An introduction to the Smart Grid

> **White paper**

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There has recently been a lot of talk in the media and debate by government officials about the "Smart Grid". The 2009 American Recovery and Reinvestment Act (ARRA) allocates billions of dollars in incentives for research and funding of projects that demonstrate Smart Grid technologies. Even though it has been researched at universities and discussed in many scientific journals and industry publications for more than a decade, there is still no clear industry definition or agreement of what the Smart Grid is.

This paper summarizes the United States Federal Government's vision for the Smart Grid, as well as the tools utilized, the opportunities created and challenges faced.

The business case for the Smart Grid

Even though today's national electrical grid is 99.97% reliable, as per the US Department of Energy (DOE), power outages and interruptions cost Americans over $150 billion each year. Given our population growth and exponential increase in electrical power consumption in this increasingly digital world, coupled with the need for electrifying our transportation system (ex: Plug-In Hybrid Electric Vehicles) to lower the dependence on foreign oil, additional infrastructure (power generation, distribution and transmission systems) must be built. It is estimated that $1.5 trillion will be spent on this infrastructure by 2030. This infrastructure will require a secure, reliable and efficient distribution system to minimize economic losses. It must also be flexible enough to integrate the new alternative energy sources such as wind, solar and other distributed generation sources.

What is the "Smart Grid"?

The electric power industry describes it as "electricity with a brain", or as a "self-healing" grid.

Some utilities are promoting the Smart Grid as the application of Advanced Metering Infrastructure (AMI) to the existing grid, which simply means more intelligent meters and control devices that are consumer interactive. The idea is that smarter customer control devices will receive signals from the grid and process this information based on the customer's real demand, then make decisions that will save energy by switching some of the consumer loads off during peak demand hours. Such advanced meters and control technology will also help utilities plan better and minimize the use of the traditional and more expensive peak shaving "peaker" power plants.

However, Advanced Metering Infrastructure (AMI) is just one component of the government's concept of the "Smart Grid". In addition to advanced metering, key players in the power market realize that there is a need for real-time load monitoring that will integrate information from a variety of sources. It will then use that data to make decisions and utilize controls to rapidly respond to any event with the appropriate solution.

According to the DOE, the new grid infrastructure must be centralized, yet able to operate in isolated sections. This means providing power to a smaller area disconnected from the primary grid, during a failure event. This microgrid structure will require that the grid be able to integrate distributed generation sources that are not usually on the grid during normal conditions. If implemented, the Smart Grid will grow the distributed generation business where small generators and renewable energy sources located close to the load will be the prime source of power during interruption of traditional utility power. These distributed sources can include CHP (Combined Heat and Power) plants and peak shaving generators located in industrial facilities as well as local peaking plants.

FIGURE 1 – Custom packaged lean burn natural gas CHP system.

Even if they don't cover all of the consumers' power requirements while in island mode, distributed generation systems can at least provide power to the most important facilities on the microgrid until conventional utility power returns. Distributed generation can also play a major role on the grid during normal conditions, where their location next to the load can help lower cost, improve reliability, reduce emissions, and expand energy options to the consumer.

While the advancements in telecommunication technologies revolutionized the world in the last few decades, the existing electric power grid still uses similar technologies to that of the original grid designed in the late 1800's and early 1900's. This will change with the new Smart Grid architecture, where digital devices and satellite communication networks will allow a two-way flow of information between utilities and customers. Such a communication network will help ease the congestion of power during peak demand hours utilizing remote monitoring capabilities and providing dynamic real-time pricing to customers. That information will allow users to respond to the advanced pricing information, shifting their usage to lower cost "off peak" periods thus helping them better manage their energy costs. This is a far better alternative to the current process of getting their monthly bill and trying to react after the fact. Such communication systems should also be able to track and store data for better planning by utilities and consumers.

Advanced network sensing and modeling devices, combined with digital controls will transform the human grid operator's role into more of an observer of the system. Since human error is the most common form of failure in complex networks, using microprocessor controls will make the grid more reliable and faster when it comes to preventing blackouts.

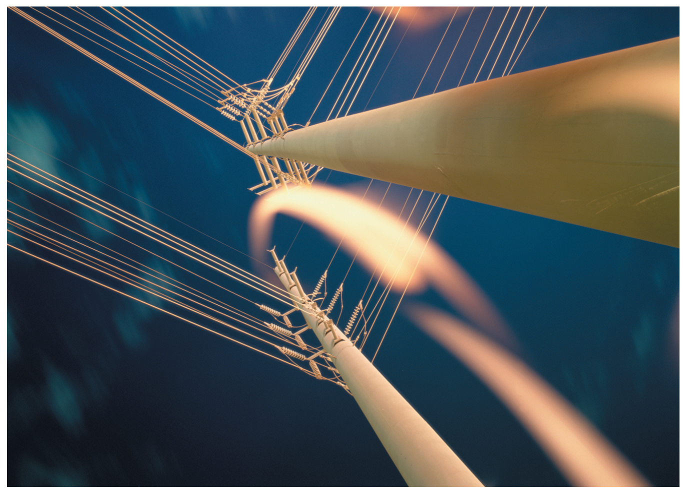

FIGURE 2 – Next generation superconductive power cables could reduce line losses and carry 3-5 times more power.

