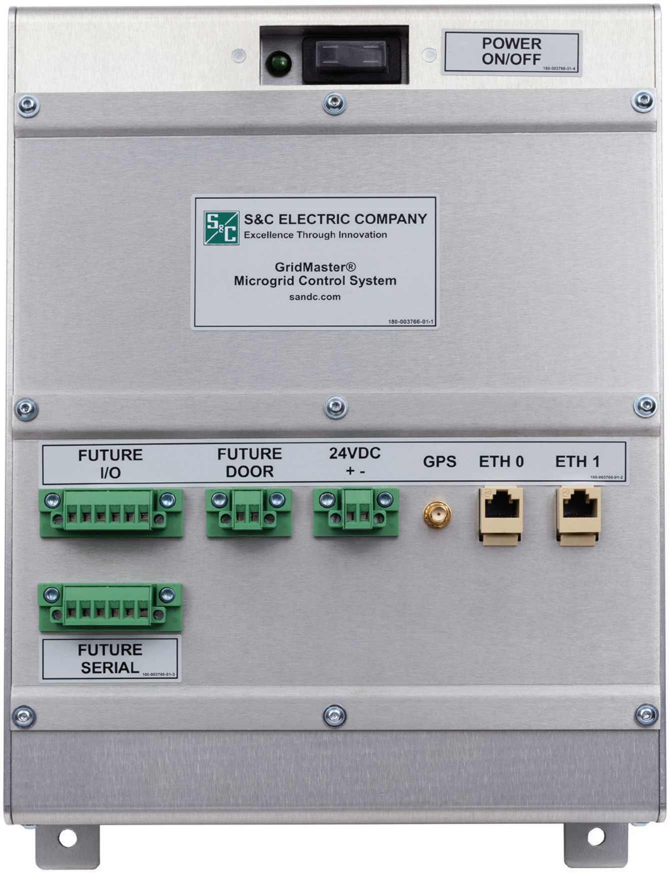
GridMaster® Microgrid Control System



Optimize and protect your microgrid with robust, cybersecure controls.

Introduction

Meet the requirements of the changing grid

The grid is rapidly changing, from the influx of renewables to consumers' rising reliance on energy. As a result, grid resiliency and sustainability are increasingly important requirements for power systems. Microgrids are a tool for utilities and commercial and industrial companies to address new grid changes, reliability challenges, and resiliency requirements.

Many companies can be tempted to skimp on controls when installing a microgrid, but doing so is risky. It not only increases the possibility of a malfunctioning microgrid, but it also increases vulnerability to cyberattacks. Choosing a microgrid control system protects your microgrid investment and maximizes the long-term value of your microgrid.

A robust control system is critical for advanced microgrids

The GridMaster Microgrid Control System is a combined software and hardware platform built for advanced microgrids. The system easily integrates and communicates with a host of different distributed energy assets. It directly controls and quickly makes decisions about the assets within the microgrid, both in **Grid-Tied** and in **Islanded** operation.

This continuous evaluation and fast decision-making is especially important when dealing with the variable nature of renewable generation. With the ability to direct every microgrid asset together and seamlessly balance and optimize the system, the GridMaster control system is like the conductor of a microgrid orchestra, ensuring every section works together harmoniously.

One of the main advantages of the GridMaster system is that it provides redundant control capabilities through its distributed architecture. GridMaster system software runs on multiple intelligent power controllers (IPCs) located throughout the microgrid that communicate with each other via an encrypted proprietary protocol. This peer-to-peer, distributed architecture eliminates single points of failure and mitigates adverse events without losing control functionality.

Because of the system's distributed intelligence, full control functionality seamlessly shifts among IPCs for maximum resiliency. At any given time, one of the IPCs serves as the lead decision-maker by requesting data from the other IPCs and making control decisions based on the observed state of the grid.

