finish restarting and try again.

7. To verify that the firmware was updated, navigate to **Actual Values > Product Info > Firmware Revisions**. If the screen has not updated, close and reopen the software.

To update the software:

1. Download the file from the GE website at
http://www.gedigitalenergy.com/multilin/software/index.htm
 The file is a .exe file.
2. Double-click the file to install the software. Settings are not lost when updating.

Backup and export settings

The settings of a U90^Plus unit can be backed up by saving them as a URS file. They can also be exported as a CSV file. The advantage of this CSV file is that it is user friendly and readable, allowing you to print and view the settings. The same settings are contained in the XML files that are created in the background when using the **Send Setup to Device** function. The exported CSV file cannot be imported; use the URS file instead to restore settings.

To back up the settings:

1. In the **Online Window** area of the EnerVista software, right-click the U90^Plus device and select **Read Device Settings**. In the window that displays, select an existing file to overwrite, or specify a location and name for a new file. Click **Receive** to start the backup. This function saves a URS file that is usable only by the U90^Plus.

To restore the settings:

1. In the **Offline Window** area of the EnerVista software, right-click the file to use and select **Write to Device**.

To export the settings:

1. In the **Online Window** area of the EnerVista software, right-click the U90^Plus device and select **Export Settings to File** to create a CSV file. The function is also available in the **Offline Window** area and from the menu.

Figure 98: Part of a CSV file

	A	B	C	D
1	header	version	1.1	
2	header	configdate	29-Sep	2012 14
3	header	name	29 Palms U90Plus	
4	header	buildversion	110	
5	control	CONTROL_CONTROL.CtrlLoopPeriod	10	
6	control	CONTROL_CONTROL.DispatchPeriod	12	
7	control	CONTROL_CONTROL.DispatchOffset	0	
8	control	CONTROL_CONTROL.DispatchUpdat	120	
9	control	CONTROL_CONTROL.CommandActic	50	
10	control	CONTROL_CONTROL.CommandTime	100	
11	control	CONTROL_CONTROL.RAEnabled	0	
12	control	SYSTEM_CONTROL.IsocMarginPlus	0	

Retrieve files

Event logs and factory data files are downloadable. The event log displays system-level events, such as the time that the EnerVista software was started and the addition of a user account. It is not the same as the event record.

Another option is to obtain a data file under **Actual Values > Data Recorder**; see the View Data Records section.

To download the event log and/or factory data file:

1. In the **Online Window** area of the software, navigate to **Maintenance > Retrieve File**.
2. In the window that displays, select a file on the left side. The DIR.TXT file lists information similar to that shown in the following figure.
3. Specify where to download the file in the **Destination directory** field or note the location.
4. Click the **Read File** button. The file download starts.

Figure 99: Select file to download
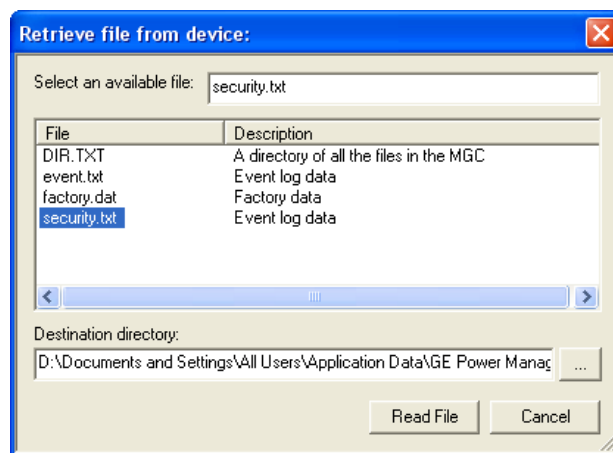
Replace module

⚠ **WARNING** Remove or insert a module only when power has been removed from the unit, else death or serious injury can result.

⚠ **CAUTION** Inserting an incorrect module type into a slot can result in personal injury, damage to the unit or connected equipment, or undesired operation.

NOTICE Use proper electrostatic discharge protection (for example, an antistatic strap) when handling the modules, else damage can occur.

All modules are delivered installed. No cards are optional on the unit. There is no need to change a module except for repair purposes.

To change a module:

1. Return the unit to the factory or have a representative perform the work on-site.

U90^{Plus} Microgrid Generation Optimization

Chapter 8: Appendix A

This chapter outlines the Modbus memory map.

