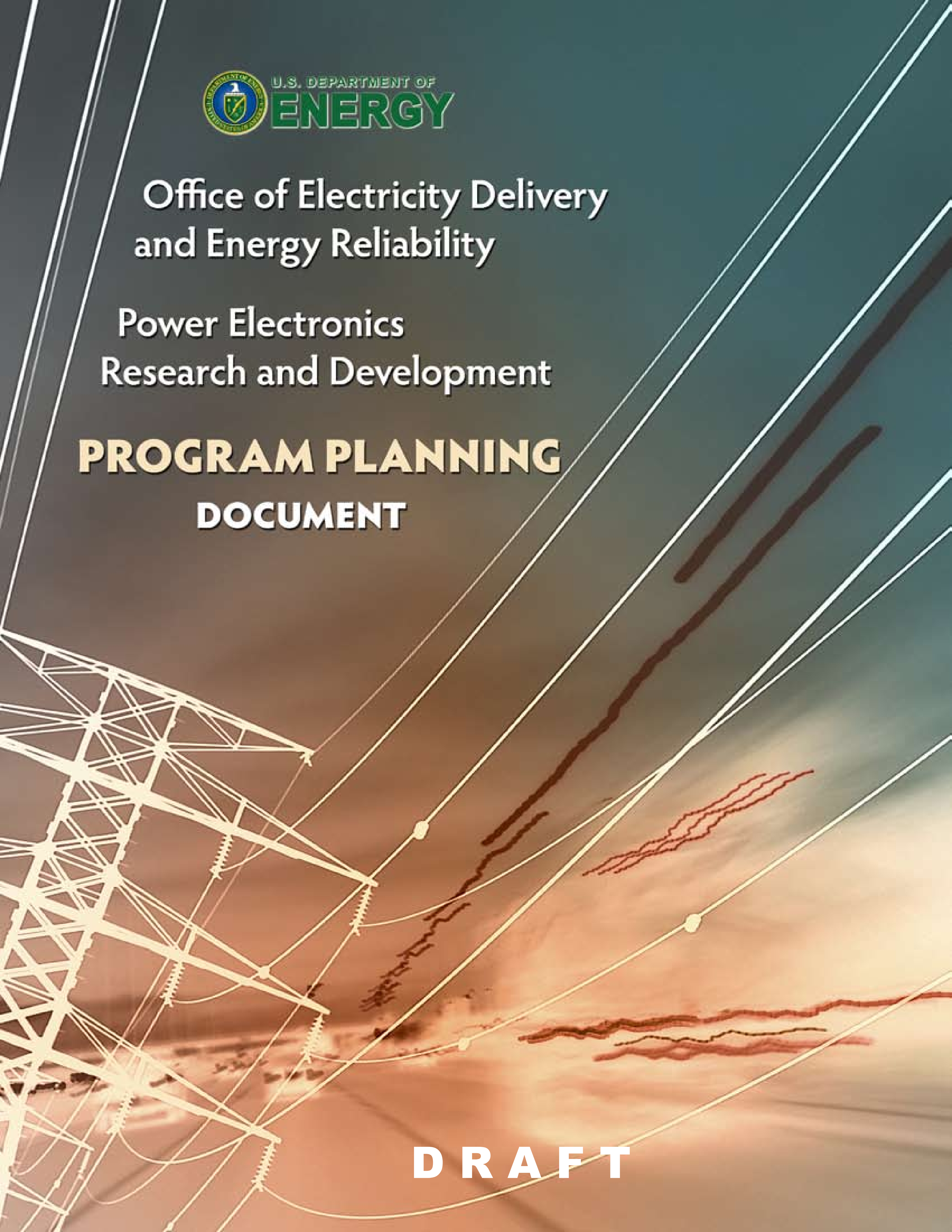

U.S. DEPARTMENT OF ENERGY

Office of Electricity Delivery and Energy Reliability

Power Electronics Research and Development

PROGRAM PLANNING DOCUMENT

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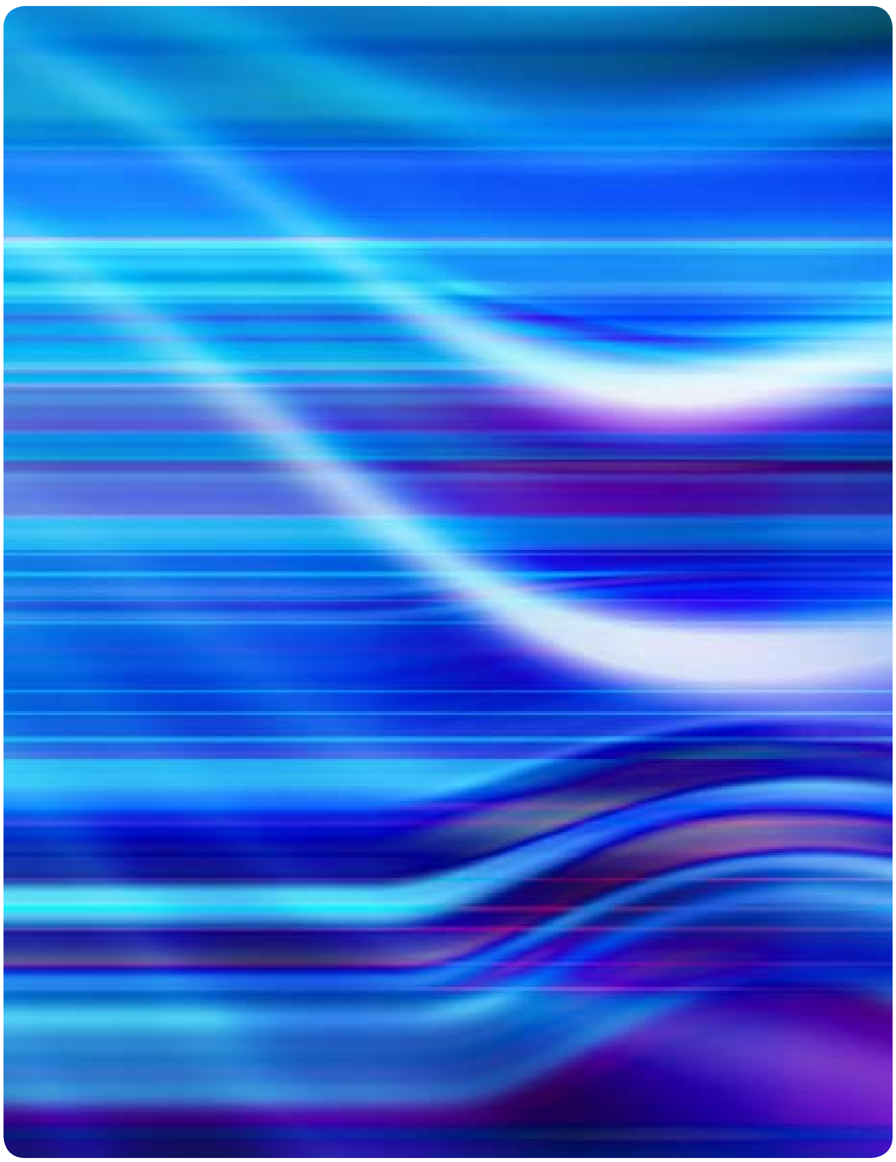
Contents

1 Introduction



The electric grid is a complex system that has been built over the last century as demand for power has grown and now has more than 180,000 miles of transmission lines, 14,000 transmission substations, and more than 100 million distributed loads. There are over 3,000 electric utilities involved with the generation, transmission, and distribution of electricity. This system is the backbone of the nation's economy, and it is imperative that the electric delivery system is modernized to meet the nation's energy future.