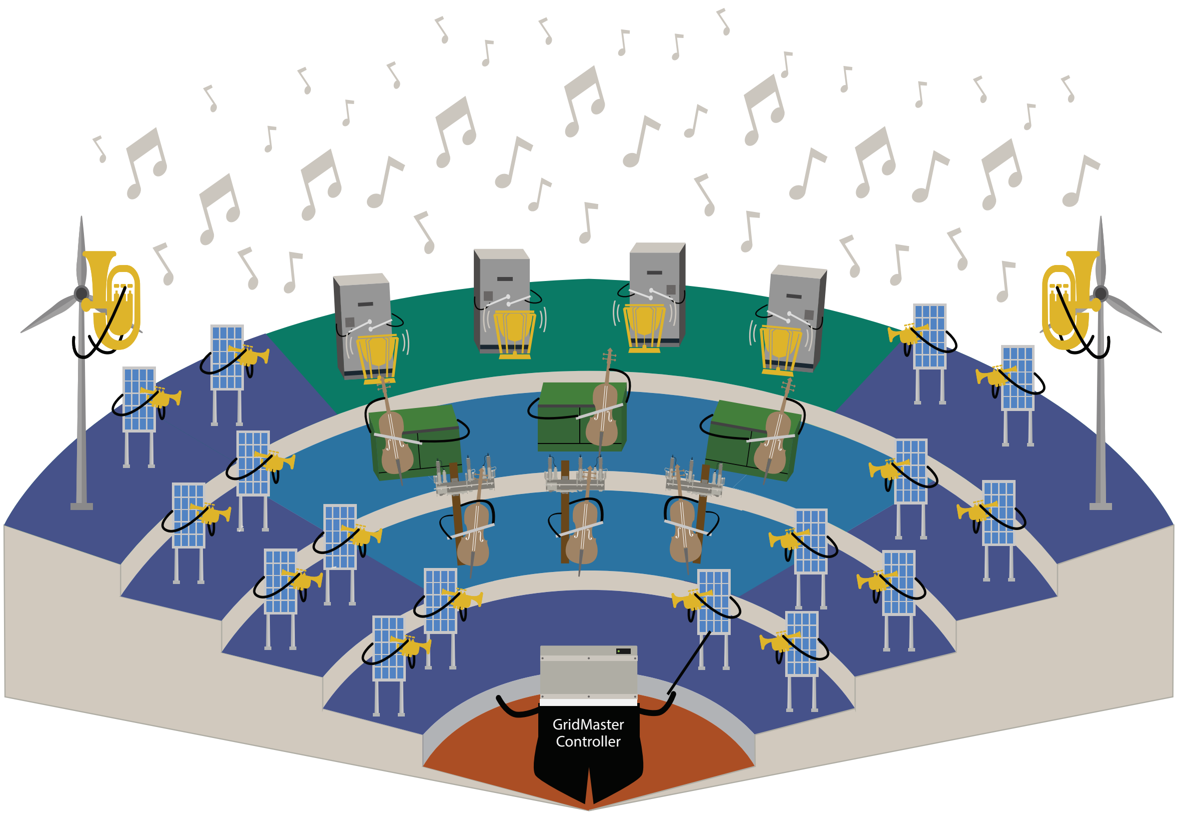


Figure 1. The controller for components in a microgrid is like a conductor for instruments in an orchestra.

Should the lead IPC fail for any reason (e.g., physical damage, loss of enclosure power, or a network failure), the other IPCs in the microgrid will recognize the decision-making IPC is no longer present, and they will collectively elect another IPC to take on the role of the main decision-maker. Should the original IPC then reconnect to the network, it will recognize the control duties are already occurring and not attempt to recapture that role.

