Advancement Of The Smart Grid Starts With FREEDM

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Technology today shapes human interaction, innovation, culture, productivity—every aspect of life. But the power behind technology—the electric grid—is stuck in an archaic structure little changed since the 1930s.

It's time for a paradigm shift in energy distribution. A sustainable grid can be likened to the Internet—allowing for ubiquitous generation, storage, use and sharing of energy. The same dramatic shift that occurred when centralized mainframes were replaced with PCs, then connected through the Internet, is needed in the power industry to enable every citizen to participate in energy production, conservation and utilization.

The FREEDM Systems Center is a National Science Foundation Engineering Research Center that aims to develop the knowledge base for the FREEDM system—a new model of the Smart Grid—and provide fundamental breakthrough technology in energy storage, power semiconductor devices, and distributed controls. Researchers at the center are developing a 1-MW FREEDM Green Energy Hub system to power the ERC headquarters and other buildings on North Carolina State University's Centennial Campus.

The FREEDM Systems Center's production and study of innovative Smart Grid technologies draws renowned researchers and substantial industry attention, and the center's mission is to bridge the gap between research, education and industry to forge a successful partnership in revamping the electric grid. These relationships and collaboration will be the foundation for the emergence of new energy companies based on IT and power electronics technologies.

Developing Technologies And Leaders

Despite consumer interest in energy-saving technologies like hybrid vehicles and renewable energy resources like solar arrays, U.S. renewable energy sourcing ranks low compared to other developed countries. Compounding this problem is dependence on foreign oil, nonrenewable fossil fuels, and increasing climate change caused by CO_2 emissions.

The U.S. not only needs technology to harness renewable energy sources, but also a reliable network that stores and distributes energy in a way that accounts for the future influx of plug-in electric and hybrid vehicles and renewable energy sources like wind power. The solution lies in better utilization of long-term, secure, sustainable and environmentally friendly energy.

The Future Renewable Electric Energy Delivery and Management Systems Center, or FREEDM Systems Center, recognizes and addresses the need for a network that better manages the electric grid and accounts for the distribution of energy generated by renewables. The FREEDM System's Centers overall goal is to address the last mile of the electric grid, where electricity is delivered to the consumer. The core of the center's mission is to create an efficient and revolutionary power grid that incorporates technologies allowing bidirectional communication between grid functions and utility companies.

FREEDM is a National Science Foundation (NSF) Engineering Research Center (ERC), and receives funding both from NSF and industry partners. Research, education and industrial engagement are key components of the center's mission to not only develop key technologies in the energy sector, but also educate and equip future energy leaders.

Research Roadmap: Harnessing Renewable Energy Sources

In the FREEDM Systems Center vision, residential users will take charge of their energy needs with innovative solar panels, wind turbines, and electric/hydrogen fuel cell vehicles. Other new technologies, unforeseen today, will emerge as a result of the massive innovation fostered by the paradigm shift advocated by the center. Residential and commercial customers will sell or store excess power generated by their solar, wind, or fuel cell energy sources back to the power companies. This will reduce the demand for new gas or coal-fired power generation plants as well as decrease green-house gas emissions.

Incorporating millions of new energy-generation sources will require wide-ranging transformation of the nation's electrical grid infrastructure. The key to solving the energy crisis is not necessarily the renewable energy itself—

though renewable energy will play a crucial role—but rather the infrastructure needed to deliver and manage widespread use of distributed renewable energy resources.

FREEDM proposes a Smart Grid paradigm shift that will enable the U.S. to take advantage of improvements in renewable energy for a secure and sustainable future.

The FREEDM System is a green energy grid infrastructure that will:

- Allow plug-and-play of any energy resource or storage device, anywhere and anytime;
- Manage distributed energy resources and storage devices through distributed intelligence;
- Pioneer a scalable and secure communication backbone;
- Be capable of being totally isolated from the central grid, if necessary, continuing to operate based on 100 percent renewable energy;
- Provide perfect power quality and guaranteed system stability;
- Have improved efficiency by operating the alternating current system with a unity power factor.

Making The Smart Grid A Reality

The FREEDM Systems Center is housed in the 20,000-square-foot Keystone Science Center, which includes ERC offices, computer laboratory, library, and power electronics, energy storage, and motor drive laboratories. The center is also equipped with a Real Time Digital Simulator lab with equipment from Quanta and the 1-MW FREEDM System demonstration hub. In addition, FREEDM has received a 40-kW solar array for the roof of the Keystone Science Center as an in-kind contribution from AEG. The parking deck is equipped with ten ports for electric vehicle charging stations and currently houses two stations donated by Eaton and TE Connectivity.

The 1-MW FREEDM System demonstration lab not only demonstrates FREEDM System technologies, it is also used to showcase third-party renewable energy technologies, such as solar, wind, fuel cell, battery storage, and plug-in vehicles. The 1-MW Green Energy Hub serves as a demonstration site for the plug-and-play feature of the FREEDM System, and powers the center's headquarters and other labs with green energy. Center industry partners have access to use of this state-of-the-art facility to conduct other research experiments related to future Smart Grid, smart home, and distributed generation.

Josh Lawrence, a mechanical engineering graduate student at the FREEDM Systems Center, makes adjustments to the electric dynamometer—a key piece of equipment in his research.