Modbus memory map

This section outlines the Modbus memory map.

Table 9: Memory map

Address	Description	Range	Units	Format	Default
Settings - Optimizer					
x1000	Prediction Horizon	1 to 48	hr	uint	24
x1001	Dispatch Time	6 to 60	min	uint	12
x1002	Isoch Margin Plus	0 to 100	%	float	20
x100C	Isoch Margin Minus	0 to 100	%	float	20
x1016	Heat Isoch Margin Plus	0 to 100	%	float	20
x1018	Heat Isoch Margin Minus	0 to 100	%	float	20
x101A	Active Mode	0 to 4	--	uint	0
x101B	Reserved	1 to 1	--	uint	1
x101C	Reserved	0 to 1000000	kW	float	50
x101E	Reserved	0 to 1000000	kW	float	50
X1020	Reserved	1 to 4	--	uint	0
x1022	Power Balance Penalty	0 to 1000	$/kW	float	0
x1024	Constraint Mode	0 to 1	--	bool	0
x1025	Heat Power Balance Penalty	0 to 1000	$/kW	float	0
x1027	Heat Constraint Mode	0 to 1	--	bool	0
x1028	Reserved	0 to 1	--	uint	0
Settings - Control					
x1045	Ctrl Loop Period	5 to 10	sec	uint	10
x1046	Dispatch Period	6 to 24	min	uint	12
x1047	Dispatch Offset	0 to 120	sec	uint	0
x1048	Dispatch Update Offset	0 to 120	sec	uint	120

Address	Description	Range	Units	Format	Default
x1049	Isoch Command Check Time	10 to 720	sec	uint	10
x104A	Isoch Command Timeout	10 to 720	sec	uint	10
x104B	RA Enabled	0 to 1	--	bool	0
x104C	Reserved	0 to 1	--	uint	0
Settings - System Commands					
x105C	Isoch Margin Plus	0 to 100	%	float	0
x105E	Isoch Margin Minus	0 to 100	%	float	0
x1060	Heat Isoch Margin Plus	0 to 100	%	float	0
x1062	Heat Isoch Margin Minus	0 to 100	%	float	0
x1064	Op Mode	0 to 3	--	uint	0
x1065	Irig Has Year	0 to 1	--	bool	0
x1066	Irig Modulation	0 to 2	--	uint	0
x1067	Watchdog Period	10 to 720	sec	uint	360
x1068	Clear Events	0 to 1	--	bool	0
x1069	Date Time	0 to 16	date	uint	0
x106B	DST Function	0 to 1	--	bool	0
x106C	Time Zone Offset	-24 to 24	hr	float	0
x106E	DST Start Month	1 to 12	--	uint	1
x106F	DST Start Day	0 to 6	--	uint	0
x1070	DST Start Day Instance	0 to 4	--	uint	0
x1071	DST Start Hour	0 to 23	--	uint	0
x1072	DST Stop Month	1 to 12	--	uint	1
x1073	DST Stop Day	0 to 6	--	uint	0
x1074	DST Stop Day Instance	0 to 4	--	uint	0
x1075	DST Stop Hour	0 to 23	--	uint	0
x1076	Reserved	0 to 1	--	uint	0
Settings - Dispatchable					
x107A	Name	--	--	char	--
x108E	Rated Power	0 to 1,000,000	kW	float	250
x1090	Min Power	0 to 1,000,000	kW	float	50
x1092	Efficiency Max	0 to 1,000	kWh/kg	float	0.75
x1094	Efficiency Min	0 to 1,000	kWh/kg	float	0.55
x1096	Start Cost	0 to 1,000,000	$	float	10
x1098	Stop Cost	0 to 1,000,000	$	float	10
x109A	Isoch Operation Mode	0 to 1	--	bool	0
x109F	Constraint Mode	0 to 1	--	bool	0
x10A0	Fuel Cost	0 to 100	$/L	float	1
x10A2	Fuel Density	0 to 1,000	kg/L	float	0.85
x10A4	Min Power Penalty	0 to 1,000	$/kWh	float	0
x10A6	Enabled	0 to 1	--	bool	1
x10A7	Reserved	0 to 1	--	bool	1
x10A8	Reserved	0 to 600	min	uint	0
x10A9	Reserved	0 to 2880	min	unit	0
x10AA	RA Turn Off All Storage Charge	0 to 1	--	bool	1
x10AB	RA Turn On All Storage Discharge	0 to 1	--	bool	1
x10AC	RA Dispatchable Actions	0 to 16	--	uint	0
x10BC	Reserved	0 to 1	--	uint	0