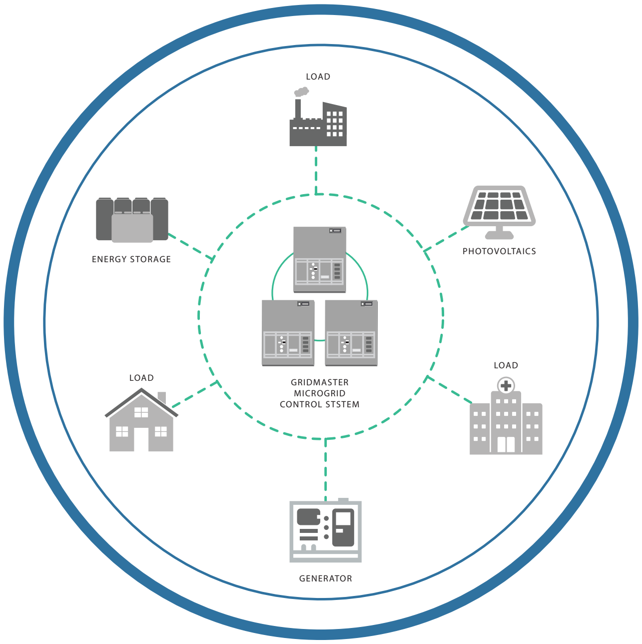


Figure 2. Distributed GridMaster control software runs on multiple IPCs located throughout the microgrid, all connected with encrypted communication.

Embedded, military-grade cybersecurity

The GridMaster Microgrid Control System is the only end-to-end microgrid control system with an Authorization to Operate (ATO) accreditation at mission-critical Department of Defense facilities. Defense-in-depth protection using multiple security layers is built into the GridMaster microgrid control system from the ground up.

The software was originally written for defense applications, and an emphasis on cybersecurity has been a part of the code base from the beginning. All data exchanged among different IPCs use 256-bit secure socket layer (SSL) encryption. Both data at rest and data in motion between IPCs are encrypted. The IPCs use whitelisting, a pre-approved list of validated devices or users, to ensure only known computers will be recognized on the network. The operating system on the IPCs also complies with the military standards for cyber-secure information systems.

Easy operation through flexible control algorithms and intuitive interface

The GridMaster Microgrid Control System makes even advanced microgrids easy to operate. The user-friendly graphical user interface (GUI) allows the operator to easily view and interact with the microgrid and microgrid control system. The easy-to-navigate interface gives operators access to all system data and can be customized to the user's preferences. The GUI is browser-based and does not require custom software.

If your needs change or if you want to scale your microgrid, the GridMaster Microgrid Control System's rules-based control algorithms evolve and accommodate changes with minimal changes to core code—unlike many programmable logic controller (PLC)-based microgrid controllers that require specific instruction sequences and cumbersome custom engineering.

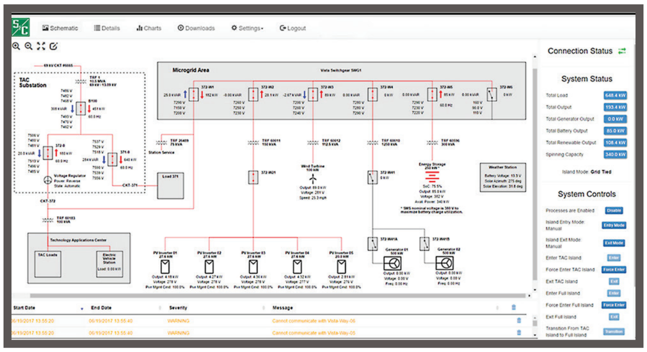


Figure 3. The main schematic page of the GridMaster control system's graphical user interface (GUI).

Islanding

The primary objective of a microgrid is to provide resilient and reliable power for a wide variety of applications, including grid-edge locations, critical operation sites, and military bases. Therefore, islanding is the core functionality of a microgrid; when the main grid loses power, the microgrid disconnects from the utility and remains energized.

There are two main ways of entering an islanded mode:

Intentional islanding can be initiated manually by the microgrid operator before an expected grid failure or to relieve load on the feeder. In these instances, the GridMaster Microgrid Control System instructs the generation sources to turn on, synchronize to the existing grid voltage and frequency, and match the microgrid load. The controller then opens the islanding breaker and notifies the various sources to operate in **Island Source** mode. Entry into this islanded mode is referred to as a soft transition and is done without loss of power to the customer load.

