

# How PV Inverters Can Help Create Utility-Friendly Solar Installations

As projects continue to come online, research is under way to prevent potential power disruptions.

■ Dr. Steven G. Hummel

The photovoltaics industry is in transition. Because of rapidly falling system costs (the cost of solar generating capacity has dropped by more than 50% over the past few years) and increasing pressure by state and federal mandates, solar power is coming online faster than most utilities anticipated.



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By the end of 2010, approximately 1 GW of PV power-producing capacity was connected to the grid - more than twice the capacity of 2009 - and this high rate of growth is expected to continue for the foreseeable future. Power utilities are being forced in real time to learn about the challenges, costs and benefits of high PV penetration.

Distributed solar power plants have the potential to be a source of stability or instability for the grid, depending on the utilities' ability to control and interact with those sources. Because the U.S. utility grids were not designed for two-way power and information flow, they will need technology upgrades in order to capitalize on the potential of distributed solar power generation.

Doing so requires collaboration

with PV system component suppliers. In particular, utilities are relying on advances in solar inverter technology to add the "smarts" to the smart grid.

There are some significant challenges caused by the proliferation of PV power sources. Current regulations (IEEE 1547/UL1741) require solar sources to disconnect from the grid during disturbances. This re-

quirement made sense while there were relatively few PV plants connected to the grid, but as solar power becomes a significant factor among generating sources, this practice can be destabilizing.

For example, if solar sources trip offline in times of need, they can cause voltage to rise or sag and lights to flicker, which has obvious negative impacts on devices and consumers that rely on high-quality power. There are system-reliability implications as well. Grid instability caused by PV sources tripping off at the wrong time can result in excessive operation of tap changers and/or capacitors at substations to compensate.

There are also potential adverse results of having too many distributed power generation sources at the wrong locations: Without active grid-integration controls being applied, the voltage can rise in those places, affect-



This 1 MW PV installation in Ohio, installed by Advanced Distributed Generation LLC, uses 260 kW PV Powered inverters.

Photo courtesy of Advanced Distributed Generation and Advanced Energy

ing the utilities' ability to control the power that customers receive.

### Solving the problems

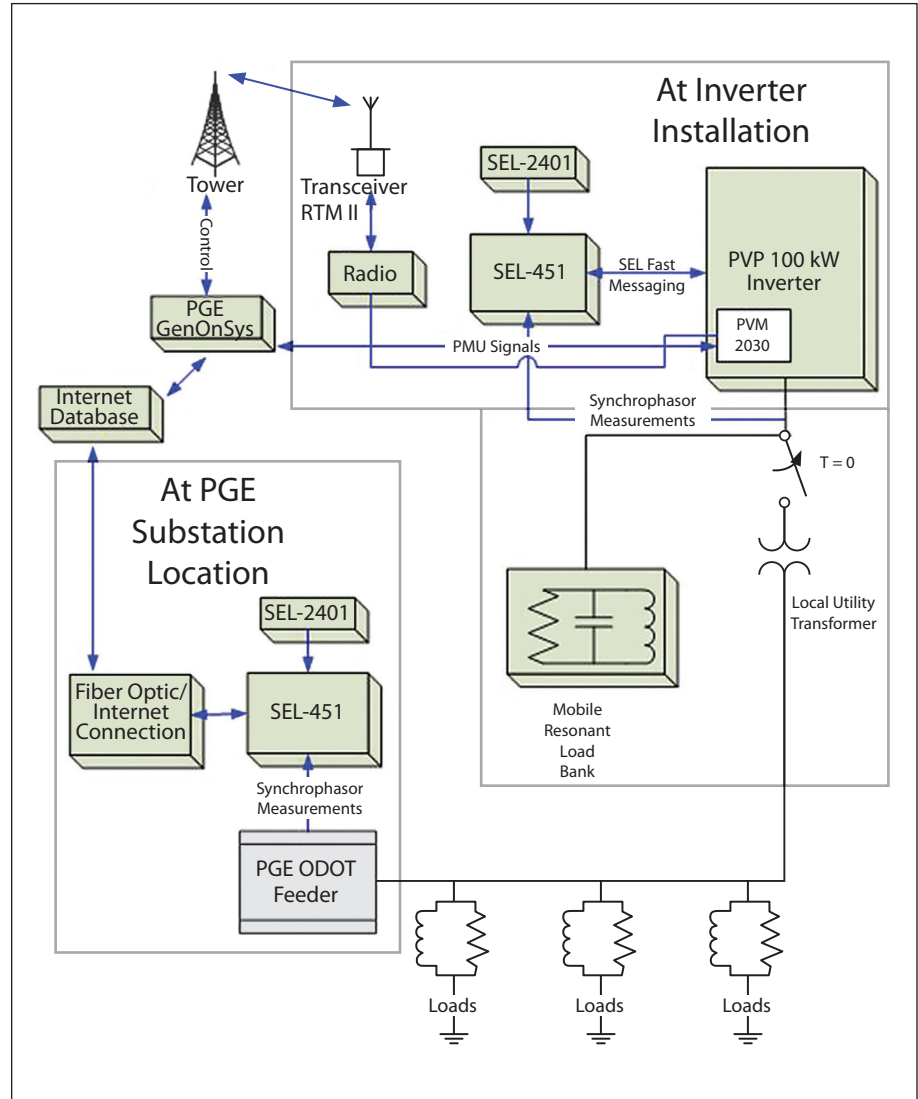
The U.S. federal government has noted some of these issues and, in the interest of smoothing the way to higher solar power usage, has chosen to fund developments that mitigate some of the problems. For example, in 2008, the U.S. Department of Energy commissioned the Solar Energy Grid Integration System (SEGIS) project as part of the Solar America Initiative. Its task is to encourage the development of new technology and products that help achieve parity between the cost of solar energy and that of other energy sources by 2015, and to increase the penetration of PV systems into U.S. utility grids.

