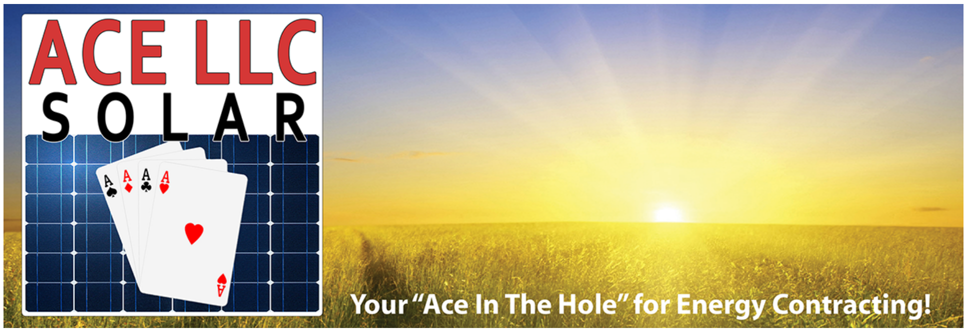


enerG•Station™

Introduction

The enerG•Station™ is a utility-scale energy harvesting, monitoring, and distribution system. It is capable of optimally harvesting energy from renewable energy sources such as PV solar, wind turbines, etc., storing this energy in batteries and then redistributing the energy flow to specified loads in a manner that optimizes the energy consumption of the system. It is, in other words, an energy flow optimizer.

Modes of Operation

NGrid Mode

NO GRID MODE

In this mode, the enerG•Station™ generates a local grid. It uses renewable energy when available and sufficient. Otherwise, it uses local energy storage from batteries to deliver the total energy demanded by loads.

UGrid Mode

UTILITY GRID MODE

In Utility Grid Mode, the enerG•Station™ performs in the same manner as NGrid except that energy delivery waveforms are synchronized with the Grid and when and if needed the system can take energy from the utility grid or, in net-metered applications, when batteries are full, feed excess energy back onto the utility grid.

LGrid Mode

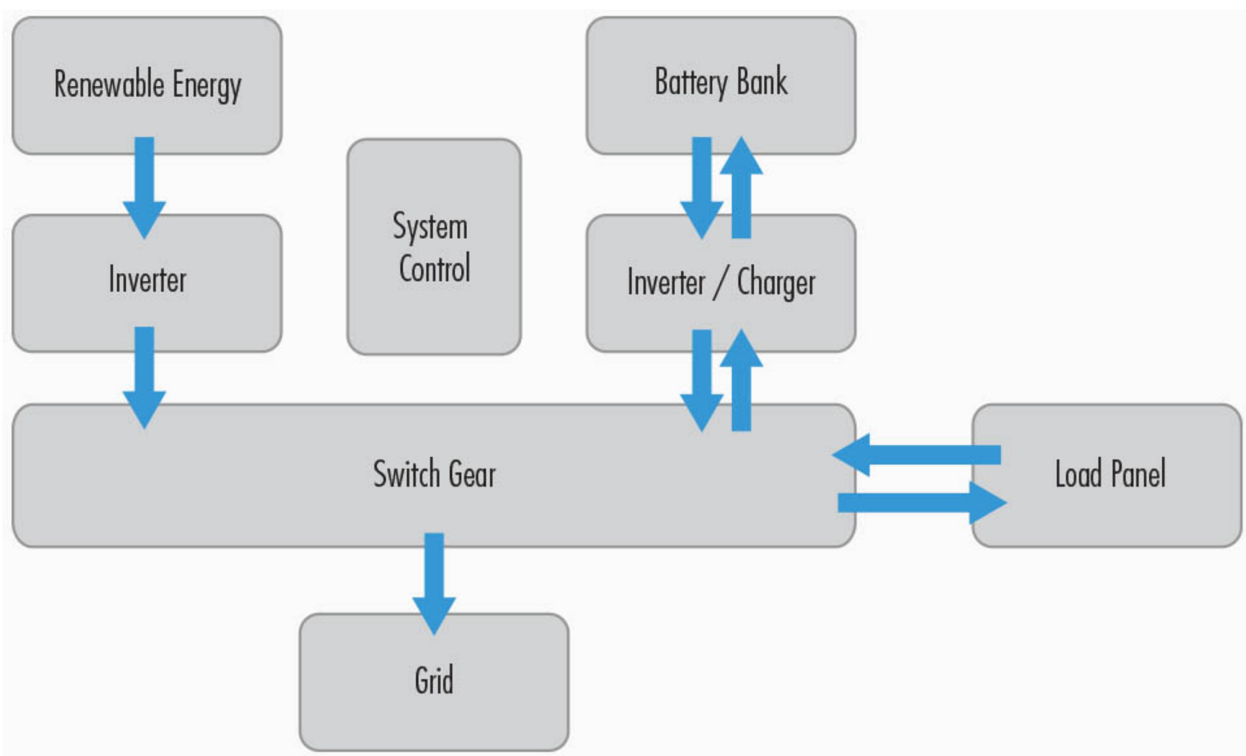
LOCAL GRID MODE

In Local Grid Mode, the enerG•Station™ performs in the same manner as NGrid except that energy delivery waveforms are synchronized with a local generator and when and if needed the system can load down the generator to fulfill the energy requirements of the loads.

