AMETEK®
PROGRAMMABLE POWER

white paper

Regenerative Utility Simulator for Grid-Tied Inverters

AMETEK's RS & MX Series with the SNK Option provides the solution

Testing of grid-tied inverters used in solar energy systems is emerging as a major application for highly repeatable ac power sources. These power sources are used both in the design phase as well as in production testing to confirm their ability to withstand variations in utility line power and demonstrate conformance to applicable standards. Yole Development, a leading market research firm, predicts the photovoltaic inverter market to more than double over the next five years[1].

Test issues dictate the need for power source features that make testing easier, as well as more accurate and more repeatable. Furthermore, the environmental and economic impact of wasting electrical energy demands that considerable attention is given to reduce energy consumption. Both aspects define the requirements for an advanced power source.

Today's Power Source Requirements

Since the utility line power in most industrialized nations typically has distortion levels of 3–5 percent with voltage fluctuations and dips easily exceeding 10 percent on an almost daily basis, an alternative power source is required for these tests. To further complicate the testing process for global products, the variations of utility voltage, ranging from 120V-60Hz in North America to 220/230V-50Hz in most of Asia, South America and Europe, or 100V-50/60Hz in Japan, make programmability an essential feature of the power source.

To produce the voltage levels, distortions, dips and interrupts 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 power and receive power from the product being tested. The latter requirement defines a regenerative system. *(See Figure 1.)*

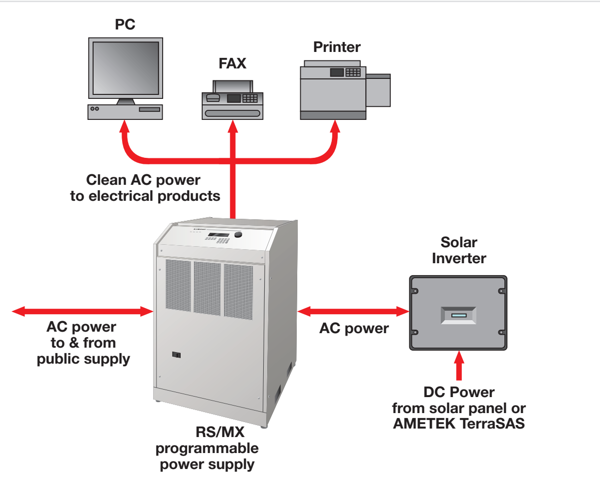

Figure 1. An advanced programmable power source can deliver and receive power from a solar inverter and supply clean AC power for testing.

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Regenerative Mode Operation

Four-quadrant linear power sources have been used to allow reverse current flow (sink current) into the power source using two of the quadrants to source power and the remaining two quadrants to sink power. In this case the second quadrant acts like a load and burns up energy in the form of thermal energy. Removing this heat from a laboratory or production line environment requires an amount of cooling energy typically equal to the generated heat - essentially doubling the wasted energy and considerably increasing the lifetime cost of ownership. The increasing awareness for environmentally responsible green companies and those actively reducing their carbon footprint makes the linear source unacceptable for many reasons. A preferred alternative solution that solves the heat generation and added cooling problem is a switch-mode AC power source. With the ability to both source and sink power, the power from a switch-mode power source is actually returned to the utility grid with minimal loss when it operates as a regenerative power source.

A solar inverter producing sufficient power can feed power continuously back to the source. When the power level cannot cover the load demand, the direction of power flow can change dynamically, even on a half-cycle by half-cycle basis. The inverter must be capable of addressing the continuous, intermittent or half-cycle situations as well as short-term events in the power flow.

Anti-Islanding

To meet the rising demand for electricity, utilities can acquire surplus energy from photovoltaic systems, microturbines, fuel cells and other local generating technologies. However, the performance, operation, testing and safety of interconnection products and services, must meet the requirements of IEEE 1547 (see Table 1 in the Standards Compliance section). The inverter must provides a means to simulate interconnect of an electric power system (EPS) with a distributed resource (DR) such as a solar panel's photovoltaic inverter as well as repeatably perform the testing required by the standard *(see Figure 2)*.