THE NEED FOR MODERNIZATION

The electric infrastructure is aging as investment in new lines lags because of economic and regulatory uncertainties associated with electricity transmission. This has led to increasing congestion, more vulnerability to cascading failures, and less reliable electric service. In addition, the grid was not designed to accommodate a diverse generation mix that includes a significant renewable energy supply or to withstand intentional attacks to disable the grid.

Historically, utilities have met demand growth by placing more steel in the ground. The conventional solution of adding additional transmission lines will be needed to meet future growth. However, this alone will not adequately address the future grid.

FUTURE TRENDS

The U.S. society is becoming increasingly dependent on a secure, reliable source of electricity as the digital economy grows and more applications rely on electricity. These advances are leading to a convergence of communications systems with the electric grid that will allow customers more interaction with making energy and electricity consumption decisions. Future electric utility systems are envisioned as being highly automated, interactive "smart" grids that can self-adjust to meet the demand for electricity reliably, securely, and economically. Transforming the electric grid to meet the increased demands and complexities it will face requires power flow control and energy storage. Power electronics is a key enabling technology to revolutionize the electric grid. Improvements in both power electronics systems and the devices on which the systems are based will be key components in the development of smart grids.

Power electronics will be a key technology to helping the nation achieve its four national energy policy goals:

1. Diversify the U.S. energy mix and reduce dependence on foreign petroleum.
2. Reduce greenhouse emissions and other environmental impacts.
3. Create a more flexible, more reliable, and higher-capacity U.S. energy infrastructure.
4. Improve U.S. energy productivity and efficiency.

Presently, 30% of all electric power generated uses power electronics somewhere between the point of generation and end use. By 2030, 80% of all electric power will flow through power electronics.

The grid of the future will have additional renewable generation. Many states have programs or requirements stipulating that up to 20% of the electricity provided will be generated by renewable energy sources within 10–20 years. Power electronics is also a key technology for interconnecting renewable generation (e.g., solar panels, fuel cells, wind turbines) to the grid, because these sources generate power at voltages and frequencies that do not match those of the electric grid. Moreover, distributed generation equipped with power electronics can provide several ancillary services to the power grid—for example, reactive power compensation and voltage and frequency regulation—and in general improve the power quality and reliability of the electric grid.

POWER ELECTRONICS WILL ENABLE THE FUTURE GRID

The electric grid is a unique system in that electricity can not be controlled (it takes the path of least resistance) or stored (constant balancing of generation and demand. To revolutionize the grid, power flow control and energy storage needs to be achieved – however, there are many barriers to realizing this vision.

Advances in power electronics devices and modules, including materials development, high temperature packaging, and control systems are needed to increase their reliability and efficiency while at the same time decreasing their installation and operating costs.

2 Power Electronics Program

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The Department of Energy is investing in wide area visualization tools, such as phasor measurement systems, that provide utilities an improved understanding of the state of the electricity system. However, they only provide an awareness and not an ability to automatically respond if needed. Power electronics will allow utilities to respond, control power flows, and improve reliability.

Vision

The vision of the Department of Energy (DOE) Office of Electricity's Power Electronics Research and Development Program is to enable highly integrated, cost-competitive, reliable power electronic systems to increase the performance, security, and flexibility of the electric utility system. This goal will be accomplished by using advanced power semiconductor devices, thermal management and packaging modules, system topologies, and control algorithms.

Program Goals

This program will focus on completing the development of silicon-based and post-silicon-based semiconductor devices and integrating them into systems to address problems applicable to the electric grid. The DOE OE Power Electronics Program will develop low-cost, high-performance, highly reliable, small-footprint PCSs with high efficiency. DOE will conduct research at several levels: basic science and materials, device development, prototype development, and system demonstration. Research will be conducted through DOE national laboratories, universities, utilities, and industry. As concepts evolve from basic ideas to demonstration systems, the involvement of industry will increase, resulting in systems that are ready for commercialization.

Overview—Power Electronics

Power electronics utilize semiconductor switching devices to control electrical power flow and convert it from one form to another to meet specific needs. The conversion process requires some essential hardware: a control system, semiconductor switches, packaging, thermal management systems, passive components (such as capacitors, inductors, and transformers), protection devices, dc and ac disconnects, and enclosures. This hardware is referred to collectively as a power conversion system (PCS). In the electric grid, power electronics have two main uses: (1) power flow control and (2) interface with electric generation and storage.

Power electronics can be found in many forms as parts of or interacting with the electric power system for power flow control or as interfaces with generation and/or storage equipment:

Power Flow Control

- High voltage direct current converter stations
- Flexible alternate current transmission system devices
- Static var compensators for reactive power control
- Fault current limiting devices
- Solid-state distribution transformer
- Transfer switches and solid-state circuit breakers
- Active filters

Grid Interface

- Plug-in hybrid electric vehicles
- Renewable and distributed energy resources
- Energy storage devices

Benefits of Power Electronics

Power electronics provide utilities the ability to more effectively deliver power to their customers while providing increased reliability to the bulk power system. These systems can play a pivotal role in improving the reliability, security, and flexibility of the nation's electric grid.

Need for Power Electronics R&D Program

Tremendous advances have been made in power electronics technologies in the last decade, providing new approaches to energy generation and use. However, even as better devices, packaging, and manufacturing processes come along, the potential benefits of power electronics systems have not been attained for reliability, performance, and cost. For example, the power conversion system (PCS) hardware costs in many systems range from 25 to 50% of the total costs. Because of perceived limited markets for PCS applications, manufacturers have been reluctant to expand or scale up the production facilities and invest in improving hardware reliability. If a significant reduction of hardware component costs, improved reliability, multi-use PCS topology, and higher quality components could be achieved via government-led research and development (R&D) or incentive programs, the cycle might be broken; and the benefits of power electronics could be fully realized.

Power electronics plays an increasingly important role in the utilization of electric power. Consequently, the requirements are also continuously being raised. Some of the important issues associated with power electronics are as follows

- **Costs.** Costs of power electronics dominate the total cost of a system. Reducing device costs should be a major priority. This requires higher power and faster switching devices. At the same time, it is necessary to improve the standardization and modularity of devices in order to reduce the costs of equipment and maintenance.
- **Reliability.** The reliability of both active and passive components is an important issue, especially for operations that involve the T&D network.
- Component Packaging and Thermal Management. As requirements for applications become more stringent, high-power, high-temperature, and high-speed devices are desirable.
- Cooling methods. Advanced cooling methods need to be considered in order to reduce the footprint of power electronics systems.
- Efficiency. Efficiency needs to be as high as possible in order to save energy, reduce cooling requirements, and improve device performance.
- Control. Advanced hardware and control strategies are needed to take full advantage of power electronics.

Benefits of power electronics

- Increased system reliability and security
- Increased transmission and distribution efficiency
- Increased loading and more effective use of transmission corridors
- Added power flow control
- Improved voltage and frequency regulation
- Improved power system transient and dynamic stability
- Added flexibility in siting new generation facilities
- Elimination or deferral of the need for new transmission lines

The DOE OE Power Electronics Program will develop low-cost, high-performance, highly reliable, small-footprint power conversion systems with high efficiency.