Technology

Block Diagram

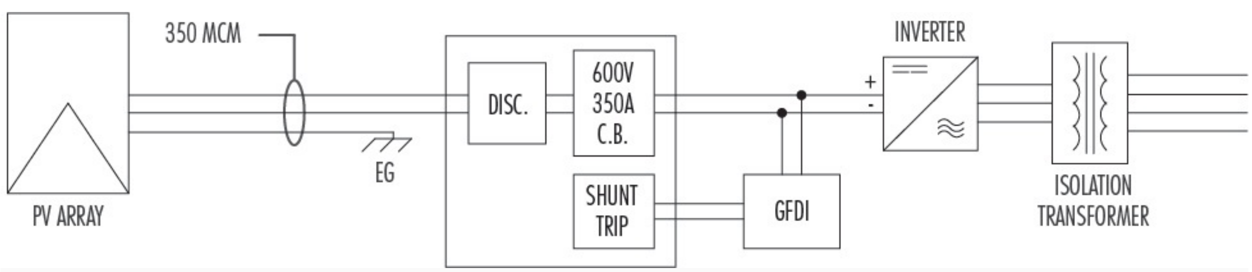
Figure below, shows a typical system block diagram.



Renewable Energy Interface Description

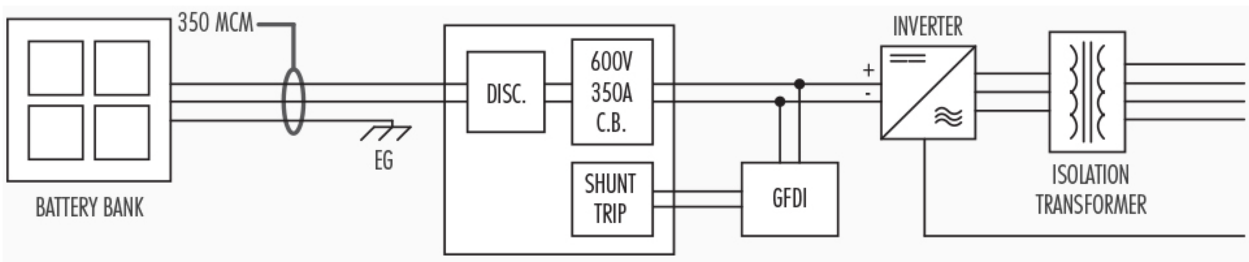
In most cases this is a carefully designed PV system rated at 100 kW and 600 VDC maximum. The UL1741-approved system inverters interface directly with the system PV and implement maximum power point tracking (MPPT) algorithm to provide maximum DC to AC efficiency rates. Multiple 100 kW PV arrays can be connected to multiple inverters to yield a system of up to twenty (20) inverters or 2 MW.

Each PV array is connected to the inverter by going through an appropriately-rated disconnect breaker and a dedicated ground fault detection and interruption (GFDI) system. This feature protects the system from the risk of unwanted or gradual degradation of wiring or system insulation.



Battery Interface Description

Battery systems of up to 580VDC may be configured. Battery controls provide flexible parametric controls for a variety of battery technologies (e.g. Flooded Lead-Acid, AGM, Gel or LiFePO4) and can be configured for battery capacities as low as 25 kWh to as high as 5 MWh. While in battery mode, the charge or discharge rates of the system may be specified by the system controller, providing a flexible methodology for controlling the flow of energy. Multiple inverters connected to PV arrays may be connected to multiple inverters that are connected to battery systems and the collection of these systems may be connected to the grid or a local generator to construct elaborate control techniques needed in demand/response, peak shaving or PV smoothing systems. Similar to the PV system, each battery bank is connected to the system through a dedicated circuit breaker and GFDI system. Figure below shows a typical battery bank interface.



Battery Technology

As mentioned, the enerG•Station™ has the flexibility to parametrically control a variety of different battery technologies. For a large enerG•Station™ system, the LiFePO4 battery technology provides the most ideal cost/performance efficiencies. Figure below briefly outline the pros and cons of the LiFePO4 technology.