Address	Description	Range	Units	Format	Default
Settings - Storage					
x158A	Name	--	--	char	--
x159E	Input Enabled	0 to 1	--	bool	1
x159F	Output Enabled	0 to 1	--	bool	1
x15A0	Max Discharging Power	0 to 1,000,000	kW	float	50
x15A2	Min Discharging Power	0 to 1,000,000	kW	float	25
x15A4	Max Charging Power	0 to 1,000,000	kW	float	50
x15A6	Min Charging Power	0 to 1,000,000	kW	float	25
x15A8	Charging Efficiency	0 to 1	%	float	50
x15AA	Discharging Efficiency	0 to 1	%	float	55
x15AC	SOC Max	0 to 1,000,000	kWh	float	300
x15AE	SOC Min	0 to 1,000,000	kWh	float	50
x15B0	UB Store Dev1	0 to 1	kW	float	0
x15B2	UB Store Dev2	0 to 1	kW	float	0
x15B4	LB Store Dev1	0 to 1	kW	float	0
x15B6	LB Store Dev2	0 to 1	kW	float	0
x15B8	Constraint Mode	0 to 1	--	bool	0
x15B9	Charging Cost	0 to 1,000	$/kWh	float	10
x15BB	Discharging Cost	0 to 1,000	$/kWh	float	5
x15BD	Charging Incentive	0 to 1,000	$/kWh	float	0
x15BF	Discharging Incentive	0 to 1,000	$/kWh	float	0
x15C1	SOC Incentive	0 to 1,000	$/kWh^2	float	0
x15C3	SOC Penalty	0 to 1,000	$/kWh^2	float	0
x15C5	SOC Min Penalty	0 to 1,000	$/kWh^2	float	0
x15C7	Hysteresis	0 to 1	--	bool	0
x15C8	Charging Min Up Time	0 to 5	min	uint	0
x15C9	Charging Min Down Time	0 to 5	min	uint	0
x15CA	Charging Limit Feedback	0 to 1	--	bool	0
x15CB	Discharging Limit Feedback	0 to 1	--	bool	0
x15CC	Used By UC	0 to 1	--	bool	0
x15D0	Charging Dissipation	0 to 1,000	kWh/h	float	0
x15D2	Type	0 to 1	--	uint	1
x15D2	Reserved	0 to 1	--	uint	0
Settings - Renewable					
x1B0A	Name	--	--	char	--
x1B1E	Rated Power	0 to 1,000,000	kW	float	250
x1B20	Operating Cost	0 to 1,000,000	$/kWh	float	0
x1B22	Isoch Operation Mode	0 to 1	--	bool	0
x1B27	Enabled	0 to 1	--	bool	1
x1B28	Internal Forecast	0 to 1	--	bool	0
x1B29	Internal Capability	0 to 1	--	bool	0
x1B2A	Reserved	0 to 1	--	bool	0
x1B2B	Reserved	1 to 24	hr	uint	1
x1B2C	RA Turn Off All Storage Charge	0 to 1	--	bool	1
x1B2D	RA Turn On All Storage Discharge	0 to 1	--	bool	1
x1B2E	RA Dispatchable Actions	0 to 16	--	uint	0
x1B3E	Reserved	0 to 1	--	uint	0