Unintentional islanding occurs when utility voltage is lost. The microgrid control system senses this loss and re-energizes the microgrid, likely undergoing a black start if the voltage loss is sudden and complete. In **Black Start** mode, the GridMaster control system opens the breakers to any loads that can be shed, opens the islanding breaker, and instructs the generation sources to turn on.

The restoration of power through a black start must be done in a methodical fashion to avoid overloading the generation. Each generation source is connected one at a time to the main microgrid backbone, with local synchronization of each generation asset occurring before it is connected. When all sources are online, the loads are brought back online one at a time in a prioritized order designated by the system operator.

Reconnecting to the grid

In automatic operation, when utility power is restored, the microgrid reconnects to the main power grid either by a manual command initiated by the system operator or by an automatic operation of the microgrid controller. When utility power has been restored for a predetermined amount of time, the controller initiates the algorithms for the reconnection. The delay in restoration ensures the main grid voltage has been restored for a sufficiently prolonged period to provide confidence it won't immediately drop again. The system operator can set this delay period.

When reconnecting to the grid, the microgrid controller first requests that the islanding breakers close. The islanding breaker will have the appropriate synchronization relays, so the breaker will not close in until the voltage and frequency of the local microgrid are sufficiently close to those of the main grid. The synchronizing relay transmits adjustment signals to the microgrid power sources, causing them to adjust their outputs to match those of the main grid. When the synchronizing relay sees that the voltage and frequency of the microgrid matches that of the utility, it allows the islanding breaker to close and the system is once again grid-tied. The status of the islanding breaker is monitored by the microgrid power sources so they will operate in **Islanded** or **Grid-Tied** mode as appropriate.