Flooded Lead Acid

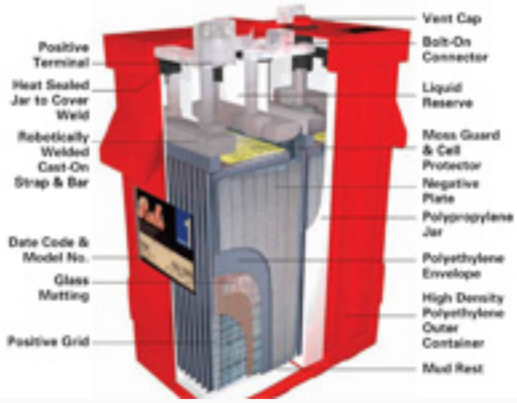
Pros

- Inexpensive
- Easy-to-find
- Proven technology
- Easy control for charging and discharging
- Medium life: (longevity) 1000 to 1500 cycles

Cons

- Requires on-going Maintenance

- Produces Hydrogen, highly explosive
- Toxic Electrolyte
- Heavy and Large



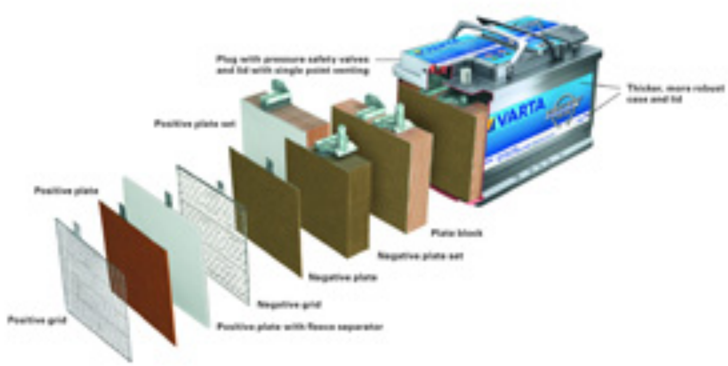
Gel and AGM Lead Acid

Pros

- Maintenance-free
- Does not produce any chemicals
- Easy control for charging and discharging

Cons

- Short life: 500 to 700 cycles
- Expensive
- Toxic Electrolyte
- Heavy and Large



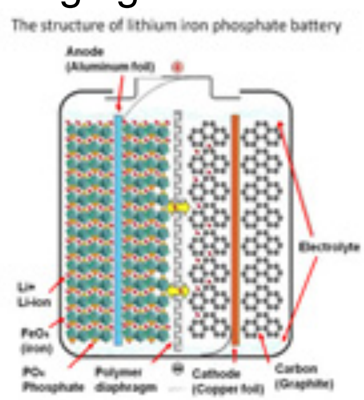
Lithium Iron Phosphate

Pros

- Long Life: 5000 to 7000 cycles
- Inexpensive when measured over the life of the system
- Maintenance-free
- Fast Charge and Discharge times
- Does not produce any toxic chemicals
- Small and compact

Cons

- Expensive on unit of storage
- Requires a battery management system for effective charging and discharging