In addition to the facility on NC State University's Centennial Campus, a network of cutting-edge, shared laboratories are in place at FREEDM's partner universities to support the diverse research agenda. The five domestic partner universities are NC State University, Arizona State University, Florida State University, Florida Agricultural and Mechanical University, and Missouri Science & Technology University. FREEDM also includes two international universities, which are RWTH Aachen University, Germany and ETH, Switzerland.

The Future Of Electric Vehicles: Advanced Transportation Energy Center

Part of the FREEDM Systems Center's research about the Smart Grid involves revamping electric vehicle technology. A sister organization of FREEDM is the Advanced Transportation Energy Center (ATEC), which aims to develop fundamental and enabling technologies that will facilitate the electric power industry to actively manage and control large amounts of plug-in hybrid vehicles (PHEV) and plug-in electric vehicles (PEV).

Reliance on gasoline-powered vehicles exacerbates our dependence on imported oil, while the emissions produced by these vehicles adversely affects our climate and air quality. Each year, four tons of CO_2 produced by the average automobile is released into the atmosphere where it remains for 45 years. Making cars more fuel efficient is imperative if the effects of climate change are to be mitigated.

By installing a battery and electric powertrain, electricity can be used to propel the vehicle. When not driven, the car will be plugged into the grid to charge the battery. The use of PEVs may eventually eliminate the need for the combustion engine in personal transportation. This approach will rely on significantly improved battery and electric drive system technology. In the short to middle term, a smaller combustion engine may still be needed, which results in the concept of the plug-in hybrid electric vehicle. In PHEVs, fuel efficiency can be as high as 150 mpg.

To be truly emission free, the electricity used to charge the PEV must be generated by green and renewable energy sources, such as solar, wind or biomass. Significant efforts in that area are also underway and many states now mandate 20 percent renewable energy penetration in the 2015 to 2020 timeframe through renewable portfolio standards. The large growth in PEV production and use must occur in tandem with this "greening of the grid," in order for the maximum environmental benefits to be realized.

ATEC develops battery and power electronics technologies to help the automobile industry develop better and more-efficient PHEVs and PEVs, which will help the U.S. move away from gasoline-based vehicles. ATEC educates the public about the advantages of PHEV and PEV through its outreach program in collaboration with industry sponsors.

ATEC also researches the energy storage possibilities that lie in secondary use of car batteries. It is recognized that after many years of use, vehicle batteries will begin to lose power and although the batteries can be recycled, ATEC researchers are looking into ways to extend the battery life before recycling. Secondary battery uses include stationary applications for back-up power in homes or businesses. Putting used vehicle batteries into service in stationary applications can effectively reduce the cost of the vehicle, extending the useful life of the battery resource, and providing valuable services to homeowners and business owners.

Educating Future Smart Grid Engineers

Through the FREEDM Systems Center pre-college and college education programs, the center has created a pipeline to increase awareness and knowledge about engineering. For the center to continue making strides in advancing Smart Grid technology, it must provide engaging and rewarding educational opportunities for students.

The pre-college program delivers knowledge of engineering and technological innovation into middle and high school classrooms. Students are introduced to engineering, and teachers gain the necessary knowledge and skills needed to continually engage with the students.

The college program addresses the different research and professional needs for undergraduate and graduate students. At the undergraduate level, students are able to engage in research activities during academic and summer terms by working closely with a faculty and a graduate mentor to explore new directions in green energy infrastructure.

Center-wide, there are many opportunities for graduate education in the fields of renewable energy systems, power electronics, distributed control, power systems, power semiconductor devices and power management ICs. Graduate students not only engage in research, but they are also involved in other center activities such as attending technology, industry and education seminars; having mentorship experiences with industry and serving as mentors to pre-college program participants; and participating in domestic and international exchanges with our partnering universities. The outcome will be a more creative, innovative, and global engineer.

NC State has also implemented a unique graduate program for workforce training in electronic power systems engineering. The Masters of Science in Electric Power Systems Engineering (M.S.-EPSE) provides students with a thorough understanding of the tools, methods and practice of electric power engineering. The M.S.-EPSE is an accelerated 10-month program addressing a critical need for careers and leadership in electric power utilities, smart grid technologies, renewable energy, hardware and software, suppliers, telecommunications and standards organizations.

Conclusion

The FREEDM Systems Center's research and development of innovative Smart Grid technologies draws renowned researchers and substantial industry involvement, and the center's mission is to bridge the gap between research, education and industry to forge a successful partnership for revamping the electric grid. These relationships and collaboration are the foundation for the emergence of new energy companies based on IT and power electronics technologies.

The establishment of the Smart Grid is more of a journey than a destination. A successful, upgraded power grid will only evolve through strong partnerships between research organizations and industry. This will not be an overnight process, but is vital for the establishment of a sustainable energy future for our country.

About The Author

Kelsey Kusterer is the communications and outreach specialist at the FREEDM Systems Center, a smart grid research center located on North Carolina State University's Centennial Campus. Prior to this position, Kelsey worked for Connect2 Communications, a public relations firm, and wrote for VYPE Magazine, a local sports magazine. She has a wide variety of interests, namely community journalism and sustainable business practices. Kelsey graduated from the University of North Carolina at Chapel Hill with a B.A. in Journalism and Mass Communication with a second major in Spanish.