Some of the emerging technologies that are expected to be utilized in the Smart Grid are:

Phasor Measurement Unit (PMU) system which uses sensors that sample voltage and current at a given location up to 30 times per second. PMU is much faster than the existing Supervisory Control and Data Acquisition (SCADA) sampling system that samples 2 to 4 times per second. Such enhanced sampling allows better diagnostic capabilities, making the grid more intelligent when it comes to predicting surges and outages.

Distribution Management System (DMS) power flow monitoring software that (in study-mode) can be used to run different grid operation scenarios pulling data from a centralized database that is always updated and synchronized with the network. This database has all the information needed to simulate situations such as three-phase unbalanced power flow, or perform contingency and short circuit analysis.

Visualizing Energy Resources Dynamically on Earth (VERDE) similar to Google Earth, VERDE simulation allows grid modeling with geographical information using real-time sensor data and weather information. This will enable the operator to visualize the condition of the grid at different levels, switching the view of the grid display from national to regional or even street level, all within a few seconds.

The new grid structure will also require advanced components in the following areas:

Energy storage technologies such as Hybrid Air Conditioning systems can convert electrical energy to thermal energy and store it. This is more economical than storing electricity in batteries. Such storage capabilities will be needed to grow the alternative energy sources, where unstable power flow from renewable energy plants such as wind and solar farms can be stored and better controlled. It can also supply power to the grid when it goes into island mode as explained above, or even reduce congestion of power on the grid during peak demand.

Superconductive power cables research in superconductivity could result in the wide use of superconductive power cables. Such cables will reduce line losses in the distribution system while carrying 3-5 times more power than the traditional copper-based cable, making it a more efficient system.

There are many theories about what the future Smart Grid should utilize, what it is and what it isn't, but the intent of this paper to give a simple description of the Smart Grid and its objectives, which can be shown in the FIGURE 3 from a white paper by D. Sc. Massoud Amin, a professor of Electrical and Computer Engineering at the University of Minnesota, and a well known scholar in the Power and Energy Industry.

The regulatory organization role in defining the Smart Grid and its characteristics

Independent System Operators (ISO), which are non-profit organizations formed at the recommendation of the Federal Energy Regulatory Commission (FERC), are in charge of coordinating, controlling, and monitoring the operation of the power system in areas that cover a state or region. Even though utilities work and meet regularly with their ISO's and other utility organizations in their regions, the current statutory arrangement has resulted in little regulatory action among states to engage in collective action on a national level. In addition