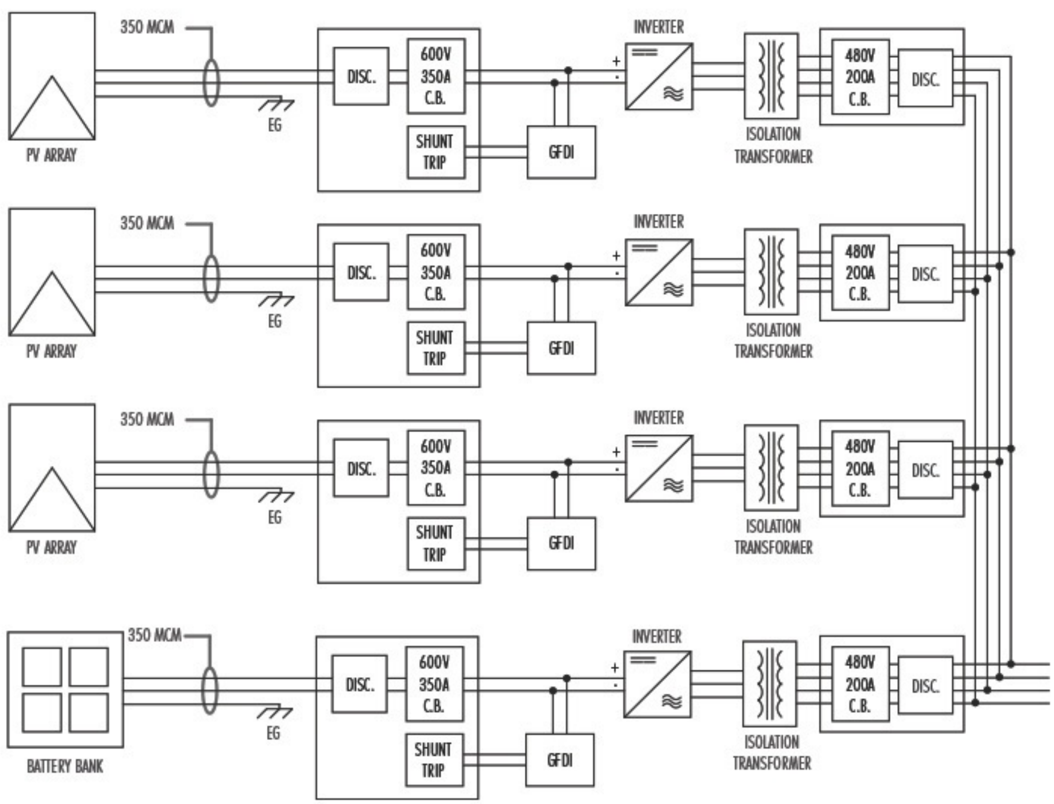
System Configuration

The enerG•Station™ systems are capable of directly interfacing with the Utility Grid (UGrid), a local generator acting as the Grid (LGrid) or without a local generator (NGrid). The enerG•Station™ interfaces with or generates 480 Vrms, 3-phase power at up to 2 MW in increments of 100 kW. The direct output/input power supplied by the AC interface is in Delta configuration. An external isolation transformer is used to convert the output of the system to WYE configuration.

Each enerG•Station™ inverter is rated at 100 kW. Up to 20 inverters may be configured in parallel to provide a 2MW system. Multiple units are connected to each other through switch gear custom-designed by ACE, LLC SOLAR to fit the specific requirements of each enerG•Station™ system.

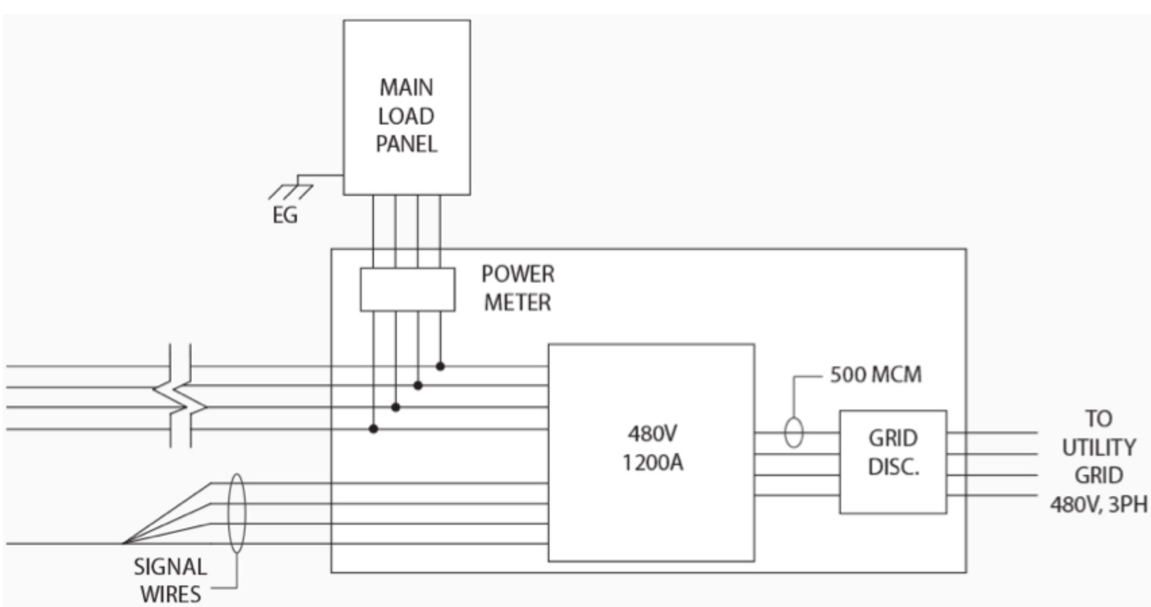
In the diagram below, there are 3, 100 kW PV arrays that are each connected to their respective inverter. In addition, a battery bank is connected to a 100 kW inverter. The output of each inverter goes through its own isolation transformer, circuit protection and switch gear and finally all outputs are connected together, to the load panel and to the utility grid (UGrid Mode) or generator (LGrid mode). If there is no grid, the collective output simply connects to the load panel.

Finally, the total energy being delivered by the enerG•Station™ system is measured once a second using a real-time revenue-grade power meter.



Grid Connection

All enerG•Station™ systems have to comply with anti-islanding requirements of UL 1741. Each enerG•Station™ inverter is equipped to handle this requirement using an internal grid contactor. But in cases where multiple inverters are used in mater/ slave configuration, an external contactor is configured as shown in the diagram below. This contactor is commanded by the inverter designated as the master in the system. In addition, it should be observed that the revenue-grade power meter below measures the energy delivered to the system loads in real-time. The enerG•Station™ system controller uses this measurement and the measurement from the System power meter to manage the flow of energy in order to achieve the system owner's objectives. For example, if the objective is minimize or eliminate the energy flow to the utility grid, the enerG•Station™ would make sure that the two system power meters read the same value (within a specified error margin) on a second-by-second basis. This would mean that the energy generated by the enerG•Station™ system and the energy consumed by the system loads are the same, implying that no energy flow is required from the utility grid.