One of the problems that can occur if the interconnection is not established correctly is a situation called islanding. As defined in IEEE 1547, islanding[2] 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

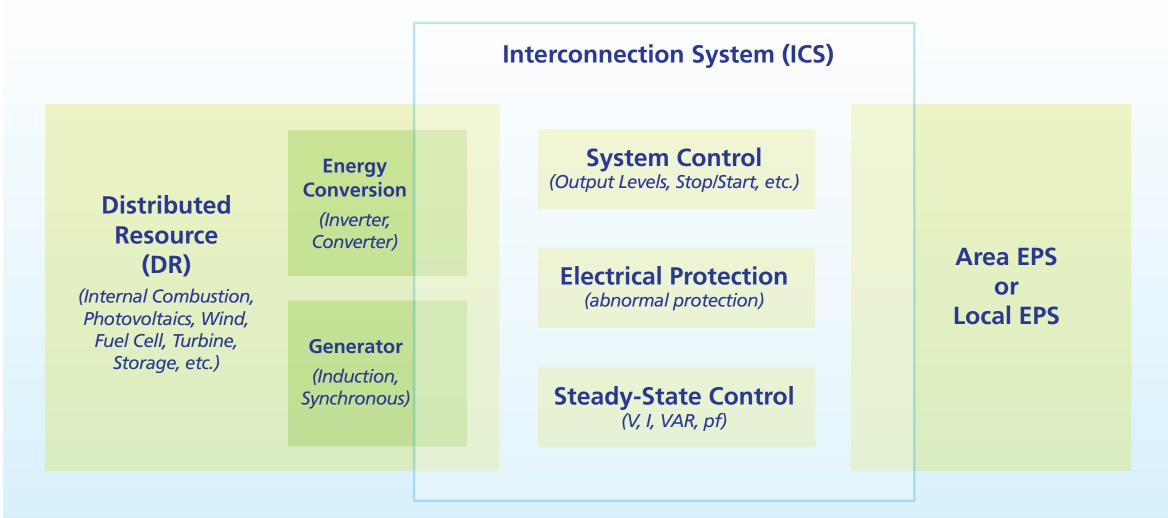

Figure 2. The characteristics of an interconnection or point of common coupling for anti-islanding prevention as identified in IEEE 1547[3].

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 inverter used in this testing must be capable of simulating this event .

The AMETEK Solution

As a leading designer and manufacturer of complete test solutions including power sources and test equipment, AMETEK has extensive knowledge in the requirements and solutions for programmable power sources. The California Instruments MX or higher power RS Series, by AMETEK Programmable Power (AMETEK), operating in the Regenerative Mode (SNK option) meets the industry's strictest demands. Figure 1 shows the interaction of the programmable power source in this application.

Regenerative Mode Operation

For efficient AC line simulation, AMETEK's RS or MX Series programmable Power Sources use switch-mode technology. In the Regenerative Mode, the RS/MX Series can accept and sink (SNK) power returning from any connected equipment to the utility grid. This power return can be a short-term event or a semi-permanent condition.

To effectively handle these occurrences under a wide range of supply voltages, the RS/MX programmable power source with the SNK option has additional features that simplify its usage. A programmable current limit that is different in the SNK mode from the current limit when sourcing current is readily accomplished using a control screen and user settable values. Figure 3 illustrates the Regenerate Control screen display.

REGENERATE CONTROL	
STATE = ON	
UNDER VOLT= 212.0 V	dFREQ = 0.45 Hz
OVER VOLT = 263.0 V	DELAY = 5.000 S
PREVIOUS SCREEN	CURR = 8.0 A

Figure 3. The values of several parameters can easily be adjusted using the front-panel display of the MX with the Regenerate Control parameter setup screen.

In addition to limiting the maximum current the inverter is permitted to inject into the source, the user selects whether the regenerate control state is either "ON" or "OFF" and the values of other parameters. The Undervoltage (UNDER VOLT) setting is the lowest voltage that the source will default to in the event of an over-current condition. Similarly, Overvoltage (OVER VOLT) is the highest voltage threshold before the source forces the inverter off-line. Delta Frequency, or dFREQ, is the change in the source's frequency that forces the inverter off-line. Delay is the time that the source will take between overcurrent and each of the steps in the other specified actions.