Among the specific goals of SEGIS are to establish two-way communications between solar plants and utilities in order to mitigate intermittency while maintaining IEEE 1547/UL1741 compliance, and to commercialize a means for islanding detection (distinguishing between cases where the grid is truly down - when the solar plant should disconnect - and cases where the grid is only partially down and the solar plant should remain online to help maintain grid stability).

To improve communications between solar power plants and utilities, SEGIS program developers are engineering means of advanced utility command and control, in effect enabling utilities to treat attached solar power producers as though they were their own power plants. This means establishing two-way communications with solar sources that dovetail with and expand on the utilities' existing supervisory control and data acquisition systems, and upgrading those systems with their solar power constituents in mind.

These efforts will enable the utilities to disconnect their fleet of distributed resources remotely, if needed,

Figure 1:  
Communication links between inverters and PGE as part of a SEGIS effort



Source: Advanced Energy

and receive status and assert control commands as necessary.

To solve the problem of power island detection, SEGIS' program developments are directed at adding a new level of intelligence and system awareness to the grid environment. The new technology leverages synchrophasor measurements taken between the solar power plant and a utility reference.

Synchrophasor measurements, which contain information about the magnitude and phase angle of the alternating voltage on the grid, are derived from phasor measurement units (PMUs) that take measurements at

different locations in a power system using the same absolute time base. By correlating values from different locations that take different amounts of time to arrive at a common collection point, the inverter can differentiate between a true, unintentional island case and a case where grid support from the PV plant would be beneficial.

### Supporting the grid

When it is determined that the PV system can provide support to stabilize the grid, one way that this can be accomplished is through low-voltage ride through. This is a capability built into inverter designs that allows the

PV system to continue providing power to the grid when the voltage in the grid is temporarily reduced due to a fault or load change in the grid.

The voltage may be reduced in one, two or all three phases of the AC grid, and the inverter will continue to feed reactive power accordingly, regulating voltage through dynamic power factor control. Developments in the SEGIS program are aimed at establishing very tight coordination between PV inverters on the grid and the utilities in order to accomplish this smoothly.

One way to improve the economics of solar energy production is to develop new inverter-based algorithms for maximum power point tracking (MPPT). MPPT algorithms vary the ratio between the voltage and current delivered by a solar array in order to deliver maximum power as the array output changes. As inverter power-conversion efficiency from the arrays nears its theoretical maximum, the accuracy and efficacy of the MPPT algorithm emerges as one of the few remaining high-value opportunities to increase total energy harvest.

The SEGIS program is developing a dynamic test plan for quantifying MPPT efficiency and a new MPPT algorithm that provides highly accurate tracking efficiency over static and dynamic irradiance conditions for a wide variety of PV technologies. Systems that are being tested range from high fill-factor technology, such as concentrated solar or mono-crystalline silicon, to low fill-factor thin-film technologies.

As utilities begin to depend more on distributed solar power plants as part of their power resource base, the importance of PV plant owners in

maintaining PV system reliability will increase. Traditionally, the weakest link in solar power system reliability has been the inverters. Inverters are the most complex system elements because environmental factors (temperature extremes and fluctuations, humidity, etc.) take a larger potential toll on active electronic components.

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To improve reliability, inverter manufacturers are taking a fresh look at how their systems are designed, re-designing their products to reduce component count, basing their systems around environmentally hardened components and incorporating systems that mitigate the effects of installation in harsh environments.

Along with improving component reliability and energy harvest for utility-scale installations, it is essential to monitor not just the performance of individual components but also the performance of each system as a whole.

For instance, a “smart combiner” device added to the system between the arrays and the inverter provides string-level current monitoring, as well as monitoring for groups of strings in the case of thin-film module technologies, where string count is high and string current is low.

Through the SEGIS program, a more tightly integrated balance-of-

system architecture is being developed that can enable better system management and increase overall energy production at an acceptable cost. These advances will lead to less downtime and more predictable operation, improving the overall economic equation for solar power plants.

With a tightly coupled and optimized grid architecture incorporating PV power generators comes the possibility for utilities to treat their solar sources as they would any of their other power-production resources.

To do so, utilities need to be able to forecast energy production from these sources. Resource forecasting is well established in the wind energy industry, and many of the same techniques can be applied to other intermittent resources, such as solar. Utilities can use these forecasts to control the power ramp rates of solar systems with little or no consideration for energy storage.

As the aforementioned developments suggest, cooperation between utilities and other PV system component manufacturers - in particular, the companies that produce PV inverters - has the potential to help utilities deal with both existing and emerging problems relating to the increasing use of solar power on the grid, while capitalizing on the opportunities that solar provides.

By building smarter, fully interactive designs, inverter companies can help bring the promise of the smart grid to reality. ☞

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