Intelligent Power Conversion

How the Next Generation of Renewable Energy Inverters Will Change the Future of Distributed Energy Production and Distribution

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The next generation of commercial- and utility-scale solar inverters will be the core enabling technologies for the growth of large-scale distributed energy systems. Through a combination of increased capacity, improved output quality, and advanced control features, these more powerful, efficient, and intelligent inverters will enable a stepped improvement in both the controllability and the overall performance of renewable energy production and distribution. These inverters will also be critical elements in improving the performance of future renewable energy systems through advanced diagnostics and prognostics that will increase availability and minimize repair and maintenance requirements and cycles.

Three unique areas of opportunity exist in alternative energy production—such as photovoltaics (PV) and fuel cells (FC)—that don't exist in traditional turbine-driven generators powered by hydraulic or steam processes. First, many alternative energy sources are direct current (DC) in nature, but have poorly regulated terminal characteristics. These DC energy sources require efficient power conversion, most commonly in the form of inverters, to change the energy into a regulated alternating current (AC) or direct current (DC) voltage for utilization by the consumer or by utilities. This electronic interconnection point can then be used to harness value-added activity.

The inverter is by its very nature the intelligent device in the energy conversion and control system. It has the ability to sense a wide variety of conditions; to store, process, and react to these conditions; and to report them to a remote management system. The true value of the inverter as the intelligent component of the system has yet to be fully realized and will be increasingly important as the penetration of renewable energy increases over the coming years. The inverter can concentrate a wide variety of sensed data and either communicate this data for remote analysis or correlate the data itself to benchmark the normal and detect or predict the abnormal in terms of system operation and performance. Diagnostics can be run within the inverter itself or on external hardware, and they can determine a system's state of health and likely causes of diminished performance, thus greatly enhancing the ability of maintenance personnel to arrive on-site equipped and prepared.

The second area of opportunity for inverters in renewable energy production results from the significant output variation that energy sources can produce because of environmental factors, such as intermittent wind and weather patterns. These energy sources have clear cycles during which their production output ranges from significant to dormant. This characteristic both differentiates alternative energy sources from the more linear production of traditional energy sources, which are ideal for base-level energy production, and complements traditional energy, since the cyclical nature of alternative production ideally coincides with peak demand periods. Given this complementary nature between base- and peak-level production traits, the challenge then becomes how to optimally manage these alternative energy systems so that each source produces maximum output across the longest power production period available.

Inverters are capable of functionality well beyond that of transferring real power to the grid. This functionality includes reactive power, phase balancing, harmonic cancellation, and so on. If an inverter connecting to a renewable energy source is underutilized, it can be an available resource to the utility as an active filter that can be under utility control. This fast or “dynamic” reactive power is critical to grid voltage stability. This was evidenced in the reports on the blackout of 2003, when inserting leading or lagging reactive power at key points could have enhanced the ability to rapidly compensate for voltage disturbances. As a distributed and dynamically controllable resource, grid-connected photovoltaic systems are inherently positioned to enable this valuable capability.

The third area of opportunity for inverters in alternative energy production results from the challenges presented by the distribution and overall quality of the energy itself. Alternative energy sources are often located away from population and load centres. This distributed dynamic extends across both the supply and demand sides of the energy network and places increased importance on the point where the two sides connect—the inverter. The role of the inverter has two facets: first, it is tasked with managing and extracting the maximum power from the input source; and second, it is tasked with conditioning the power—putting clean and compliant AC power on the grid. Because of the electronic nature of the inverter and the switching frequency (which is many orders of magnitude higher than the line frequency), the quality of the output power can be exceptional.

Inverters have the speed and the intelligence to be a powerful resource on the grid. They also have the communications capabilities needed to be aggregated and controlled in unison, so they can effectively act as a large power plant or an active power network device. High-speed, aggregated, distributed power generation has proved to be extremely valuable in the modern power grid, even replacing spinning reserve requirements in certain locations. In this context, grid-connected inverters offer the ultimate in speed of response and controllability. An important trend to acknowledge is the move toward large, multi-megawatt, renewable energy distributed-generation systems. These large systems achieve economies of scale in terms of installed cost, enhanced efficiencies from large-scale interconnection and inverters, and more efficient grid integration through direct medium-voltage interconnection.

Because electronics are capable of acting much faster than traditional grid-connected devices, there is understandable concern about the effect of grid-connected inverters on the stability of the grid. Strong interconnection regulations such as UL1741 and IEEEP1547 have been developed to specify and control this interconnection. The high-speed nature of the inverter has acted as an encumbrance in terms of the majority of the interconnection requirements, which are orders of magnitude tighter than for thermal power plants. A shift in attitudes toward inverters and requirements is extremely likely as penetration grows, as evidenced by the ride-through requirements that have emerged for grid-connected wind replacing the interconnection requirements that still apply to other renewable and distributed resources. The role of advanced inverters will become increasingly important, since they enable renewable energy resources to ride through grid disturbances rather than trip off, operate in islanded conditions under utility control, and operate in microgrid mode with the addition of complementary generation, storage, or real-time load control.

The next-generation inverter will be the glue that ties renewable or alternative energy sources such as PV or fuel cells to the utility grid. The inverter will become the interconnect that supplies distributed intelligence to a power system. It will be high speed and large scale, offer additional active-filter features, and be remotely controlled. The ingredients are in place; grid integration and integration into utility SCADA systems are the logical next steps to make inverters and renewable energy sources a true utility asset.

About

Satcon Technology Corporation, a leading provider of utility-scale, grid-connected renewable energy solutions for distributed power markets, enabling the industry's most advanced, reliable, and proven clean-energy alternatives.

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