3 Advanced Power Electronics For Utility Applications

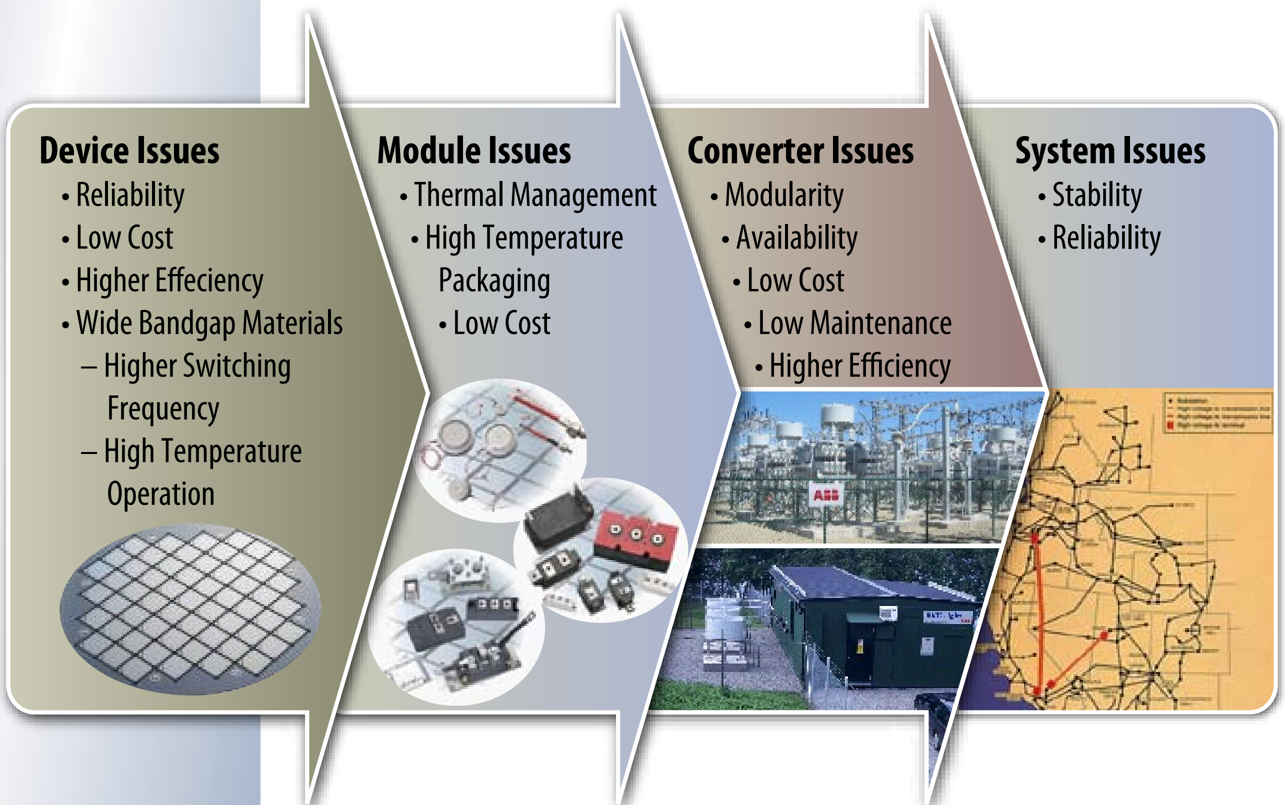
Power electronics can be found across many industrial sectors including military, transportation and consumer products applications. Within the electric grid infrastructure, power electronics can be viewed as devices, modules and converters that will be deployed within the system to provide either power flow control or as an interface of electrical components (distributed generation systems) to the grid.

Power electronics devices are viewed as semiconductor switches, which are the fundamental building block for a variety of applications. These devices can be assembled into modules, which have packaging requirements to manage heat generated in high voltage and high current applications.

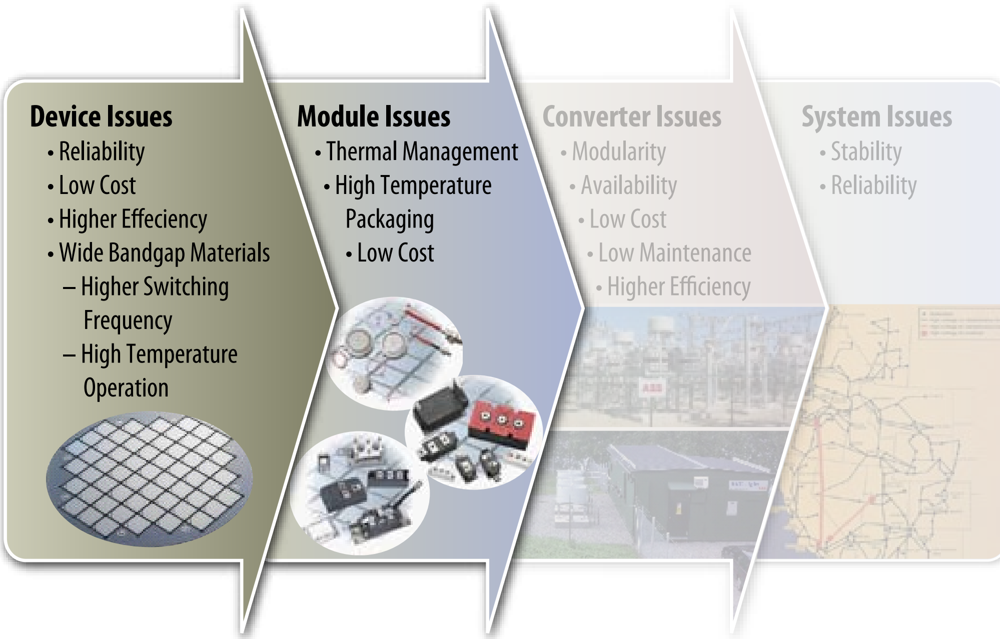
Modules can be assembled into converters, such as inverters and rectifiers, having more intelligence built into the system for applications with grid interface. Additional components can be integrated for power flow control at the system level. Each of these areas have technical challenges that need to be addressed before widespread deployment of distributed generation and solid-state devices will occur.

Four research areas are needed in power electronics for utility applications.

Utility-Scale Power Electronics Needs



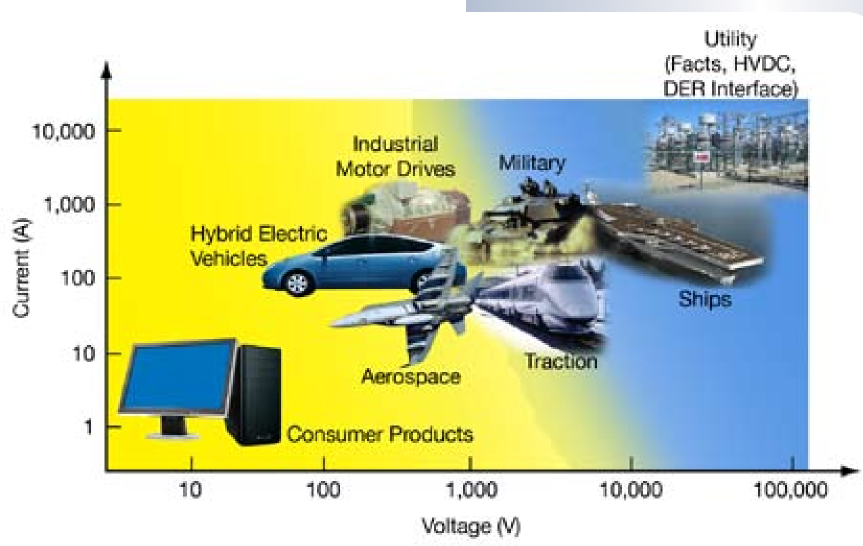
POWER ELECTRONIC DEVICES & MODULES



The power electronics revolution began in 1948 with the development of the silicon transistor out of Bell Telephone Laboratories, followed in 1957 with the invention of the thyristor by General Electric. Today, traditional devices include thyristors, transistors and diodes. These devices can be operated as a simple switch with limited intelligent controls. However, to utilize these systems for electric utility applications, further advancements are required.