Output Switch Gear and System Controller

The various system components discussed above are brought together in a single system, as shown in the figure below. In this particular example, to separate systems are delivered in the same container to connect to two separate buildings that are in close proximity to each other but they each have a separate grid connection. In this example, each system is controlled by its own system controller which is a rack-mount PC connected with inverters, GFDI devices, battery management systems and user interface computers positioned to provide a convenient user interface for the system user or system manager.

Applications

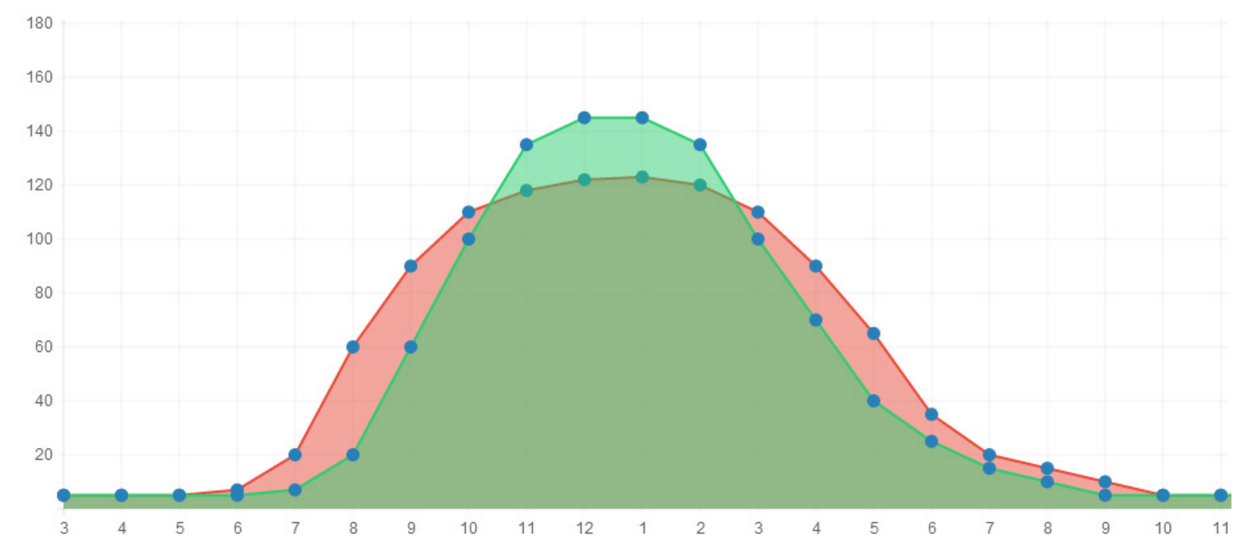
There are virtually an unlimited number of ways that the enerG•Station™ system may be configured. However, some of the most common schemes are discussed below.

Shoulder Energy Storage

A typical PV system is only capable of delivering power during 4 to 5 hours of a sunny day. Other renewable energy sources such as wind enjoy even a less predictable pattern. Battery systems are often designed to compensate for this lack of renewable energy inconsistencies.

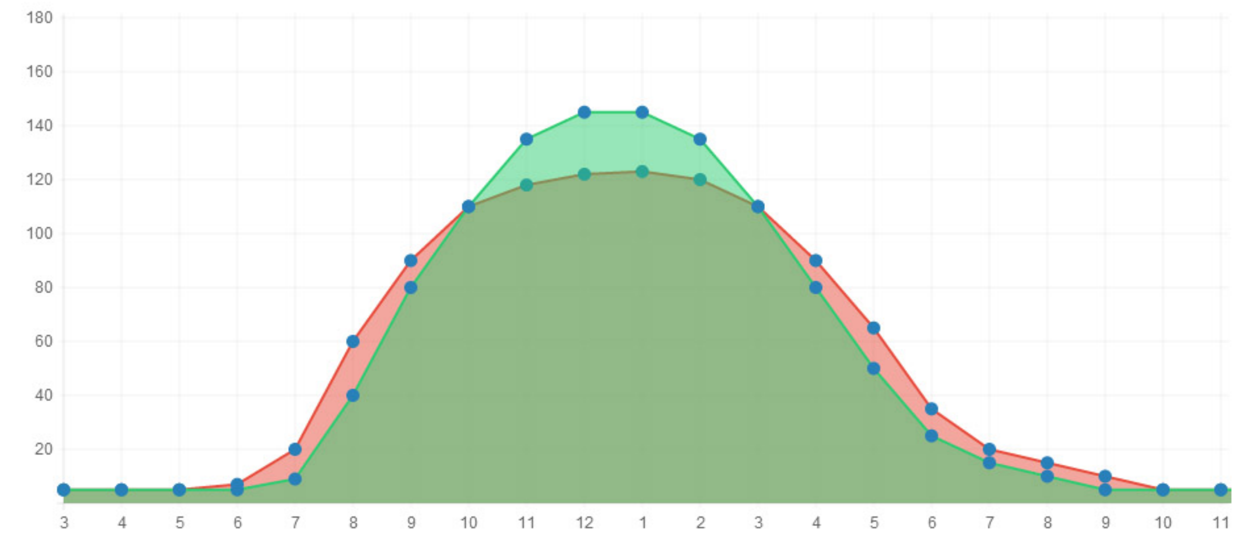
In a typical commercial building, the building occupants (factory workers, office staff, etc.) are typically at work and requiring energy between the hours of 7 AM and 6 PM. When these hours and the respective energy consumption are overlaid on the power production hours of a typical solar system, the early hours of the morning (7 to 10:30 AM) and early hours of the evening (3 to 6 PM) are clearly times when the building requires energy and PV is not able to directly generate the required energy. These hours are referred to as shoulder hours. If the PV system is designed to generate excess energy during the hours of 10:30 AM and 3 PM, this energy can be stored in system batteries and used during shoulder hours.