As an example of the programmability of the RS/MX with the SNK option, the current limit for power sourced by the RS/MX can be set to 40A with the regenerate control state "OFF," while the maximum current that is returned by the RS/MX to the utility could be set to 10A with the regenerate control state "ON". In Regenerative Mode, the current limit functions exactly opposite to the "normal" operating mode of a power source. Instead of reducing the voltage to limit the current, the RS/MX will increase its voltage level to the user-programmed Over Voltage limit.

The dFREQ setting provides additional functionality for the RS/MX Series with SNK option. When the duration of an overcurrent condition equals the user-specified Delay time, the RS/MX changes its frequency by the dFREQ value. This will usually force the inverter off-line. If this does not occur within the specified DELAY seconds, the RS/MX will decrease its voltage. If the overcurrent condition continues and the inverter does not go off-line, the RS/MX will open its output relay and then shut down. Setting dFREQ to zero causes the RS/MX to skip the frequency step and transition directly from the overvoltage value to the undervoltage limit.

Anti-Islanding

The RS/MX with SNK option provides a means to interconnect an electric power system (EPS) with a distributed resource (DR) such as a solar panel's photovoltaic inverter as well as repeatably perform the testing required by the standard *(see Figure 2)*.

RS/MX operation with the Regenerate State ON supports the "balanced mode" anti-islanding test required by IEEE 1547 and other standards such as UL 1741and CA Rule 21. To balance the inverter output and load demand, the load is set to exactly absorb the output power of the inverter so that zero current flows. In Regenerative Mode, the RS/MX with SNK option's output relay can be opened while the voltage is at the programmed level, instead of requiring output voltage to be programmed "zero" before opening the output relay, which is the case without the SNK option. This difference allows the testing of the inverter's ability to detect that the "public supply" has been disconnected, a situation that can occur when the circuit breaker in the house trips or during a power outage. IEEE 1547 also requires the power source to disconnect itself from the inverter and load while the load is perfectly balanced. The characteristic differences between unbalanced and balanced conditions are shown in Figure 4.

In the left-hand image, the inverter is an unbalanced load. Within about a half a cycle, the inverter detects that the power source, the public supply, is no longer present and disconnects. In the right-hand image, after the source has disconnected, the inverter's voltage gradually increases over the last 8-9 cycles taking about 150ms for the inverter to detect an islanding event and then shut down.

GUI Software Programmability

The SNK option provides users the flexibility for performing several tests for regenerative power systems. In addition to front panel controls, the RS/MX's PC-based MXGUI graphical user interface software also supports the SNK option. As shown in Figure 5, this allows users to access various parameters to easily perform a broad range of inverter tests.

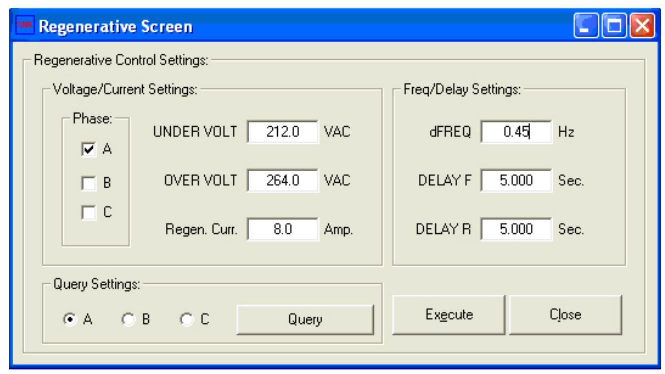

Figure 5. The MXGUI screen easily allows the selection of values for Regenerative Control parameters.

