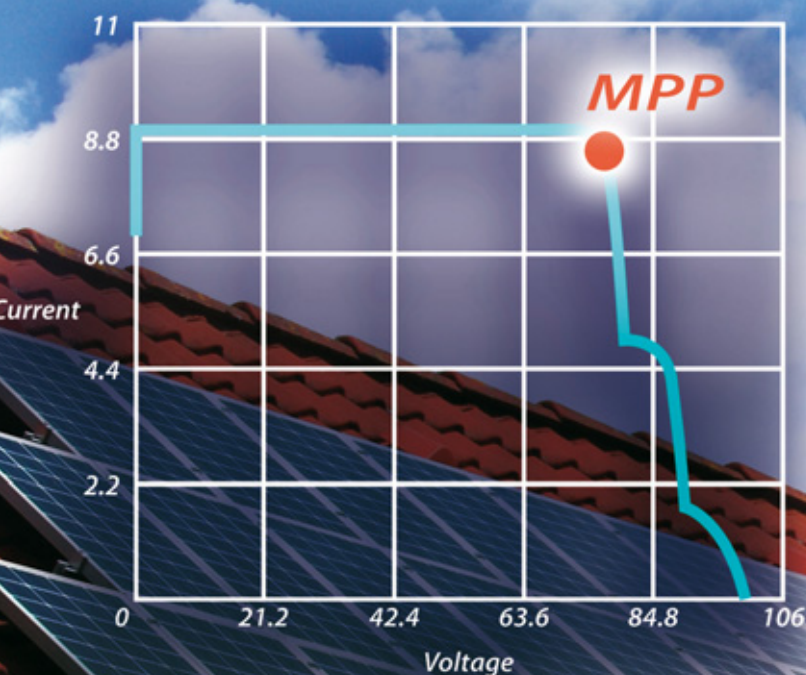


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Encompassing inverters

AMETEK discusses testing grid
tied solar inverters

Solar Industry Awards
Winners announced

Plastic solutions
Materials shaping future solar



Surround testing



Rapid growth requires fast reactions to industry needs. Every aspect of a solar array is under scrutiny for improvements in performance. **Eric Turner**, Product Marketing Manager and head of Renewable Energy Initiatives at **AMETEK Programmable Power** discusses comprehensive test solutions for grid-tied solar inverters and suggests surrounding the inverter when simulating expected conditions when in the field.

Improvements in solar array technology and competitive cost pressures in solar energy products are enabling rapid industry growth. As a result, solar systems are becoming increasingly cost-effective for residential and commercial use, especially when global government incentives for implementing green technologies are taken into account.

Figure 1. A typical grid-tied photovoltaic system has several different components and voltage levels—each requiring special testing

Yole Development, a market research and business development consulting company, has been watching the photovoltaic (PV) market for many years. Yole forecasts the CAGR for the PV inverters used for solar panels to exceed 30 to 45% over the next 5 years. The market for residential PV applications was approximately \$3.8B in 2009.

About 5% of these sales are test and measurement related, representing a total available market (TAM) of \$190M for residential applications. The equipment includes everything from testing the IGBTs that go into the inverters used in solar power all the way up to products that perform system-level compliance testing.

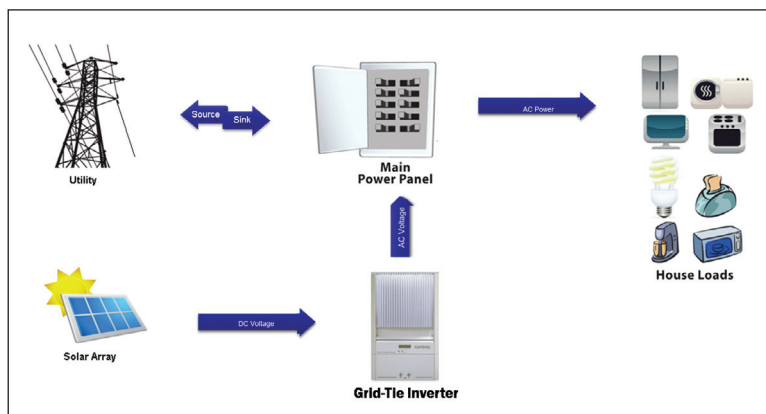
Supporting Market Requirements

The demand on solar inverter manufacturers to support the market's rapidly accelerating requirements can create difficulties. The challenges include:

- Keeping up with developments in solar array technology
- Evaluating solar panel array performance parameters
- Complying with utility interface requirements, and
- Keeping up with utility programs

Fundamental to all of these areas is a myriad of testing requirements. Historically, the industry has directly involved the sun and solar arrays in the testing process. Because of variations in these areas, repeatability is one of the biggest challenges for PV testing today.