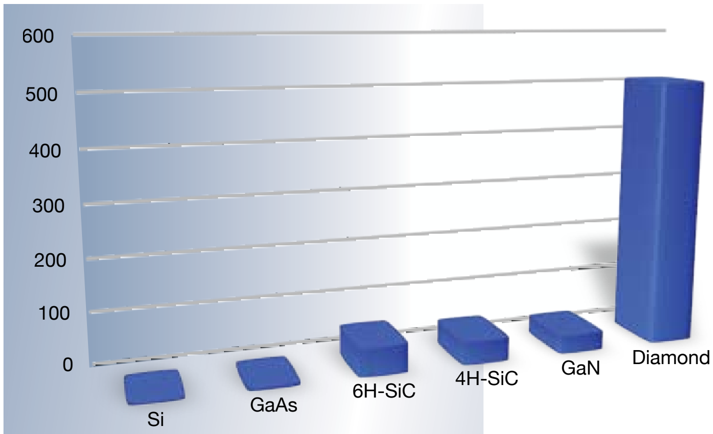
Wide Bandgap Semiconductors

The fundamental building block of power electronic devices is the power semiconductor. Silicon is by far the most widely used semiconductor material. Indeed, for over five decades, silicon-based semiconductors have been the power device of choice for most, if not all, high-power applications. In particular, silicon-based insulated-gate bipolar transistors (IGBTs) and gate turn-off thyristors (GTOs) have been the dominant semiconductor switches for high-power applications, and technology improvements over the last several decades have resulted in consistently higher power levels for these devices.

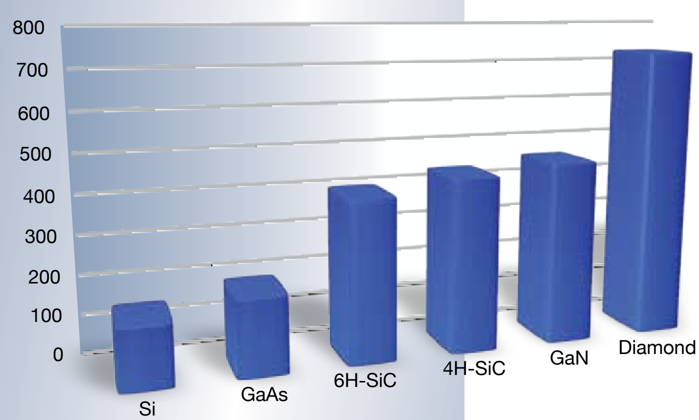


Limitations of Today's Devices

Silicon-based semiconductors have inherent limitations that reduce their suitability for use in utility-scale applications. These limitations include a low voltage blocking ca-



Maximum breakdown voltage for different power devices at the same doping density normalized to silicon.



Maximum operational temperature (in °C) for different semiconductor materials.

pability (10 kV), low switching speeds at high power (2 kHz), and a limited junction operating temperature (150°C). Switch-mode power supplies (e.g., pulse-width-modulation–based converters), which feature greater control capability and provide better conversion efficiency, have been developed in the last two decades and have changed the way power is converted in many high-power applications. However, utility-scale applications would directly benefit from the development of semiconductor switches with higher voltage blocking capability (greater than 20 kV) and a higher junction temperature capability (greater than 150°C).

Future In Wide Bandgap Materials

Recently, new, wide bandgap (WBG) materials such as silicon carbide (SiC) have become attractive alternatives to silicon for semiconductor switches. These materials offer the potential for higher switching speeds, higher blocking voltage, lower switching losses, better thermal conductivity, and higher junction temperature than traditional silicon-based switches. Systems based on SiC devices show substantial improvements in efficiency, reliability, size, and weight even in harsh environments. Therefore, they are especially attractive for high-voltage, high-temperature, high-efficiency, or high-radiation uses, such as military, aerospace, and energy utility applications.

Power electronics applications for power systems, such as static transfer switches, dynamic voltage restorers, static var compensators (SVCs), high-voltage direct current (HVDC) transmission, and flexible alternate current transmission systems (FACTS) have become more economically feasible. Some of these applications require voltage-blocking capabilities in the tens and hundreds of kV. SiC devices can be an alternative for high-voltage applications. While the voltage rating of SiC power devices is much higher than that of silicon, the current rating of SiC devices is much less than that of silicon devices because the SiC wafer technology is far from mature. Higher voltages and higher operating temperatures pose numerous development challenges that must be resolved before commercial systems can be built.

Basic research is also being conducted in diamond- and gallium-nitride–based switches. These devices, although further away from commercialization than SiC-based devices, offer similar advantages to SiC-based devices in terms of improved voltage standoff capability, increased operational flexibility, and higher current density capability than traditional silicon-based devices.

Research needs

Presently, most wide bandgap semiconductor research is focused on reducing defects and improving the quality of the material. For utility power electronics, the following types of research on WBG power devices are needed:

- WBG wafer development.
- High-voltage WBG devices.
- Packaging of WBG devices: New power device packages need to be developed

that can handle WBG devices running at 250°C or above.

- One major problem associated with building WBG IGBTs is the SiO_2 interface. This interface still poses structural problems as well as high temperature operation problems.
- SiC GTOs: Higher voltage and current can also be achieved by controllable thyristor technology such as GTOs. Research is needed in material defection for these devices to be feasible.
- System-level impact in terms of cooling, converter design, system efficiency.

Packaging and Thermal Management of Power Electronics

After power devices are built in silicon or SiC, they must be packaged so that they can be used in power converters. When these power converters are operated, the heat generated because of the losses in the switches must be dissipated using a thermal management system. The reliability of power electronics is directly related to whether the devices can be kept well within their safe operating levels; and the cooler that a device can be kept, the less likely it is to fail. Therefore, packaging and thermal management are two important supporting aspects of power electronics.

Reliability of packaging at high temperatures and thermal cycling from low to high temperatures and back are two important issues for power electronics. This reliability is more of an issue for packaging SiC-based power devices that can run at much higher junction temperatures of up to 500°C, compared with the 150°C junction temperature limit of Si power devices. The availability of more reliable cooling systems for much higher power dissipation requires novel cooling technologies.

Typical packages used for devices consist of multiple elements. In designing a package for power electronic devices for operation at up to 500°C in harsh environmental conditions, several factors must be considered:

1. Materials used must be stable at the higher temperatures and be able to maintain their properties during prolonged exposure to these temperatures and harsh environments
2. Mitigation of thermal stresses caused by thermal expansion mismatches between the devices and various package elements, including the substrate
3. Thermal shock resistance needed to withstand thermal cycling during service
4. Heat dissipation to keep the temperatures at safe operating levels

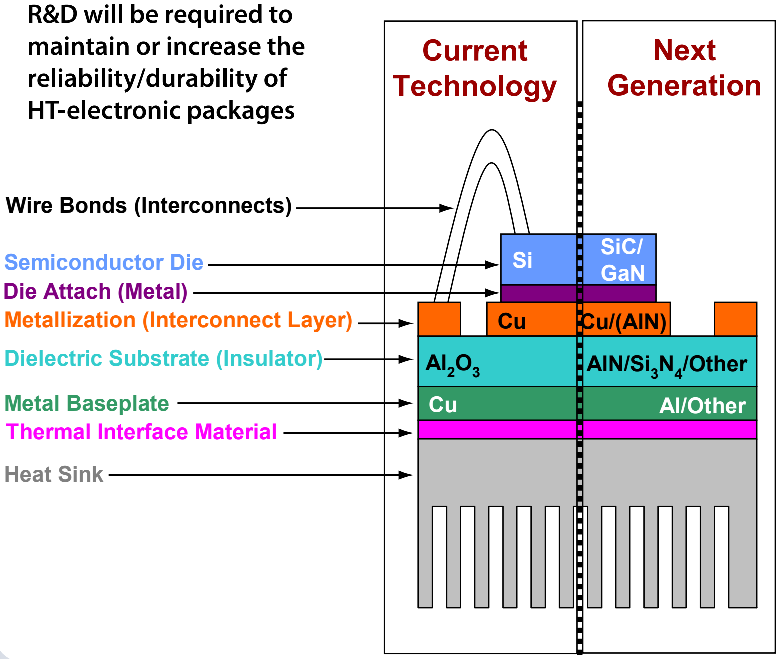
Research needs for packaging

The following areas have been identified as critical to the further development of packaging technologies for wide bandgap devices for use at high temperatures:

1. Identification and/or development of alternate materials for use in existing packaging concepts
2. New concepts for high-temperature package designs
3. Design and development of alternative processes/process parameters for packaging and assembly
4. Methodologies for high-temperature electrical properties testing and reliability testing

The major source of heat affecting power electronics is the heat generated by the power semiconductors. An appropriate thermal management system (cooling system) is needed to dissipate the heat generated by power converters and keep the junction temperatures of power devices well below the limits.

