Are Your Transformers Ready for the Smart Grid?

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National challenges like the aging power grid, increasing energy demands, spiraling cost of generating electricity and its cost on the environment are all pointing towards the need for a grid that can produce and distribute energy more efficiently and reliably.

For years technologists have been toying with the idea of a “smart grid”, an electricity distribution system that uses digital technology to eliminate waste and improve reliability. Adoption of the smart grid is expected to enhance every facet of the electric delivery system, including generation, transmission, distribution, and consumption. Advocates of the smart grid also say that it would open up new markets for large and small scale alternative energy producers by decentralizing generation.

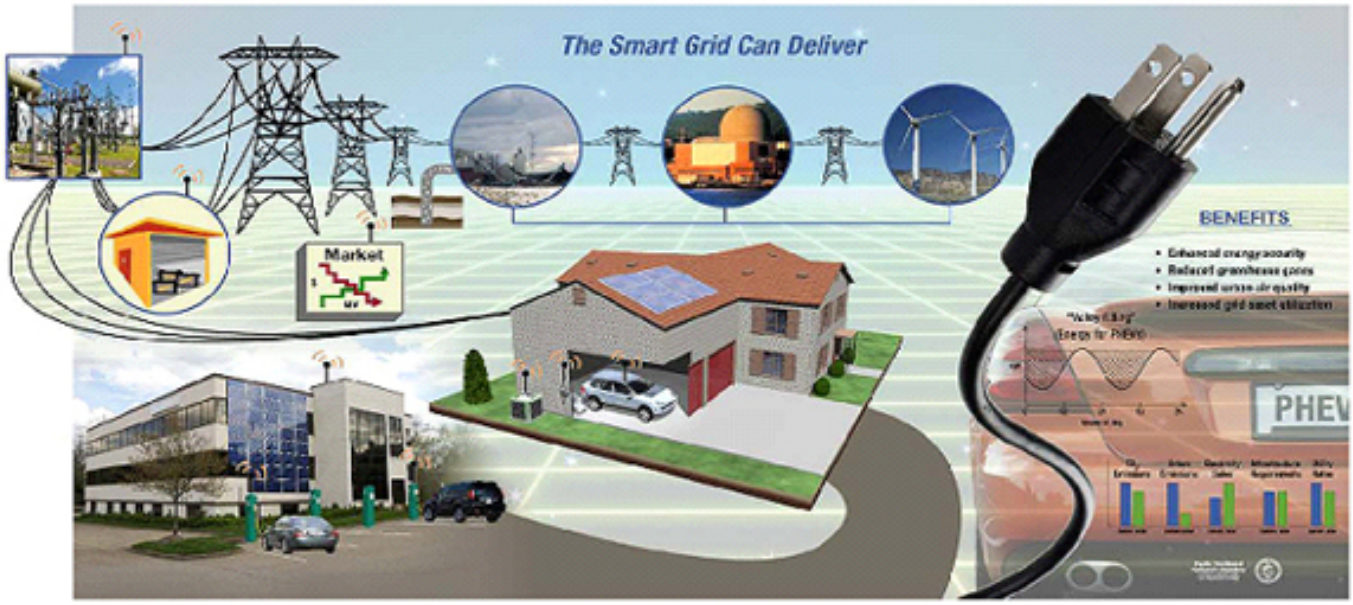
Transformers serve as a hub for collection and distribution of energy and are a key component of a successful transition to a smart grid. Some transformers are located where grid communication is mature enough to allow or require interaction, while others are not. Transformers used in the transmission of power are immediate candidates for integration into smart grid technology, and will immediately benefit from improvements to reliability and efficiency that result from some of the new online monitoring technologies. Transformers used mainly for distribution circuits will probably be affected more as the smart grid matures.

Most of today’s transformers are by no means ready for the smart grid because they were placed into service years before the age of interactive information transfer. Building the next generation of transformers will require incorporating remote monitoring of a wide range of transformer and system parameters.