Figure below shows an under-designed PV system. When comparing the energy requirements during shoulder hours (295 kWh) to the excess energy generated by the solar PV system, the net energy production is negative. This means that the PV energy generation capabilities of the system cannot keep up with the buildings requirements.



As shown in the diagram below, by increasing the sizing of the PV system only slightly, we are able to not only reduce the energy deficit during the shoulder hours, but increase the energy generated during the surplus hours and hence bring the net energy of the system to a slight surplus.

Using the enerG•Station™, it is the combined use of renewable energy and battery technologies that make possible the realization of such systems. These systems provide their owners or operators with the opportunity to manage energy flow independently with minimal reliance on the utility grid.

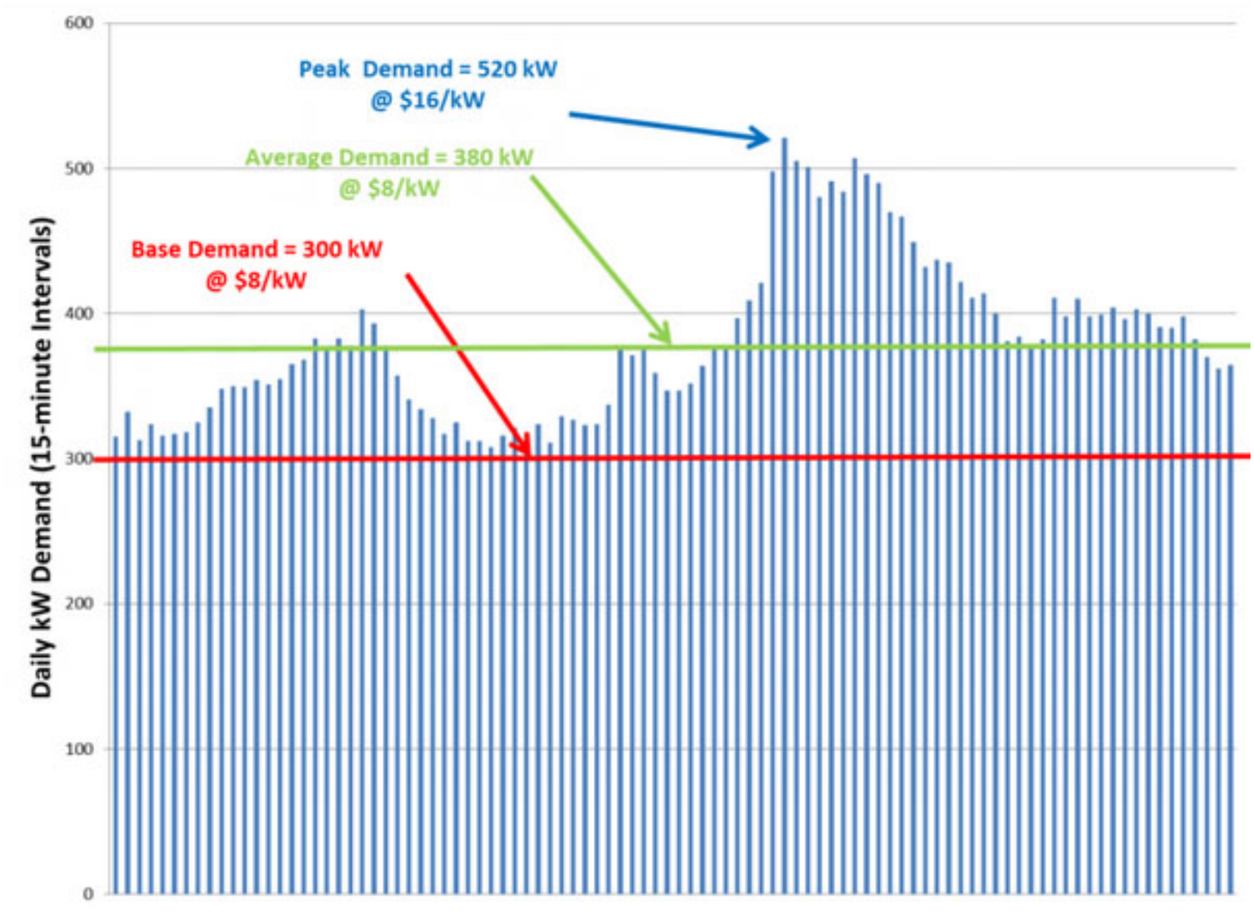


Demand Shaving

A typical commercial customer of the utility grid receives a monthly electricity bill that consists of two major components:

- a. Energy Consumed measured in kWh
- b. Power consumed measure on 15-minute intervals measured in kW