R&D will be required to maintain or increase the reliability/durability of HT-electronic packages



Component Design & Life Prediction
Existing methodology can be adapted to predict and optimize system performance and service life.

Wire Bonds
Major cause of failure – novel designs with better cooling needed.

Temperature Capability
Epoxys and low-temperature solders need to be replaced by more stable solders. Active and passive cooling strategies.

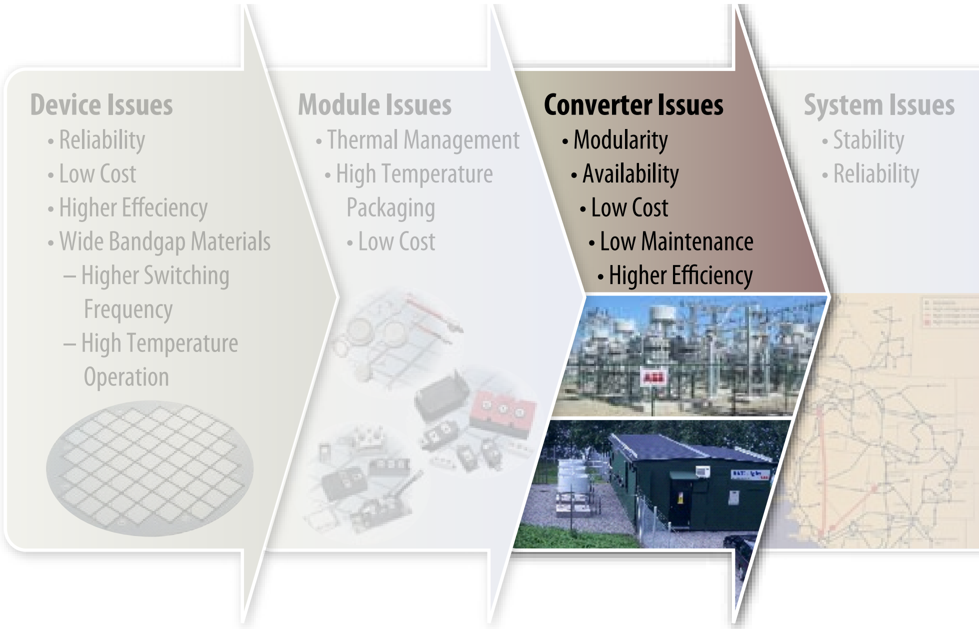
Coefficient of Thermal Expansion (CTE)
The CTE mismatch between the ceramic layers (diode & dielectric) and the copper layers cause stresses that lead to failure. New materials need to be developed with more similar expansions.

Research needs for thermal management

The technical challenges for the R&D in thermal management systems for power electronics include the following:

1. Definition of the thermal regime for high-voltage and high-current power electronics applications.
2. Development of new cooling technologies for utility applications. These would include cooling technologies for dissipating power on the order of 1 MW.
3. Research on newer fluids that can transport much more heat is required for cooling for utility-scale high-power applications.
4. Improvement of the efficiency of power devices and passive components to reduce the cooling system.
5. Nondestructive diagnostics or process monitoring equipment/sensors to ensure appropriate reliability for utility applications.

ADVANCED MODULAR CONVERTERS



There are many different power converter circuits that can be used for various transmission and distribution (T&D) applications. The present applications do not take advantage of the potential for using common modules for each of these applications. The development of a utility voltage power electronics module could enable a wide variety of applications including use of transmission lines to their full capacity, HVDC transmission, FACTS, static VAR compensation, solid-state transformers, traction drives, rectifiers, and inverter applications, as well as aggregation of multiple energy storage and renewable energy sources. Modules developed for utility applications will be required to be highly reliable by virtue of being durable and flexible. Modules should have fault-current-limiting features and detection circuits that enable them to limit current through the module resulting from external faults and identify and isolate internal faults so the remaining modules can continue to operate with only minimal disturbance to the utility or customer.

Interface for Plug-In Hybrid Electric Vehicles and Energy Storage

Plug-in hybrid electric vehicles(PHEVs) are expected to have a significant impact on the U.S. transportation system by reducing the use of oil. However, these vehicles will require significant amounts of electricity from the grid and so studies are needed on how PHEVs will ffect the grid as their numbers increase. PHEVs could also provide grid support by providing reactive power to the grid even while charging.

An efficient, inexpensive means of storing electricity would help to revolutionize the electric grid since lack of storage at the present time implies that loads and system losses must be balanced in real time with generation. Power electronics will be a key component for energy storage as it will be required to act as an interface and regulate the charge and discharge of the energy storage whether it is advanced batteries, electrochemical capacitors, flywheels, or superconducting magnetic energy storage (SMES) systems. In addition to providing real power to meet short term demand, these interfaces will also enable the energy storage installation to provide ancillary services as outlined in the following renewable energy interface section.

Ancillary services that can be provided by power electronics connected to energy storage and/or renewable generation:

1. Voltage control and reactive power compensation
2. Frequency regulation
3. Load following
4. Spinning reserve
5. Non-spinning reserve
6. Harmonic compensation
7. Network stability
8. Seamless transfer from grid-connect to stand-alone

Renewable Energy Interface

A number of technical challenges exist for power electronics modules used as a renewable energy interface. First, additional energy storage capacity such as electrochemical capacitors or advanced batteries is needed to assist the power electronics system. Second, a significant unknown is the interaction of multiple renewable energy systems connected to the power grid. If not designed properly, they may have the tendency to "fight" one another rather than work in a coordinated fashion. Third, as the total installed capacity of renewable systems increases (to 10% or more), the impact on the protection coordination of distribution systems becomes a concern. The existing distribution system is not designed to accommodate multiple renewable energy sources because of the relatively high impedance, the tailored protection coordination, and utility circuit breakers that are near their fault current limits. However, using power electronics as the interface can compensate for these disadvantages, since power electronics can provide fast switching to prevent fault current contribution and to respond to abnormal events.

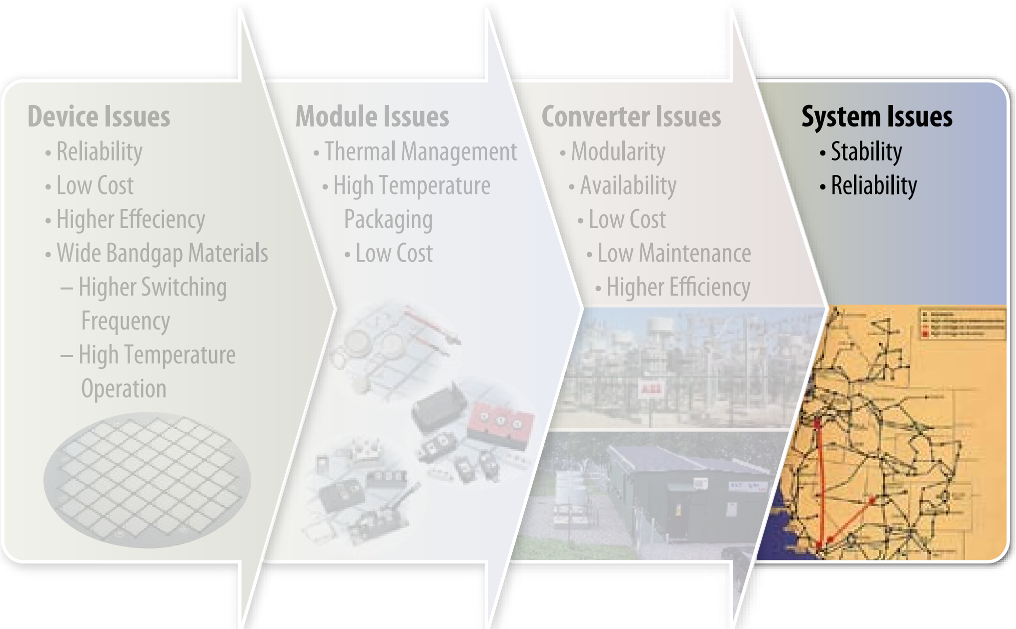
The cost of power electronics is a significant portion of a renewable energy system, up to one-third of the total installed cost. Most of these systems are too expensive to achieve a short-term payback. Markets for ancillary services and more inexpensive packaging for power electronic systems must be developed to reduce system costs.

