# ENHANCED INVERTER FUNCTIONS – EXECUTIVE SUMMARY

August 7, 2013

Customer owned solar photovoltaic (PV) systems are rapidly proliferating in San Diego and other parts of the country as prices are reduced and business models have become more sophisticated. These PV generation systems inject power at various points along electric distribution lines, increasing the voltage of the lines at the point of interconnection. The output from PV systems is also intermittent. Their output can change significantly over short periods of time due to environmental conditions like cloud movement and fog burn off. As the PV systems' output fluctuates, it causes voltage swings on the electric distribution lines. Traditionally electric utilities have controlled the voltage on electric distribution lines with legacy electromechanical equipment like line regulators and capacitors. However, as the penetration level of PV generation increases, the magnitude and frequency of the voltage swings caused by PV generation will become increasingly difficult to control with legacy equipment. The voltage swings will also cause the legacy equipment to operate excessively, requiring additional maintenance and operational costs, and early replacement.

One way to mitigate the voltage swings caused by PV systems and manage the voltage within the allowed operating range is to use inverters similar to those deployed in Europe with enhanced functionality like dynamic reactive power control. Early generation inverters and many simple inverters still manufactured in the US today can produce only real power (watts). They cannot produce reactive power (volt-amperes reactive, i.e. VArs). Most inverters produced for the US market today have the physical components required to provide enhanced functionality, but they lack the firmware, although increasingly the firmware is provided but not enabled. With only modest increases in manufacturing costs, firmware could be added during the manufacturing process to produce inverters with enhanced functionality that would generate or consume reactive power and mitigate voltage swings associated with PV systems.

Enhanced inverter functionality is also desired to achieve fault ride through capability, so that PV and distributed renewable generators could contribute to grid stability during system disturbances where the grid voltage or frequency may go outside the normal operating ranges. Existing voltage trip settings prescribed in technical standard IEEE 1547 are conservative, forcing generators to trip off line quickly to avoid islanding. Conversely Germany has developed standards that require inverters to provide fault ride-through capability and dynamic reactive support. In fact, Germany has determined that it is necessary to retrofit 315,000 existing inverters at a cost of approximately $300 million to achieve enhanced inverter functions including fault ride through capability and provide grid support during faults, voltage recovery during post-fault conditions, and avoid a system blackout. Another enhanced inverter function that would support grid stability would be diversified disconnection of inverters once voltage trip points are reached, and diversified reconnection of inverters when grid power is restored. Randomization of timing for trip and reconnection functionality would support this.

Communications capability is also necessary to enhance inverters' functionality by remotely enabling functions or change of operating set point. Various communication protocols exist, however, a single protocol has not been identified as a standard for use in inverters. Whatever protocols are adopted and implemented into inverter capabilities must be able to support security requirements required by electric utilities.

Given these considerations, it is desirable that new inverters have the following enhanced functions:

- Communications capabilities
- Real and reactive power support
- Dynamic VAR injection
- Expanded frequency trip point
- Low voltage ride through
- Randomization of timing for trip and reconnection

These functions are available in inverters sold in Europe, however, they are not widely available or enabled in the US. Technical standards and interconnection rules in the US need to be modified to support these inverter functions. As of February 1 SDG&E had interconnected 21,696 customer owned PV generation systems with 162.5 MW of capacity. Over the previous 12 months the number of PV generation systems has increased by 33%[1] and the MW capacity has increased by 35%[1]. This growth rate creates urgency to begin installing inverters with enhanced functionality as soon as possible.

The development of enhanced inverter functions is supported by California and US federal regulators. The California Public Utilities Commission has issued an Order Instituting Rulemaking (OIR) R.11-09-011, which covers distribution level interconnection rules for electric generators and storage. Phase I of this OIR pertaining to the Rule 21 Settlement for SDG&E was finalized in 2012. Some sections of Rule 21 contain language adopted directly from technical standard IEEE 1547, and in other places IEEE 1547 requirements were paraphrased. Phase II of the OIR, which includes technical operating standards for smart inverter functionality and

[1] On January 31 2013 SDG&E had interconnected 21,696 customer owned PV generating systems with 162.5 MW capacity under the Net Energy Metering (NEM) program. On January 31, 2012 SDG&E had interconnected 16,046 customer owned PV generating systems with 122.1 MW capacity under the NEM program. The annual growth rate over this period is 33.1% in the number of PV generating systems and 35.2% in the MW capacity.

generator output, is proceeding through scheduled workshops with a goal to adopt the enhanced inverter functions described above.

The Federal Energy Regulatory Commission (FERC) has issued a Notice of Proposed Rulemaking RM13-2-000 that will modify the pro forma Small Generator Interconnection Agreement (SGIA) in order to address reliability concerns in Germany and the US. The German issue is related to the potential for over-frequency resulting from imbalances between generation and load. The impact of the loss of PV generation during an over-frequency event is not yet an issue in the US, although over-frequency events have occurred in the US[2]. The North American Electric Reliability Corporation (NERC) has identified a related bulk electric system reliability concern as part of its Frequency Response Initiative where residential and commercial scale PV systems could trip during under-frequency conditions. This could become a matter of concern at high penetrations of PV resources. While the German government has ordered the retrofit of thousands of PV systems at significant cost to address its frequency issue, FERC proposes to prevent such problems now to mitigate this risk. The proposed revisions to the pro forma SGIA will require the PV owners to design, install, maintain, and operate their systems in accordance with the latest version of applicable standards to prevent automatic disconnection during an over- or under-frequency event and to ensure that rates remain just and reasonable.

[2] FERC & NERC, Arizona-Southern California Outages on September 8, 2011: Causes and Recommendations (2011), http://www.nerc.com/files/AZOutage_Report_01MAY12.pdf.