Address	Description	Range	Units	Format	Default
Settings - Load					
x1F3A	Name	--	--	char	--
x1F4E	Internal Forecast	0 to 1	--	bool	0
x1F4F	Enabled	0 to 1	--	bool	1
x1F50	Reserved	0 to 1	--	bool	0
x1F51	Reserved	1 to 24	hr	uint	1
x1F52	Reserved	0 to 1	--	uint	0
Settings - Grid					
x21BA	Name	--	--	char	--
x21CE	Max Import Power	0 to 1,000,000	kW	float	100,000
x21D0	Min Import Power	0 to 1,000,000	kW	float	50
x21D2	Max Export Power	0 to 1,000,000	kW	float	100,000
x21D4	Min Export Power	0 to 1,000,000	kW	float	0
x21D6	Power Resolution	10 to 1,000,000	kW	float	10
x21D8	Import Enabled	0 to 1	--	bool	1
x21D9	Export Enabled	0 to 1	--	bool	1
x21DA	Reserved	0 to 1	--	bool	1
x21DB	Reserved	0 to 1	--	bool	1
x21DC	Reserved	0 to 1	--	uint	0
Settings - CHP					
x21EA	Name	--	--	char	--
x21FE	Electric Rated Power	0 to 1,000,000	kW	float	250
x2200	Electric Min Power	0 to 1,000,000	kW	float	50
x2202	Heat Rated Power	0 to 1,000,000	kW	float	250
x2204	Heat Min Power	0 to 1,000,000	kW	float	50
x2206	Electric Efficiency Max	0 to 1,000	kWh/kg	float	5.25
x2208	Electric Efficiency Min	0 to 1,000	kWh/kg	float	4.2
x220A	Gas-to-Electric Ratio	0 to 1	--	float	0.35
x220C	Gas-to-Heat Ratio	0 to 1	--	float	0.45
x220E	Fuel Density	0 to 5	kg/Nm^3	float	0.8
x2210	Fuel Cost	0 to 100	\$/Nm^3	float	0.35
x2212	Start Cost	0 to 1,000,000	\$	float	10
x2214	Stop Cost	0 to 1,000,000	\$	float	10
x2216	Isoch Operation Mode	0 to 1	--	bool	0
x221B	Electric Constraint Mode	0 to 1	--	bool	0
x221C	Electric Min Power Penalty	0 to 1,000	\$/kWh	float	0
x221E	Reserved	0 to 1	--	bool	0
x221F	Reserved	0 to 1,000	\$/kWh	float	0
x2221	Reserved	0 to 600	min	uint	0
x2222	Reserved	0 to 2,880	min	uint	0
x2223	Enabled	0 to 1	--	bool	1
x2224	Reserved	0 to 1	--	uint	0
Settings - Boiler					
x2422	Name	--	--	char	--
x2436	Rated Power	0 to 1,000,000	kW	float	250
x2438	Min Power	0 to 1,000,000	kW	float	50
x243A	Fuel Cost	0 to 1,000	\$/Nm^3	float	0.35

Address	Description	Range	Units	Format	Default
x243C	Fuel Density	0 to 1,000	kg/Nm3	float	0.8
x243E	Start Cost	0 to 1,000	$	float	50
x2440	Stop Cost	0 to 1,000	$	float	50
x2442	Efficiency	0 to 1,000	kWh/kg	float	13.5
x2444	Constraint Mode	0 to 1	--	bool	0
x2445	Min Power Penalty	0 to 1,000	$/kWh	float	10
x2447	Enabled	0 to 1	--	bool	1
x2448	Reserved	0 to 1	--	uint	0
Settings - Heat Load					
x2772	Name	--	--	char	--
x2786	Internal Forecast	0 to 1	--	bool	0
x2787	Enabled	0 to 1	--	bool	1
x2788	Reserved	0 to 1	--	bool	0
x2789	Reserved	1 to 24	hr	uint	1
x278A	Reserved	0 to 1	--	uint	0
Settings - Reserved					
x29F2	Reserved	1 to 10,000	s	uint	300
x29F3	Reserved	1 to 100	%	uint	25
x29F4	Reserved	0 to 1	--	bool	0
x29F5	Reserved	1 to 10,000	min	uint	30
x29F6	Reserved	0 to 1	--	uint	0
Settings - Data Logger					
x29FE	Input Resolution	1 to 1,000	min	uint	1
x29FF	Output Resolution	1 to 1,000	min	uint	12
x2A00	Reserved	0 to 1	--	uint	0
Settings - Command Scheduler					
x2A08	DU Turn On Interval	0 to 60	s	uint	10
x2A09	DU Turn Off Interval	0 to 60	s	uint	10
x2A0A	DU Turn OnOff Interval	0 to 60	s	uint	10
x2A0B	SU Out Turn On Interval	0 to 60	s	uint	10
x2A0C	SU In Turn Off Interval	0 to 60	s	uint	10
x2A0D	SU Out Turn Off Interval	0 to 60	s	uint	10
x2A0E	SU In Turn On Interval	0 to 60	s	uint	10
x2A0F	Reserved	0 to 1	--	uint	0
Inputs - Dispatchable					
x3000	Net Metered Power	0 to 1,000,000	kW	float	0
x3002	Online	0 to 1	--	bool	0
x3003	Input Isoch Mode	0 to 1	--	bool	0
x3004	Availability	0 to 1	--	bool	0
Inputs - Storage					
x3050	Net Metered Power In	0 to 1,000,000	kW	float	0
x3052	Net Metered Power Out	0 to 1,000,000	kW	float	0
x3054	Input Availability	0 to 1	--	bool	0
x3055	Output Availability	0 to 1	--	bool	0
x3056	Input Online	0 to 1	--	bool	0
x3057	Output Online	0 to 1	--	bool	0
x3058	SOC	0 to 1,000,000	kWh	float	0