Research needs

To more effectively utilize power electronics in renewable energy systems and increase their value streams, the power electronics research program will

1. Develop new materials and packaging to decrease the cost of power electronics for renewable energy systems.
2. Develop software tools that can analyze the dynamic capabilities of power electronics interfaces for renewable energy systems and/or energy storage.
3. Standardize controls and communication interfaces for power electronics for renewable energy systems.
4. Develop new distribution circuit designs that offer none of the limitations of current radial systems and take greater advantage of the power electronics interface.
5. Develop advanced control algorithms for power electronics systems to take full advantage of the compensation capabilities of converter systems, such as reactive power injection.
6. Evaluate the capability of power electronics interfaces to provide ancillary services and the likelihood of a market for those services.
7. Test single and multiple power electronics–based systems on distribution networks to identify the performance characteristics and limitations of existing technology.
8. Identify guidelines for the interconnection and operation of single and multiple renewable energy systems with power electronics.
9. Develop analysis tools that can help optimize the placement of energy storage and reactive power compensation in a system so that they have the greatest positive impact on the distribution network.

ADVANCED CONTROL SYSTEMS



Growth in electricity demand and new generation, lack of investment in new transmission facilities, and the incomplete transition to fully efficient and competitive wholesale markets have allowed transmission bottlenecks to emerge, which result in several operating limits being reached, and creating serious reliability concerns. Traditional solutions to upgrade the electrical transmission system infrastructure have been primarily in the form of new transmission lines, substations, and associated equipment. However, this process is extremely difficult, expensive, and time-consuming. Power flow control technologies, such as High Voltage DC converter stations, Flexible Alternating Current Transmission Systems (FACTS) controllers, fault current limiting devices and solid state transformers provide advanced solutions as alternatives to new transmission line construction.

In bulk power transmission systems, advanced power-electronics-based systems have been used to improve the stability of the electric utility system at both transmission and distribution voltage levels. These systems can provide a high degree of power control in a small footprint, and, in some cases, higher system efficiency and lower maintenance than traditional electromagnetic and electromechanical control methods. As the existing, vertically integrated electric utility structure gives way to a system that incorporates much more (and much smaller scale) distributed generation, centralized (i.e., large-scale electromechanical) control of the bulk power system will no longer be effective.

A FACTS uses a power electronic–based device for the control of voltages and/or currents in ac transmission systems to enhance controllability and increase power transfer capability. It is an engineered system of advanced power semiconductor-based converters, information and control technologies (software), and interconnecting conventional equipment that builds intelligence into the grid by providing enhanced-power system performance, optimization, and control. Compared with the construction of new transmission lines, FACTS require minimal infrastructure investment.

HVDC technology is used to transmit electricity over long distances by overhead transmission lines or submarine cables. It is also used to interconnect separate power systems where traditional ac cannot be used. The major benefit of an HVDC link is its ability to control the power flow and its flexibility to adapt to different ac system characteristics at both sides of the interconnection. As power electronics become more reliable and inexpensive, it is expected more HVDC lines will be constructed by utilities to allow greater control over power flow and enable transmission of electricity from remote wind farms to major cities and industrial load centers.

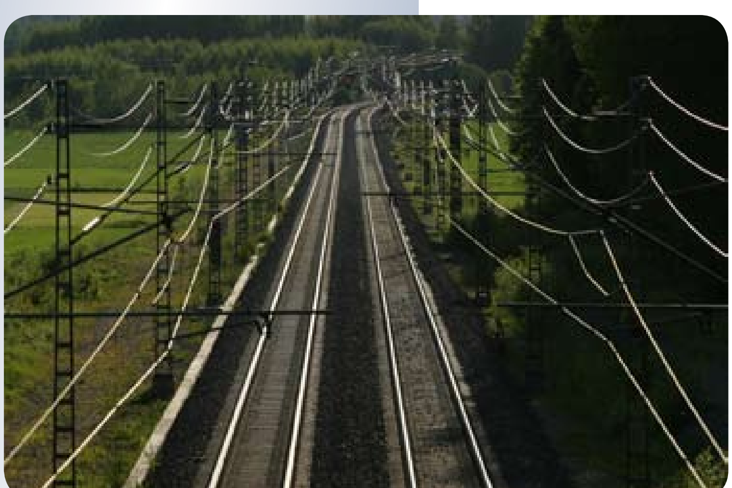
Research needs

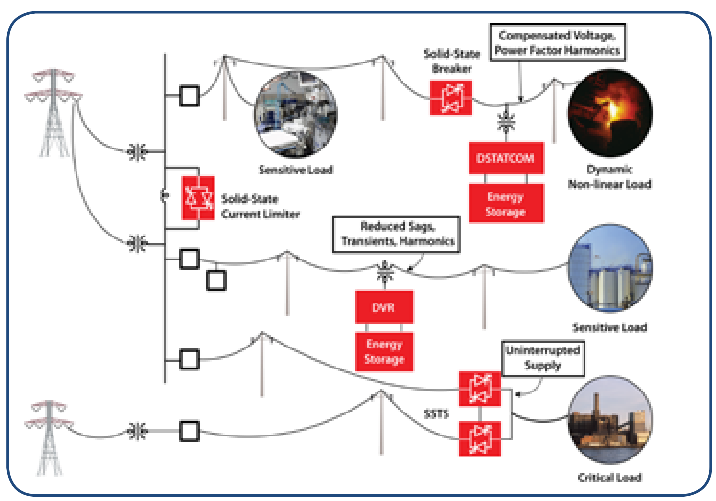
In order for advanced technologies to become widely deployed, utilities need to be assured that these systems are reliable and cost-effective. There is a need to safely demonstrate advanced technologies that can alleviate constraints on the grid. Premature failure of any technology in a critical location, can exacerbate an event on the grid. Thus, utilities cannot afford to take the risk of technology failures in critical areas.

A power electronics test-bed is needed to provide a full spectrum of events and demonstrate reliable operation to accelerate adoption of power flow control and energy storage technologies into the market place.