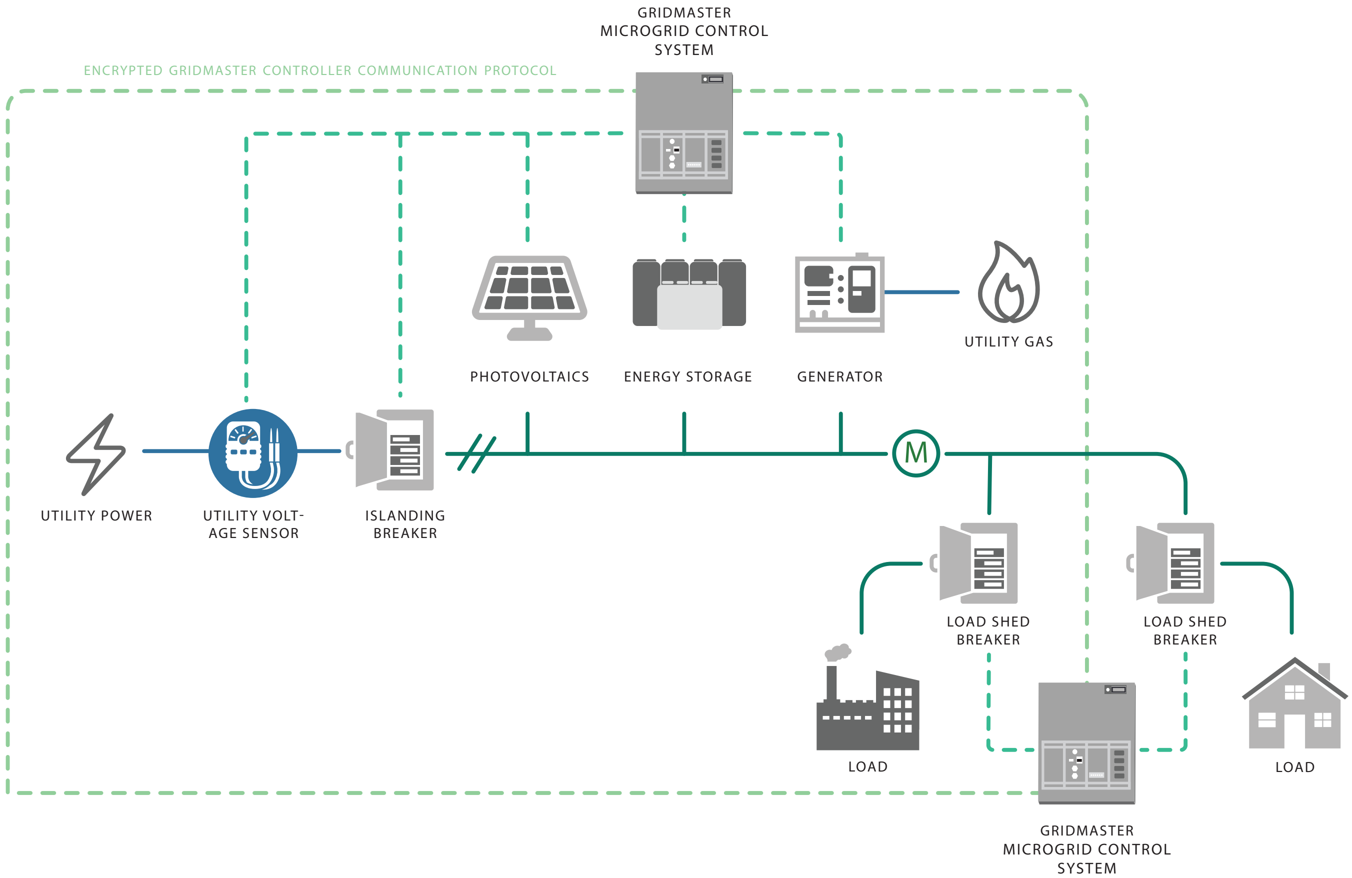


Figure 4. This microgrid configuration example demonstrates a utility connection, microgrid assets, the GridMaster Microgrid Control System, loads, and breakers.

Construction

Figure 5. The wall-mounted GridMaster controller.

A **POWER ON/OFF Toggle Switch**—The recessed power switch has a green LED that illuminates when the unit is turned on.

B **Input Power Connection**—Each unit accepts 12- to 36-Vdc input and consumes less than 20 W.

C **GPS Antenna Connection**—The GPS system can be used to set the internal time.

D **Ethernet Ports**—The controller supports two network interfaces.

E **Door Status Connection**—Future versions will support an enclosure door status input.

F **Digital I/O Connection**—Future versions will support digital Input/Output connections.

G **Serial Connection**—Future versions will support two serial connections.

Grid-Tied: When utility power is available, the microgrid control system will monitor the state of the microgrid components and make the data available to operators.

Islanding: The microgrid controller will electrically isolate the microgrid from the utility and then bring generation assets and as many of the remaining loads online with the available capacity.

Load Shedding: When the system is islanded and the electricity demand begins to approach the capacity of available generation, the microgrid controller will prioritize loads and remove the least-important loads first to ensure the critical loads remain energized.

Black Start Transition: If a voltage loss is sudden and complete, the control system will reenergize the microgrid by safely synchronizing and connecting generation sources before bringing loads back online in a prioritized order.

Green Mode (Islanding with Renewables): The microgrid can be programmed to maximize the use of renewables whenever possible during an islanded mode.

Renewable Smoothing: If the microgrid includes energy storage, the controller can help minimize the variation in apparent load introduced by intermittent output of renewable assets, such as photovoltaic (PV) systems on partly cloudy days.

Distributed Energy Resources Monitoring & Control: The GridMaster Microgrid Control System can control distributed energy resources (DER) during islanded operation, regulate the energy storage state of charge through the dispatch, and curtail generators and renewables, such as PV inverters or wind turbines.

Storm Preparedness: The microgrid can be programmed to preemptively charge batteries to prepare for impending weather events, allowing microgrid operators to power emergency services.