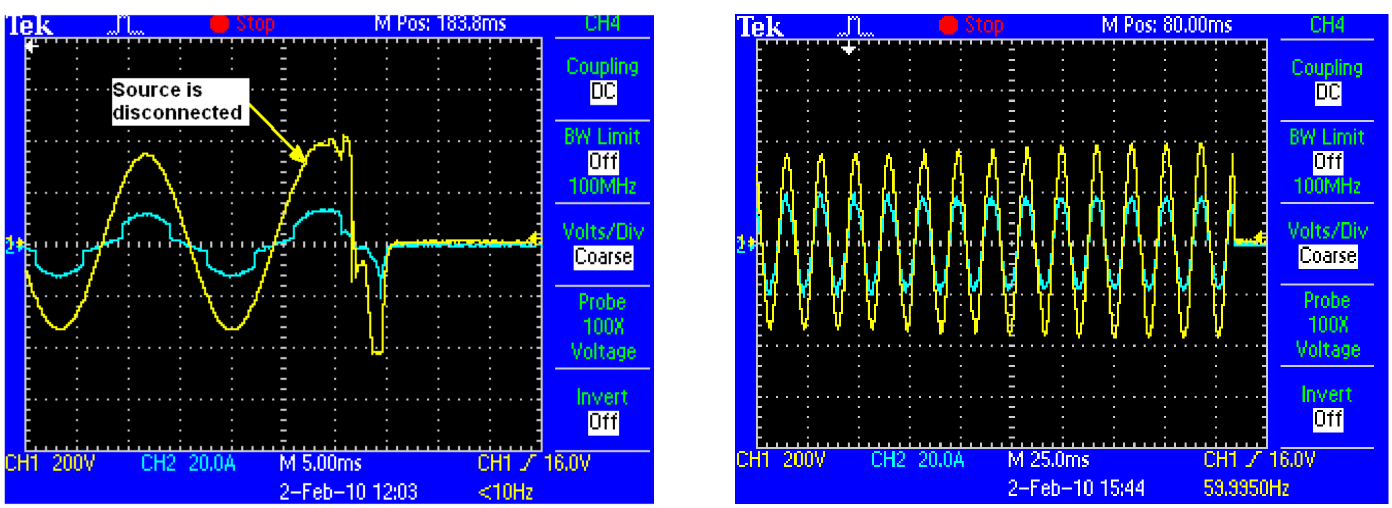

Figure 4. The difference between an inverter disconnecting with unbalanced (left) and balanced (right) load is an abrupt versus gradual event.

With the Transient List function, the overall system behavior can be determined as shown in Figure 6. In this example, the power source is programmed to step down from 240V to 195V in 5V increments, initiating around 20 seconds after the inverter has synchronized and come on line.

Using the MXGUI's Transient List function, users may make other measurements including the delta frequency test. In this test, the RS/MX is programmed to step through a series of frequency changes from 60Hz by increasing amounts in both positive and negative directions with fixed time and voltage settings.

Looking forward, software will increasingly play a key role in bringing the hardware test elements together and reduce user's time to generate test results.

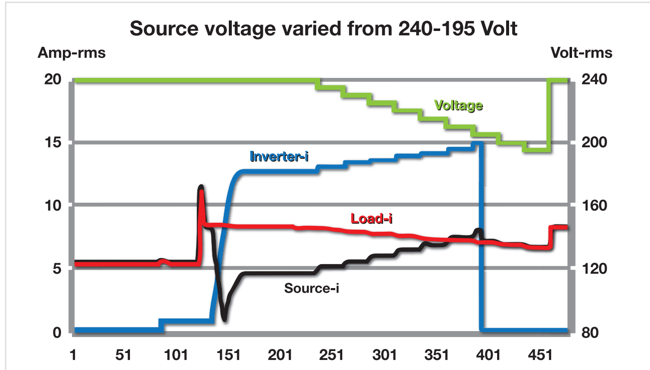

Figure 6. After voltage steps in the Transient List are programmed through the MXGUI, the resulting current and voltage steps are easily measured during the execution phase.

Standards Compliance

The Regenerative Mode capability of the RS/MX with SNK option is essential to perform many of the tests required in 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.

References

[1] PV Inverter Trends, Octover 1, 2009, Yole Development

[2] 1547-2003 IEEE Standard for Interconnecting Distributed Sources with Electric Power Systems

[3] IEEE 1547 Interconnection Standards, Tom Basso, Presentated at IEEE PESMeeting, June 9, 2004

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 source to determine conformance.