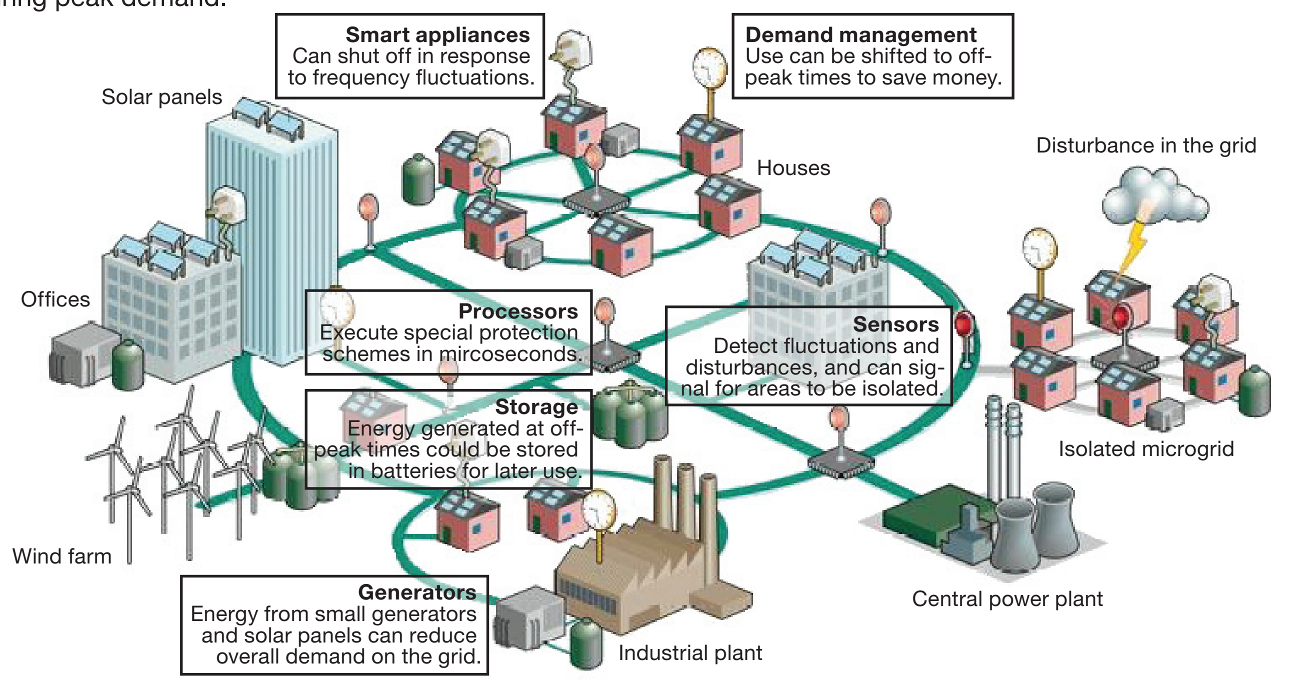

FIGURE 3 – Infrastructure integration of microgrids and diverse generation and storage resources into a system of a smart self-healing grid. Taken from, *Smart Grid: Opportunities and Challenges Toward a Smarter and Stronger Grid*, presentation delivered by D. Sc. Massoud Amin.

to that, regulated utilities have been traditionally reactive because they are well aligned for utility operation but not necessarily well positioned for strategic national initiatives like the Smart Grid.

This pushed the policy makers and legislators on both state and federal levels to step up the pressure to develop the Smart Grid, which will help expedite the renewable portfolio standards that more than 30 states have adapted. These portfolio standards require some states to generate up to 25% of their power via renewable energy sources, and in order to meet their goals, utilities in these states will need a reliable distribution system to integrate the new alternative energy sources into the grid.

As an incentive to utilities to invest in the Smart Grid, in 2009 the US federal government passed the American Recovery and Reinvestment Act (ARRA), which allocated around $4.5 billion to research and projects that demonstrate Smart Grid capabilities which meet the characteristics and objectives defined in Section 13 of the Energy Independence and Security Act (EISA) of 2007:

"… to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

1. Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
2. Dynamic optimization of grid operations and resources, with full cyber-security.
3. Deployment and integration of distributed resources and generation, including renewable resources.
4. Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.
5. Deployment of ''smart'' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.
6. Integration of ''smart'' appliances and consumer devices.
7. Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.
8. Provision to consumers of timely information and control options.
9. Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.
10. Identification and lowering of unreasonable or unnecessary barriers to adoption of Smart Grid technologies, practices, and services."

Challenges to the Smart Grid

There are regulatory as well as technical challenges. Some examples are:

- Power transmission is an inter-state transaction. With some utilities regulated and others not, this could lead to conflicts between utilities and the federal statutes that may deregulate power on a national level to maximize competition which means regional utility companies may have to divest themselves from their own generation operation.
- Studies show that power generation facilities are being built at double the rate of new transmission line infrastructure. This is putting a lot of stress on our existing power lines which will not be able to handle such congestion in the near future. Given the time it takes to obtain public approval for construction and many years required, the approval for funding for building and implementing Smart Grid technologies is time critical.
- Developing communication standards that are interoperable between appliances and equipment connected to the grid, yet secure and not vulnerable to cyber attacks, is key to achieving the objectives of the Smart Grid. The National Institute of Standards and Technology (NIST), an agency of the US Department of Energy, was charged with evaluating all the existing grid standards and identifying common communication protocols that will meet all the requirements of the Smart Grid as defined by EISA. To achieve this, NIST is working with the Electric Power Research Institute (EPRI), an independent, non-profit, organization whose methodology for developing requirements on energy systems is recognized and published by international standards organizations such as the International Electrotechnical Commission (IEC).

About the author

Wissam Balshe, Sales Application Engineering—Commercial Products, joined Cummins in 2007, as point of contact generator set sizing, codes and standards, transfer switches and general standby power systems application considerations. He graduated from the University of Minnesota in 2002 with a B.S. degree in Electrical Engineering. He then worked for three years as an Uninterruptible Power Supply System Engineer and then two years as an Aerosol Technology Application Engineer, detecting and analyzing Particulate Matter from Engine Exhaust Emissions.

Conclusion

The key players in the power industry seem to be moving closer to an agreement on what the Smart Grid characteristics and objectives are, and the work for standardizing the communications protocols to be used in the Smart Grid has started. Therefore, companies in the power industry should start planning for investment in the Smart Grid to capitalize on the opportunities created by the ARRA and EISA federal acts, and to prepare for a revolution in the power distribution technology.

For additional technical support, please contact your local Cummins Power Generation distributor. To locate your distributor, visit www.cumminspower.com.

References

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