Taking solar technologies from the laboratory to



residential and commercial installations requires testing at several points including product validation, production and installation. As new approaches such as micro PV inverters are introduced, the requirements for testing increase.

Micro inverters use many smaller inverters instead of one large inverter. This results in improved efficiency and reliability as well as reduced safety issues. Figure 1 shows several facets of implementing solar power for a residential application including the voltage transitions.

Inadequate testing can seriously impact any product's success. Difficult-to-implement test equipment, testers with inadequate accuracy and repeatability, and equipment that does not easily interface with other parts of the PV system can cause significant delays in a new product's introduction. Three areas of PV/solar technologies that need to be explored further include solar array simulation, house load simulation and utility simulation. In addition, continually evolving and newly emerging standards add to the complexity of the solar power situation. The following four sections address each of these areas.

Solar Array Simulation

Solar arrays operate in an uncontrolled environment. The output is highly dependent on a range of conditions including the intensity of the sunlight (full sun vs. cloudy conditions), ambient temperature, external shading effects (from tree branches or chimneys), dust, bird droppings and other factors. All of these elements affect the capacity of the solar array to produce power.

The inverter must be designed to allow for maximum power transfer from the solar array to the inverter. This maximum power point (MPP) is most commonly determined on a continuous basis. Most PV inverters are designed to harvest the maximum amount of energy available from the PV array at any point in time. To do this, they typically use an MPP tracking control algorithm to continuously present the optimum load to the PV array for maximum power transfer.

The testing of inverters for this application (both in development as well as in production) requires a power source — a Solar Array Simulator (SAS) — that can reliably simulate actual performance. With virtually hundreds of solar array panels available in



Figure 2. Solar Array Simulators, like the AMETEK Terra SAS shown here, make it possible to test solar inverters over a range of input conditions

the marketplace, this can be a daunting requirement. Fortunately, the National Renewable Energy Laboratory (NREL) maintains a Solar Advisor Model (SAM) database that catalogues key parameters such as V_{oc} , I_{sc} , V_{mpp} at 24°C and standard 1000 W/m² isolation for hundreds of commercially available PV products. The SAM provides powerful tools to help designers predict system performance for virtually any fill factor or solar material. A solar array simulator with the ability to access this data and incorporate it into a realistic, dynamic, interactive test of the inverter can pay big productivity dividends.

Many solar inverters generate AC ripple on their DC input that is connected to the photovoltaic array. For single-phase inverters, the frequency of this ripple is twice the line frequency (120 Hz for US models). The simulator's power supplies must not suppress this ripple as a function of their regulation loop.

An increasing number of inverters (and virtually all micro-inverters) accurately measure amplitude and phase of the ripple voltage and current to quickly track the MPP of the array. This approach allows tracking the MPP at a much higher speed when compared to conventional dithering techniques (also called perturb and observe).

Faster tracking of the MPP results in a much higher overall efficiency in cloudy conditions, where the irradiance is constantly changing. It is likely that all solar inverters will use this approach in the near future, since end users are very sensitive to the



Figure 3. A programmable power source like the AMETEK MX shown here is required to simulate the interface between the utility and solar array inverter output

The standards state that when the grid supply is lost, the inverter must turn off within a specified amount of time and the voltage rise must be limited. Tests to verify these capabilities are just being developed. Custom software as well as hardware is required to perform specific anti-islanding tests

overall efficiency of their solar energy installations. To satisfy this requirement, the PV simulator must be capable of reproducing the voltage / current behaviour of a solar array even in the presence of this ripple.

Another requirement of this process is the ability to simulate the MPP for multiple strings of solar panels since most installations use a large number of panels.