What is a smart grid?
Everyone is talking about the concept of the smart grid, but the actual definition is still fluid. The Department of Energy notes that the smart grid will be an automated, widely distributed energy delivery network, characterized by a two-way flow of electricity and information and able to monitor everything from power plants to customer preferences to individual appliances. [1]

Figure 1 illustrates the fact that the smart grid concept ties together all aspects of the power system, from the plug in the wall at a house or office, to a factory, to the distribution system, to power plants of all kinds.

Figure 1 – The Smart Grid



Distributed computing and communications technology will be incorporated to deliver real-time information and enable the near-instantaneous balance of supply and demand down to the device level. In short, the smart grid will deliver electricity from suppliers to consumers using digital technology to save energy, reduce cost, and increase reliability and transparency.

Table 1 compares key features of today power distribution grid with that of a smart grid. Adoption of the smart grid is expected to enhance every facet of the electric delivery system, including generation, transmission, distribution, and consumption. [2]

Table 1 – Features of Current Grid Compared to Smart Grid		
	Current Grid	**Smart Grid**
Communications	None or one-way; typically not real-time	Two-way, real-time
Customer interaction	Limited	Extensive
Metering	Electromechanical	Digital
Operation and maintenance	Manual equipment checks, time-based maintenance	Remote monitoring, predictive, condition-based maintenance
Generation	Centralized	Centralized and distributed
Power flow control	Limited	Comprehensive
Reliability	Prone to failures and cascading outages	Pro-active, real-time protection and islanding
Restoration	Manual	Self-healing
Topology	Radial	Network

To say that there is quite a lot riding on a successful transition to a smart grid is a colossal understatement. The smart grid is expected to ensure the reliability of the power system, maintain its affordability, reinforce the United States' global competitiveness, fully accommodate both renewable and traditional energy sources, potentially reduce our carbon footprint, and be structured to facilitate the introduction of new advancements and efficiencies that have not even been dreamed of yet.

Table 2 lists the key component technologies that are expected to be available to facilitate transition to the smart grid.

Table 2 - Technologies Necessary for Smart Grid Evolution
▪ Integrated communication that connects grid components to open architecture
▪ Software that can be upgraded and enhanced for real-time information
▪ Control, allowing every part of the grid to 'talk' and 'listen'
▪ Sensing and measurement technologies that support remote monitoring
▪ Time-of-use pricing (pricing determined as the power is used, rather than weeks later when a meter is read) for companies and consumers

Today's transformers are not ready for tomorrow's smart grid
Although just one piece of the smart grid puzzle, transformers serve a key role as the hub for collection and distribution of energy. For the smart grid to work efficiently there will be a need for smart transformers. As part of the distribution network, there are millions of transformers in the country; unfortunately very few of them have any intelligence or communication capabilities that meet advanced metering infrastructure (AMI) standards or are parts of an advanced sensor infrastructure (ASI) network.

Transformer manufacturers are seeing an increasing emphasis on online transformer monitoring, but the fact of the matter is that today's transformers are for the most part, not ready for tomorrow's smart grid.
The first reason for this state of affairs is that transformers have a long useful life expectancy, generally 20 to 30 years of service. Most were installed before the age of interactive information transfer, which is the foundation of a smart grid.

As they are replaced with contemporary technology, communication capability can be included as an upgrade. However, a product with such a long projected useful life span changes only very gradually over time. If we consider that all transformers have about a 25 year life span, each year only 1/25th of those installed would likely need to be replaced. Optimistically that's only 4 percent per year for the next 25 years. That is a long time to wait for a smart grid, if typical replacement patterns apply.

A second reason is that the wide range of transformer applications means some transformers are in a position/location/application where grid communication is mature enough to allow/require interaction, while other are not. Transformers used in the transmission of power are immediate candidates for integration into smart grid technology, while transformers used mainly for distribution circuits will be affected by a smart grid only after it matures to a greater degree.