Address	Description	Range	Units	Format	Default
x305A	Max Discharging Pwr	0 to 1,000,000	kW	float	0
x305C	Max Charging Pwr	0 to 1,000,000	kW	float	0
Inputs - Renewable					
x3130	Net Metered Power	0 to 1,000,000	kW	float	0
x3132	Online	0 to 1	--	bool	0
x3133	Isoch Mode	0 to 1	--	bool	0
x3134	Availability	0 to 1	--	bool	0
Inputs - Load					
x3180	Net Metered Power	0 to 1,000,000	kW	float	0
x3182	Online	0 to 1	--	bool	0
x3183	Availability	0 to 1	--	bool	0
Inputs - Reserved					
x31C0	Reserved	0 to 1,000,000	--	uint	0
Inputs - CHP					
x31C4	Net Electric Metered Power	0 to 1,000,000	kW	float	0
x31C6	Net Heat Metered Power	0 to 1,000,000	kW	float	0
x31C8	Electric Online	0 to 1	--	bool	0
x31C9	Heat Online	0 to 1	--	bool	0
x31CA	Electric Isoch Mode	0 to 1	--	bool	0
x31CB	Heat Isoch Mode	0 to 1	--	bool	0
x31CC	Electric Availability	0 to 1	--	bool	0
x31CD	Heat Availability	0 to 1	--	bool	0
Inputs - Boiler					
x3214	Net Metered Power	0 to 1,000,000	kW	float	0
x3216	Online	0 to 1	--	bool	0
x3217	Isoch Mode	0 to 1	--	bool	0
x3218	Availability	0 to 1	--	bool	0
Inputs - Heat Load					
x328C	Net Metered Power	0 to 1,000,000	kW	float	0
x328E	Online	0 to 1	--	bool	0
x328F	Availability	0 to 1	--	bool	0
Inputs - Grid					
x32CC	Net Metered Power	0 to 1,000,000	kW	float	0
x32CE	Online	0 to 1	--	bool	0
x32CF	Availability	0 to 1	--	bool	0
x32D0	Importing	0 to 1	--	bool	0
Outputs - Dispatchable					
x4000	Power Ref	0 to 1,000,000	kW	float	0
x4002	Start	0 to 1	--	bool	0
x4003	Output Isoch Mode	0 to 1	--	bool	0
x4004	Watchdog	0 to 1	--	bool	0
x4005	Start Time	0 to 24	hr	uint	0
x4006	Op Mode	0 to 3	--	uint	0
Outputs - Storage					
x4070	Power Ref In	0 to 1,000,000	kW	float	0
x4072	Power Ref Out	0 to 1,000,000	kW	float	0
x4074	Input Start	0 to 1	--	bool	0