Figure 4. A complete test solution such as one offered by AMETEK verifies the product's capabilities and ability to meet the numerous industry standards as well as the product's datasheet performance requirements at every point in the solar array system

House Load Simulation

Simulating residential loads is an area that requires special test considerations. For example, if the grid-tied inverter is putting out 5 kW and the home is only consuming 3 kW, how does the inverter respond to high crest factor (HCF) loads? (Note: HCF is the ratio of the peak value to the root-mean-square (rms) value of a waveform.) This can occur with the switching power supplies in TVs, computers, microwaves and even when a refrigerator turns off and on. Products with switching power supplies can also be a source of

harmonic distortion. How do all these different types of loads affect the PV grid-tie inverter? A load simulator provides the answer for testing.

Utility Simulation

Utility simulation is among the newest testing requirements. There are very few established standards but several areas of concern to utility companies. These include:

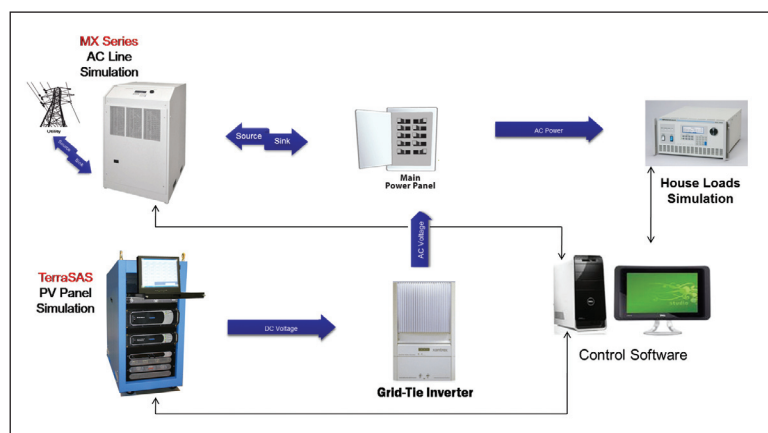
- Anti-islanding
- DC injection
- Utility anomalies, including phase loss, voltage dips and interruptions, and frequency disturbances
- Harmonically enriched waveforms test inverter tracking capability
- Testing for interharmonic susceptibility

One of the problems that can occur if the connection to the utility grid is not established correctly is a situation called islanding. As defined in IEEE 1547, islanding is "a condition in which a portion of an Area Electric Power System (EPS) is energized solely by one or more Local EPSs through the associated point of common coupling (PCC) while that portion of the Area EPS is electrically separated from the rest of the Area EPS." Since unintentional islanding of a distributed power source may cause power quality issues, interference with grid protection devices and other problems, an anti-islanding function in equipment ensures the detection of electrical islands and proper disconnection from the electric power system.

The standards state that when the grid supply is lost, the inverter must turn off within a specified amount of time and the voltage rise must be limited. Tests to verify these capabilities are just being developed. Custom software as well as hardware is required to perform specific anti-islanding tests.

Utility companies actually have a small, 300 to 500 mV DC component on their AC power, so testing for DC injection is one of the required tests. This testing determines how an inverter reacts to the DC component. Simulating the utility mains requires adding the DC components.

With 500 mV of DC in a saturated mode, the power output could drop to half. The IEC committee realizes that these situations can occur and is working feverishly to develop test standards to cope with various situations.



Standard	Topic
IEC 62116-2008	Islanding prevention for utility-interconnected PV inverters
IEC61000-3-15	EMC Low frequency phenomena (in draft)
GS S1 – TUV	Full compliance to GPSG and LVD for CE compliance
IEC 61727	Utility connected PV systems operating in parallel
IEC TS 62578	Power electronics systems and equipment – operation and characteristics of active in-feed converter applications
IEC 62124	Photovoltaic (PV) stand alone systems - Design verification
UL1741	UL Standard for Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
IEEE 1547	Standard for Interconnecting Distributed Resources with Electric Power Systems
GB/T19064	Chinese National Standard
GB/T19535	Chinese National Standard
GB/T19604	Chinese National Standard
IEC 61000-3-15	Electromagnetic compatibility (EMC) - Part 3-15: Limits - Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network

Table 1. International and national standards that require accurate and repeatable power sources to determine conformance

To produce the voltage levels, distortions, dips, interrupts and other anomalies that end products normally experience while operating off the utility line power, the power source used in product testing requires either manual or computer programming capability. While these immunity tests evaluate a product's ability to withstand common public supply disturbances, additional tests are required to measure emissions or the disturbance contribution that the product itself may produce. Accomplishing both requires clean AC power sources that supply and receive power from the product being tested. The latter requirement defines a regenerative system.