Another key factor is the need for a sea change in how the industrial sector sees transformers. Their concern has traditionally focused on power continuity; heavy industrial users have typically not paid a great deal of attention to how their transformer can be used to affect power flow or load switching on a regional or national scale. The danger with this mindset is that industrial transformers being purchased today, which will be in service for the next 20 to 30 years, may not contain the systems necessary for monitoring of communication likely to be required within the next 5 years. Clearly, transition to the smart grid will require a degree of re-education in the industrial sector.

Of course, legislation may play a part in accelerating the change and transition to transformers that are compatible with smart grid concepts. We saw that recently, as DOE mandated higher efficiency ratings for all distribution transformers in 2010, and we saw it in the late 1980s where legislation mandated that PCB-contaminated transformers be replaced.

There is already an increased use of digital monitoring in transformers. Vital statistics like temperature, pressure, and vacuum levels are being collected and transmitted in real time to a central clearinghouse. Many transformer manufacturers are recognizing this growing demand for online transformer monitoring products and diagnostic services, and investing in building them, especially for step up transmission high voltage transformers.

These technologies will be critical for improving grid reliability and helping utilities avoid transformer failures and resultant blackouts. They will also reduce maintenance costs and defer capital expenditures by extending a transformer's

useful life.

For example, in the past few years, there has been a burgeoning interest in conducting dissolved gas analysis (DGA) of the oil in transformers. With DGA, samples are taken of the oil's exhaust gases to determine if any events have occurred that might be detrimental to the transformer and reduce its life. Both industrial transformer users and utilities are setting up these planned sampling programs, using online devices that can monitor the oil for quality. This can greatly improve reliability, because users will know in advance when something has to be replaced, rather than risk enduring an unscheduled outage. For food processing plants and mills, which can lose millions of dollars if their power is interrupted, this type of sampling program is being undertaken to ensure reliable power.

Transformers in place now are already using various smart devices for load switching. In the 21st century, the move will be towards monitoring systems that promote transformer reliability. Ensuring reliability on the grid by replacing equipment before it fails and anticipating upcoming problems is what transformer manufacturers will be focusing on.

Pacific Crest Transformers is responding to this growing demand for transformers that can be integrated into the smart grid as it matures. As it builds next generation transformers, PCT is incorporating remote monitoring of a wide range of transformer and system parameters. Table 3 shows typical monitoring parameters necessary for smart grid integration.

Table 3 - Typical monitoring parameters for smart grid integration

		Communication		
	Units	Alarm	Local	Remote
Transformer Parameters				
Tank pressure	psi	Y	Y	Y
Tank vacuum	psi	Y	Y	Y
Oil temperature	o	Y	Y	Y
Winding temperature	o	Y	Y	Y
Pressure relief device operation	on/off	Y	Y	Y
Sudden pressure relay operation	on/off	Y	Y	Y
Liquid level	on/off	Y	Y	Y
Hydrogen gas %	%	N	N	Y
Water content in oil	%	N	N	Y
System Parameters				
Fans on	on/off	Y	Y	Y
Loss of control power	on/off	Y	Y	Y
Ambient temperature	o			Y
Input current	amps	N	N	Y
Input voltage	volts	N	N	Y
Output current	amps	N	N	Y
Output voltage	volts	N	N	Y

Though laudable, it must be said that the concept of using these smart grid concepts to ensure system reliability is definitely still in its infancy. All parts of the system must work together to develop a system that monitors the transformer and other parts of the grid at all times. There is still a bit of an island mentality amongst those building system components, including switches, cabling, and capacitors, to name just a few. Symbiosis amongst the components could happen, but it has not done so yet.

So, it is clear that the answer to the question, “Is your transformer ready for the smart grid?” is complicated. Depending upon where the particular transformer is used in the power generation and distribution system, the answer is either yes, no, or maybe. Pacific Crest Transformers is among those moving forward to develop transformers that can be part of smart grid initiatives to improve power reliability and efficiency.

Sources

The SMART GRID: An Introduction, prepared for the U.S. Department of Energy by Litos Strategic Communication under contract No. DE-AC26-04NT41817, Subtask 560.01.04
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