Diagram below shows the demand curve during a 24-hour period for an industrial application. Notice that there is a steady base demand at 300 kW. The peak demand during warm hours of a summer day would fall between 2 and 4 PM. For this building, the peak demand on this particular day is 520 kW. These peak demands during the peak hours could cost the building owners a significant amount less if such demand was to be distributed over the entire length of the day. Such a scheme would reduce the average demand to 380 kW which would typically be charged at a low rate.



In Demand Shaving applications, the demand curve of the building (the blue vertical bars in the diagram below) is compared to an optimal supply curve (the green horizontal line in the diagram below) and the battery capacity and renewable energy resources are sized to achieve an optimal economical result for the building owner.

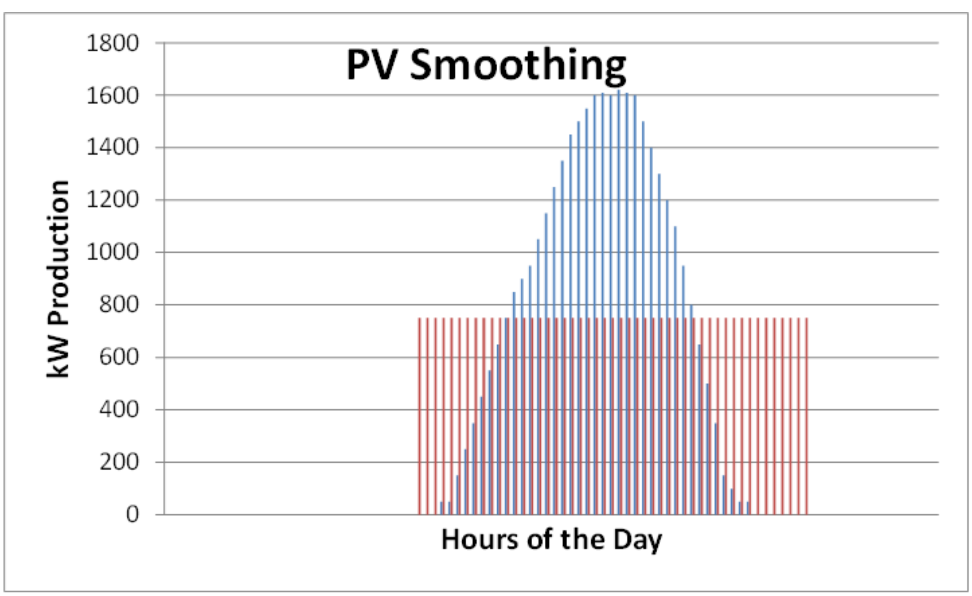
PV Smoothing

Depending on the size of the Grid and the utility subscribers' usage pattern, location, etc., some utility operators and utility generators have deemed the use of proportionally large renewable resources destabilizing. This is primarily due to the unpredictability of the generation capacity of the renewable resources.

In an increasing number of situations, local grid operators do not allow the connection of renewable resources to the grid. This, in turn, leaves customers in a situation where they are not positioned to take advantage of the abundant and inexpensive energy available from such resources. PV Smoothing is designed to eliminate this issue.