The importance of odd and even harmonics and their impact on the power grid is well known, however, interharmonic susceptibility/distortion is a rather recent development. Values in between the integer harmonics, such as the 2.6 or 3.5 harmonic, can cause problems in some common products such as microwaves, washing machines and more. For example, the safety switches in these products can be affected by certain interharmonic values and not function properly.

All of these aspects must be addressed in a solar inverter. Testing the inverter to verify its capability and establish its performance levels requires programmable power.

Standards Compliance

Perhaps today's biggest challenge for PV systems is the testing required to comply with the standards.

To establish conformance, suppliers must test their product(s) to demonstrate that they meet the requirements of local, national and international standards. Table 1 shows some of the more critical standards, including the latest standard expected to be released in late 2010, IEC 61000-3-15.

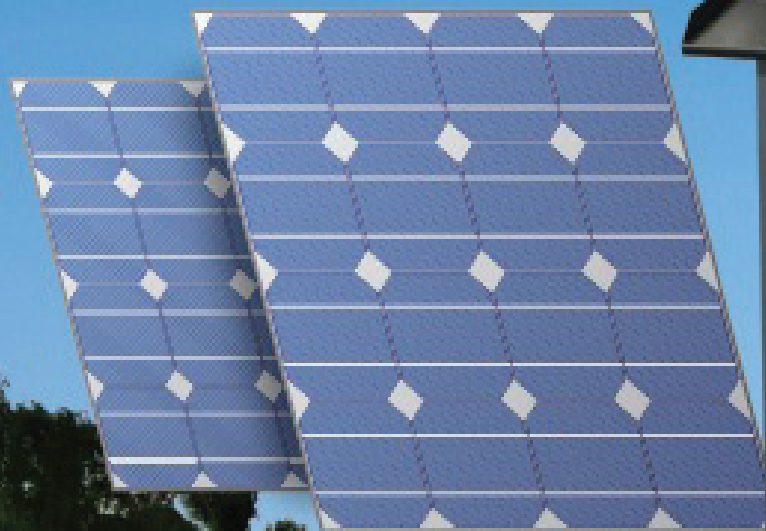
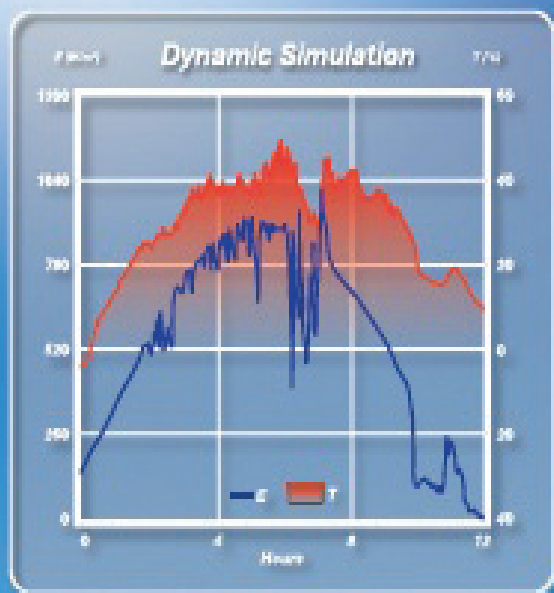
In many cases, products are being developed concurrently with the standards. As a result, it is necessary to bridge the gap between standards and the testing that must be performed to meet them. This can be accomplished by working with a supplier that is closely tied into the standards development agencies and their subcontractors.

Comprehensive Testing: Surround the Inverter

Surrounding the inverter with programmable devices to simulate the output of solar arrays, simulate the loads applied to the output of the inverter and simulate the interface with the grid provides a comprehensive and energy-efficient means of testing these devices. Figure 4 is an example of a comprehensive testing system.

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TerraSAS
Terrestrial Solar Array Simulator