Address	Description	Range	Units	Format	Default
x4075	Output Start	0 to 1	--	bool	0
x4076	Input Watchdog	0 to 1	--	bool	0
x4077	Output Watchdog	0 to 1	--	bool	0
x4078	Op Mode	0 to 3	--	uint	0
Outputs - Renewable					
x4100	Isoch Mode	0 to 1	--	bool	0
x4101	Watchdog	0 to 1	--	bool	0
x4102	Op Mode	0 to 3	--	uint	0
Outputs - Load					
x4130	Watchdog	0 to 1	--	bool	0
x4131	Op Mode	0 to 3	--	uint	0
Outputs - Grid					
x4150	Start	0 to 1	--	bool	0
x4151	Watchdog	0 to 1	--	bool	0
x4152	Op Mode	0 to 3	--	uint	0
Outputs - CHP					
x4153	Electric Power Ref	0 to 1,000,000	kW	float	0
x4155	Watchdog	0 to 1	--	bool	0
x4156	Op Mode	0 to 3	--	uint	0
x4157	Isoch Mode	0 to 1	--	bool	0
x4158	Reserved	0 to 3	--	uint	0
Outputs - Boiler					
x419B	Power Ref	0 to 1,000,000	kW	float	0
x419D	Start	0 to 1	--	bool	0
x419E	Isoch Mode	0 to 1	--	bool	0
x419F	Watchdog	0 to 1	--	bool	0
x41A0	Op Mode	0 to 3	--	uint	0
Outputs - Heat Load					
x420B	Watchdog	0 to 1	--	bool	0
x420C	Op Mode	0 to 3	--	uint	0
Virtual Inputs (256)					
x5000	Value	0 to 1	--	bool	0
Virtual Outputs (256)					
x5100	Value	0 to 1	--	bool	0
Virtual Analogs (512)					
x5200	Value	-3.4 to 3.4	--	float	0
Forecasts - Renewable					
x6000	Value	0 to 1,000,000	kW	float	0
x61E0	Resolution	0 to 1,440	min	uint	0
x61E1	Offset	0 to 1,440	min	uint	0
x61E2	Update Cmd	0 to 1	--	bool	0
Forecasts - Load					
x7E30	Value	0 to 1,000,000	kW	float	0
x8010	Resolution	0 to 1,440	min	uint	0
x8011	Offset	0 to 1,440	min	uint	0
x8012	Update Cmd	0 to 1	--	bool	0
Forecasts - Grid Buy					

Address	Description	Range	Units	Format	Default
x9C60	Value	0 to 1,000,000	$/kWh	float	0
x9E40	Resolution	0 to 1,440	min	uint	0
x9E41	Offset	0 to 1,440	min	uint	0
x9E42	Update Cmd	0 to 1	--	bool	0
Forecasts - Grid Sell					
x9E43	Value	0 to 1,000,000	$/kWh	float	0
xA023	Resolution	0 to 1,440	min	uint	0
xA024	Offset	0 to 1,440	min	uint	0
xA025	Update Cmd	0 to 1	--	bool	0
Forecasts - Renewable Capability					
xA026	Value	0 to 1	---	float	0
xA206	Resolution	0 to 1,440	min	uint	0
xA207	Offset	0 to 1,440	min	uint	0
xA208	Update Cmd	0 to 1	--	bool	0
Forecasts - Heat Load					
xBE56	Value	0 to 1,000,000	kW	float	0
xC036	Resolution	0 to 1,440	min	uint	0
xC037	Offset	0 to 1,440	min	uint	0
XC038	Update Cmd	0 to 1	--	bool	0
Alarm Settings					
x400	Index	0 to 65,535	--	uint	0
x401	Reserved	0 to 1	--	bool	0
x402	Reserved	0 to 65,535	--	uint	0
x403	Pk Up	0 to 3,600	sec	uint	0
x404	Drop Off	0 to 3,600	sec	uint	0
Alarm Flags					
x900	Alarm State	0 to 65,535	--	bits	0
x910	Annunciator Alarm Reset	0 to 65,535	--	bits	0
x920	Annunciator Flash State	0 to 65,535	--	bits	0
x930	Annunciator On Off State	0 to 65,535	--	bits	0

U90^{Plus} Microgrid Generation Optimization

Chapter 9: Appendix B

This chapter contains information about revisions to this document and includes the product warranty.

Revision history

The table outlines the releases of this manual.

Table 10: Revision history

Publication number	Part number	Firmware	Release date	ECO
GEK-113242	----	1.0x	6 March 2010	Draft - never released
GEK-113242	1601-0039-A1	1.1x	30 September 2012	12-3474

Warranty

GE Multilin warrants each relay it manufactures to be free from defects in material and workmanship under normal use and service for a period of 24 months from date of shipment from factory.

In the event of a failure covered by warranty, GE Multilin will undertake to repair or replace the relay providing the warrantor determined that it is defective and it is returned with all transportation charges prepaid to an authorized service centre or the factory. Repairs or replacement under warranty will be made without charge.

Warranty shall not apply to any relay which has been subject to misuse, negligence, accident, incorrect installation or use not in accordance with instructions nor any unit that has been altered outside a GE Multilin authorized factory outlet.

GE Multilin is not liable for special, indirect or consequential damages or for loss of profit or for expenses sustained as a result of a relay malfunction, incorrect application or adjustment.

For complete text of Warranty (including limitations and disclaimers), refer to GE Multilin Standard Conditions of Sale.

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