Peak Shaving: The controller can determine whether the microgrid should dispatch the local generation assets to reduce demand at the meter. The operation can be performed to reduce customer costs during peak demand hours.

Curtailment: The controller can dispatch or curtail microgrid generation assets to attain a specific goal. The system operator can prioritize certain criteria (e.g., emission reduction, power reliability), and the microgrid controller will find the "best fit" matrix of operation of the DER assets to achieve the desired goals.

Power Factor Correction: The GridMaster controller can instruct inverters capable of injecting vars into the grid to do so in response to low power-factor values measured at key points throughout the grid.

Wall-Mounted Configuration

Physical dimensions of the wall-mounted GridMaster Microgrid Control System are approximately 9.25 inches (235 mm) wide by 14.0 inches (356 mm) tall. See Figure 6. The unit weighs 9.5 pounds (4.3 kg) and is approximately 3.6 inches (91 mm) deep, allowing it to fit easily inside a weather-resistant enclosure. Rated for -40°C to +65°C (-40°F to +149°F) operation, it has a single-board computer, dual Ethernet ports, and is hardened for environmental (e.g., temperature, vibration) and security resilience.

Rack-Mounted Configuration

Physical dimensions of the rack-mounted GridMaster Microgrid Control System are approximately 19 inches (483 mm) wide by 3.5 inches (89 mm) tall. See Figure 7. It weighs approximately 8 pounds (3.6 kg) and is rated for -40°C to +50°C (-40°F to +122°F) indoor operation. Dual Ethernet ports provide data connection.

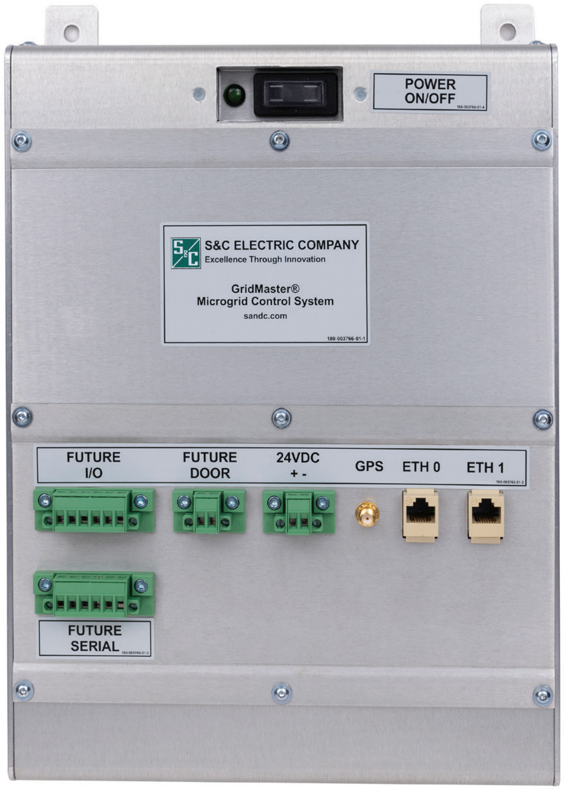


Figure 6. The wall-mounted GridMaster controller.

Figure 7. The rack-mounted GridMaster controller.

Table 1. The GridMaster Microgrid Control System uses built-in cybersecurity that is compliant to the following applied security frameworks:

NIST 800-82	NIST 800-53	DoDI 8500.2	CNSSI 1253 App I
Guide to Industrial Control Systems (ICS) Security	Security and Privacy Controls for Federal Information Systems and Organizations	Information Assurance (IA) Implementation	Security Categorization And Control Selection For National Security Systems

Table 2. The GridMaster system complies with the following industry microgrid controller standard:

IEEE 2030.7
IEEE Standard for the Specification of Microgrid Controllers

Table 3. GridMaster Microgrid Control System Specifications

Power Requirement	Communications		
Input	Ethernet		
12 to 36 Vdc (< 20 W)	IEEE 802.3 Ethernet interface	1000/100/10 Base T	IPV6 standard; IPV4 compatible