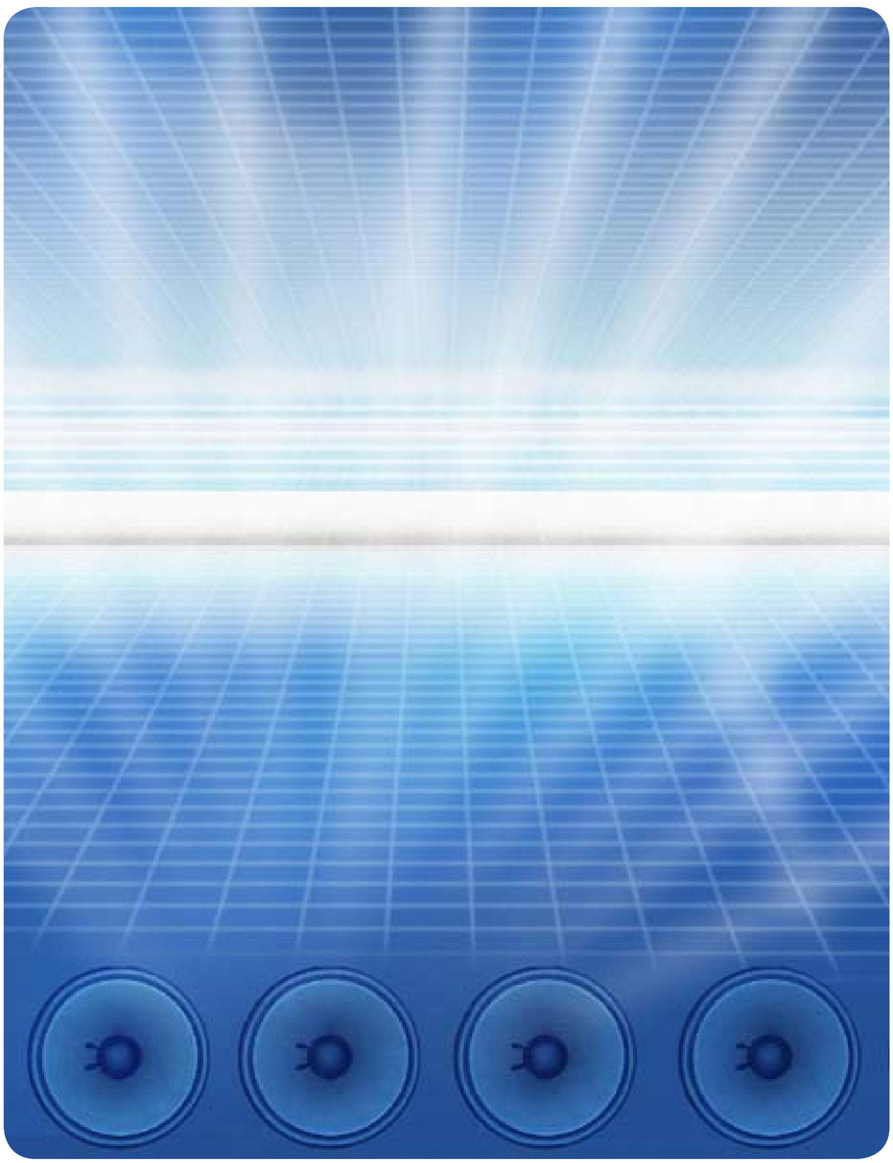
Additionally, electricity providers need to find a means of local control to address problems such as uneven power flow through the system (or loop flows); transient and dynamic instabilities; subsynchronous oscillations; and dynamic overvoltages and undervoltages. Several advanced power electronics controller topologies have already been proposed to mitigate such problems, but transmission service providers have been reluctant to use them, usually due to cost and a lack of systematic control of both the system itself and its interaction with other parts of the power system.

To achieve higher levels of operational control and integration with existing power networks, researchers are currently investigating the ability of advanced control systems to receive and respond to signals remotely. Although such advanced integration between utility infrastructure and existing computer networks would require both advanced control algorithms and extensive security measures, the additional flexibility would make T&D networks using such methods much more resilient to natural disasters and intentional attacks.





4 Timeframe and Metrics



Both the technical objectives and the metrics are outlined below.

The program plan is designated to start in 2009.

Key Activities	Technical Objective	Metrics
Semiconductor Switch	Develop a highly integrated 20 kV, 100-A, 20 kHz semiconductor switch	Prototype 10-kV, 20-A SiC switch by 2010 Prototype 10-kV, 50-A SiC switch by 2011 Prototype 15-kV, 50-A SiC switch by 2012 Prototype 20-kV, 100-A SiC switch by 2013
Fundamental Materials for Packaging and Thermal Management	Develop more efficient packaging and thermal management techniques for post-silicon semiconductor die to enhance reliability and reduce cost	Report on fundamental research areas in advanced semiconductor materials, packaging, and thermal management in 2009 Thermally optimized semiconductor package for 200°C in 2010 Advanced thermal management system for 200°C in 2011 Fully optimized packaging and thermal management system in 2013
Advanced Converter Demonstration	Develop low-cost, high-performance, highly reliable, modular, small-foot-PCSs with high efficiency	Report benchmarking current system designs in 2009 PCS with 2× increase in system efficiency in 2010 PCS with 2× increase in voltage rating in 2011 Prototype PCS operating at 200°C in 2012 Demonstrate PCS with 50% reduction in cost, 5× increase in power density, 5× increase in reliability
Systems Impact Study	Develop systems level simulations to determine impact for various advanced converter demonstrations	

Timeline

2009	2010	2011	2012	2013	2014

5 Partnership Strategies

Building and maintaining effective public–private partnerships is one of the key strategies for achieving the aims of this Power Electronics program and the mission, vision, and goals of the DOE Office of Electricity. The electric power industry is the primary stakeholder, and Power Electronics program activities are focused on addressing the present and future needs of that industry. Primary partners include electric utilities and manufacturers of power electronics for utility applications, including interfaces with energy storage and renewable energy systems. Secondary partners include electricity consumers, project developers, and state and regional agencies.

Because the primary focus of this Power Electronics program is improving the reliability and security of the electric grid, electric utilities are the primary partners in shaping the directions and priorities of the research activities. These include investor-owned utilities, public utilities; electric cooperatives; and federal utilities such as the Tennessee Valley Authority, Bonneville Power Administration, and Western Area Power Administration.

The involvement of utilities and other industry will ensure that technologies developed by this program are relevant and applied to the grid of the future.

Another key stakeholder is the electric power and materials research community. The Power Electronics program will leverage federal resources and partners with co-sponsors on technical research initiatives led by the nation's most technically capable organizations and individuals, thus achieving the best returns on taxpayer investments. Primary research partners include the following:

- National laboratories
- Universities
- Industry research organizations
- State energy research and development agencies
- Sponsoring agencies such as the Department of Homeland Security, Department of Commerce, and Department of Defense

The public–private partnerships for this Power Electronics program will take several forms. Technical exchange partnerships are critical and will be achieved through periodic conferences, workshops, informal meetings, and joint R&D planning sessions. This program will hold annual peer review meetings, maintain a Web site, and hold technical workshops and Webcasts to foster information sharing and technology transfer. All stakeholders and interested parties will be invited to participate in the Power Electronics Program Technical Exchange Partnerships.