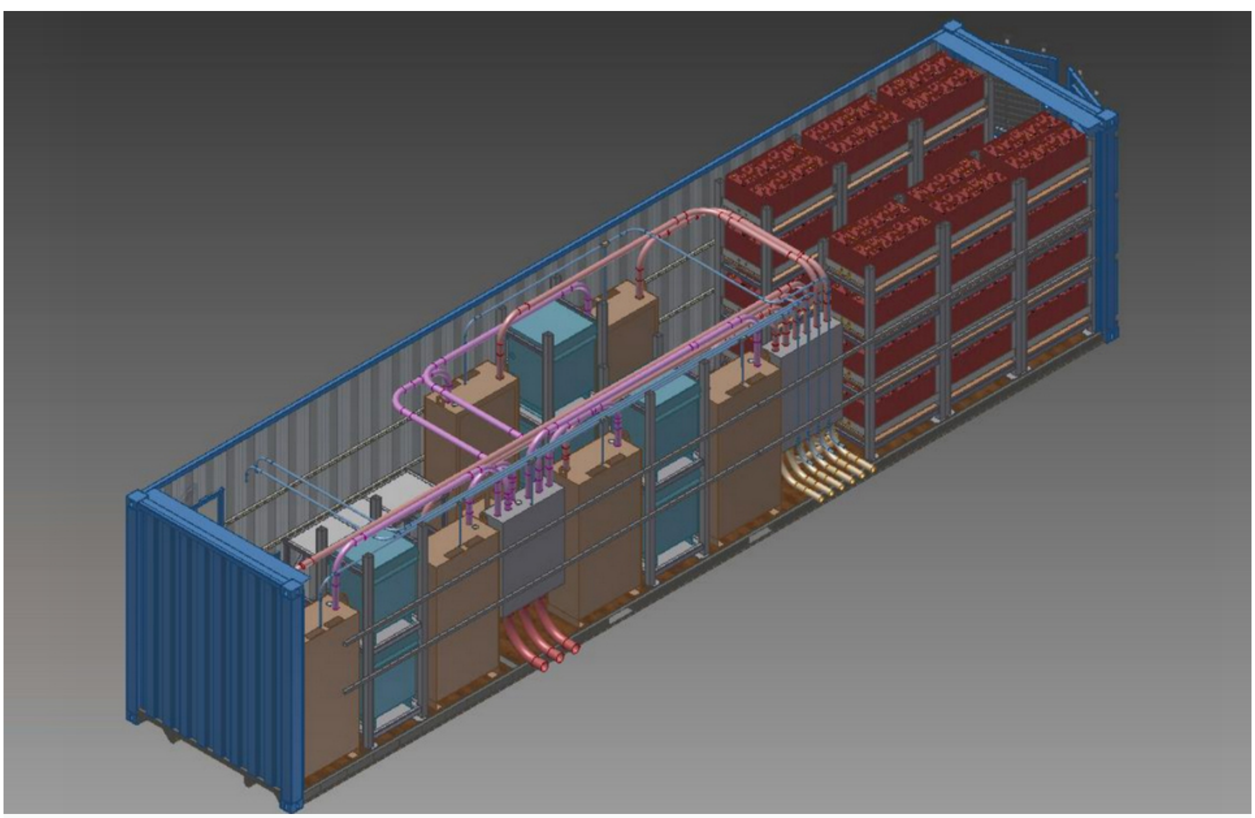
In a PV smoothing scenario, the PV system owner and the utility operator agree on a certain rate of power delivered by the PV system depending on the day and the hour of the day over a certain number of hours during such a day.

Combining renewable and battery storage, the enerG•Station™ system delivers the PV power that is agreed upon as is being generated and the excess is stored in batteries. When the associated renewables are not capable of generating direct energy, the energy stored in the batteries is used to compensate for the deficit.



Delivery

The enerG•Station™systems are designed to be delivered for applications that often allow for minimal space. In addition, building and testing such systems often require that the system is built and tested in a laboratory environment before being deployed in the field. Therefore, careful, space-efficient design is one of the requirements for the enerG•Station™ systems. At ACE, LLC SOLAR we use CAD design techniques to figure out the smallest detail of such a system so that we could minimize unpredictability in both design and deployment of the system. Figure below shows a computer model for an entire system before it was built. This system shows the battery racks close to the cargo doors of a 40-ft container. All electrical wiring is routed inside appropriately-sized EMT tubing.



In addition, it is important to pay close attention to the weight limitations imposed by the DOT for over-the-road, air or ocean transportation.
To protect the system against environmental and climate conditions, all containers are insulated using POLYISO insulation board and radiant barriers. As can be seen from the picture below, each container is equipped with its own power system to provide lighting, and power to security system and computing power needed to program and maintain a system. A folding technician's bench is often designed into such systems, as well.

Fire Suppression

To protect the batteries and the electronics that are installed inside the container, at the request of our customers we install a fire suppression system commonly referred to as the "Clean Agent System." This system uses a gaseous fire suppressant agent that does not result in any damage to the electronics, electrical systems or the batteries contained in the system in case of a fire. It simply suffocates the fire by replacing the oxygen in the area around the fire. A 40-foot container is typically equipped with 4 to 6 nozzles depending on the distribution of the components inside the container. These systems are professionally installed by a certified installer either on location or are installed at ACE, LLC SOLAR and certified by a certified agent after the system arrives at it’s final destination.

Contact Us:

ACE, LLC SOLAR
117 West Madison
Pulaski, TN 38478

Phone: (931) 638 - 4639

Email: info@acellcsolar.com
Website: www.acellcsolar.com