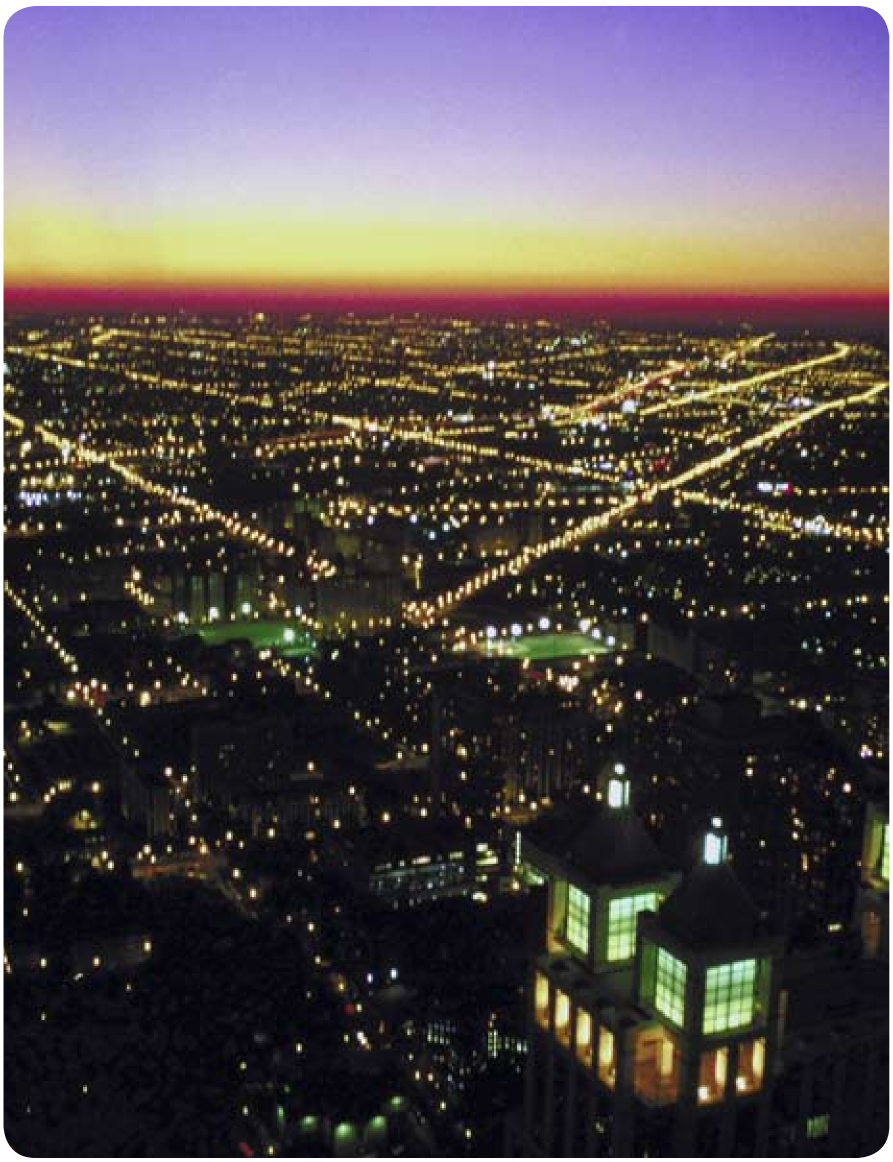
Cost-shared R&D projects are another critical form of partnership with the Power Electronics Program. To raise funds for such projects, DOE OE is interested in building partnerships with other sponsoring organizations, both public and private, to leverage resources that can be focused on accomplishing tasks of mutual interest.

DOE OE will use competitive solicitations to engage the nation's top R&D performers in projects to design, fabricate, laboratory test, field test, and demonstrate new technologies, tools, and techniques. The cost-sharing requirements for these types of cooperative agreements are specified in the Energy Policy Act of 1992.

Another mechanism for engaging researchers will be Small Business Innovative Research (SBIR) grants, which can be used by federal agencies to nurture innovative concepts from small businesses.

The national laboratories will play a key role in the Power Electronics Program activities. Targeted capabilities at the national laboratories will be applied to program management and implementation, as well as to research needs that require specific scientific and engineering talent.

6 Managing for Results



The President's Management Agenda and the Government Performance and Results Act contain principles for ensuring programmatic success through results-oriented procedures and practices. This plan outlines the activities and milestones that will be used in fulfilling the management guidelines and requirements of the Office of Management and Budget and the Chief Financial Officer of DOE.

One of the top management priorities is to develop an appropriate multi-year plan and use the metrics presented in this plan for measuring progress and cost-effectiveness.

These metrics will measure the effectiveness of developing new power electronics technologies that ultimately will help to improve the reliability of the electric system and more cost effectively enable renewable energy sources to provide a larger share of the nation's electricity. Metrics will be established to show how the power electronics technologies help accomplish the following objectives:

- Increase the delivery capacity of T&D lines to enable more electric energy to be transported through existing rights-of-way.
- Increase flexibility and enable grid operators to have a wider array of options at their disposal in making real-time decisions to balance electric supply and demand.
- Increase the percentage of electricity generated by renewable energy sources by providing a more cost-effective interface and enabling better control over the real and reactive power that these sources provide.
- Increase the number of PHEVs that can be reliably charged from the electric grid.

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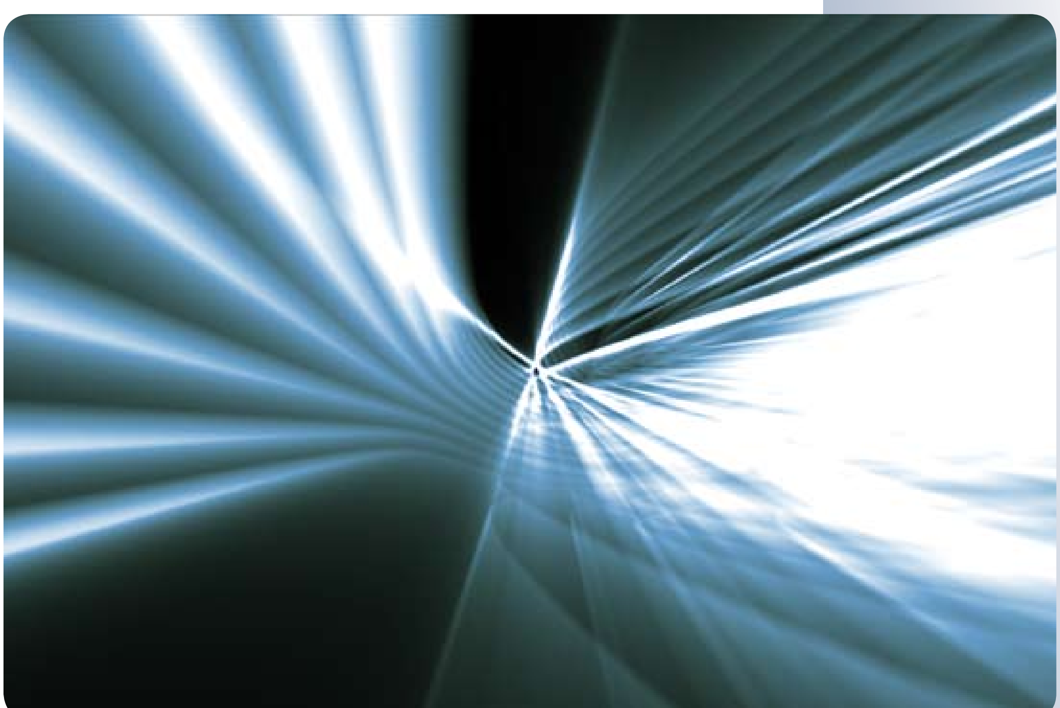
Increasing the delivery capacity of the electric system will improve reliability by addressing transmission bottlenecks and lowering the risk of outages and power quality disturbances from supply constraints, which cost the U.S. economy an estimated $80 billion annually. Power electronics will enable a faster detection and correction of load unbalances, frequency issues, voltage sags or spikes, or other faults on the grid. Power electronics controls will allow for automatic responses to grid problems and allow for a more rapid system restoration if an outage does occur.

Increasing system flexibility will improve reliability by providing more tools for grid operators to deal with T&D power flow issues. All of these features will help to improve the security of grid assets and make the entire electric system somewhat less vulnerable to terrorist attacks.

Additionally, the DOE OE will hold an annual peer review for the Power Electronics program. The review will involve independent subject-area experts evaluating both the technical qualities of the projects and the management qualities of the program. These recommendations offer important insight into what aspects of R&D work are seen as beneficial and which projects should be improved upon or eliminated.

The involvement of utilities and other industries will ensure that technologies developed by this program are relevant and applied to the grid of the future.

Additionally, the Power Electronics program activities will be coordinated with other DOE OE activities in order to identify opportunities for joint funding of projects, provide for the best leveraging of resources, and boost results.



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