

## 1.3.6 POWER ELECTRONICS

### Technology Description

Improved power electronics, as part of the next-generation electricity T&D system, could significantly increase the efficiency of electricity generation and delivery, thereby reducing the greenhouse gas emissions intensity associated with the electric grid. Power electronics is the technology that is used to provide the interface between different types of electrical power, such as DC and 60-Hz AC. Power electronics equipment transforms frequency, voltage, and power factor. Power levels and voltages from a few kilowatts and 120 volts – all the way up to transmission-level powers and voltages – are now possible with today's technology. Power electronics can enable the simple connection of various types of electrical infrastructure links like distributed energy resources. It can help to regulate voltage in the distribution system and transmission grid, and can solve power-quality and voltage-dip problems. Most important, power electronics can provide for an integrated approach to reliability, where all the components – energy conversion, energy storage, control, and power electronics – work together.

About 60%-70% of the nation's electrical power is used to drive motors and motors are reasonably efficient at their designed or rated speed and load. However, efficiencies can be tremendously improved by operating motors at variable speeds that match the system requirements. Motors driven by power electronics to achieve variable speed capability are increasing dramatically in numbers as the technologies become available. Continued development of power electronic devices with higher power-handling capability and reliability will offer an unprecedented opportunity for U.S. industry and utilities to reduce energy consumption and improve competitiveness.

Power electronic structures have been developed to overcome shortcomings in solid-state switching device ratings so that they can be applied to high-voltage electrical systems. The unique structure of multilevel voltage source power electronics allows them to reach high voltages with low harmonics without the use of transformers. This makes these power electronics suitable for flexible AC transmission systems (FACTS) and custom power applications. The use of power electronics to control the frequency, voltage output (including phase angle), and real and reactive power flow at a DC/AC interface provides significant opportunities in the control of distributed power systems.

As distributed power sources become increasingly prevalent in the near future, power electronics will be able to provide significant advantages in processing power from renewable energy sources using fast response and autonomous control. Additionally, power electronics can control real and reactive power flow from a utility-connected renewable energy source. These power electronic topologies are attractive for continuous control of system dynamic behavior and to reduce problems such as voltage harmonics, voltage imbalance, or sags.

#### System Concepts

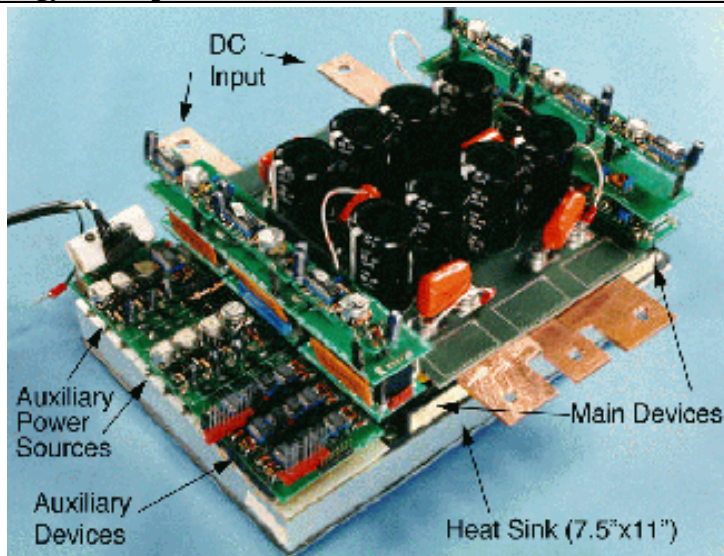
- Advanced inverter topologies: Inverter circuitry that accommodates and takes advantage of advanced solid-state devices while further improving the overall efficiency, packaging, and performance of the inverter.

#### Representative Technologies

- Megawatt-level inverters, fast semiconductor switches, sensors, and devices for Flexible AC Transmission Systems (FACTS).

#### Technology Status/Applications

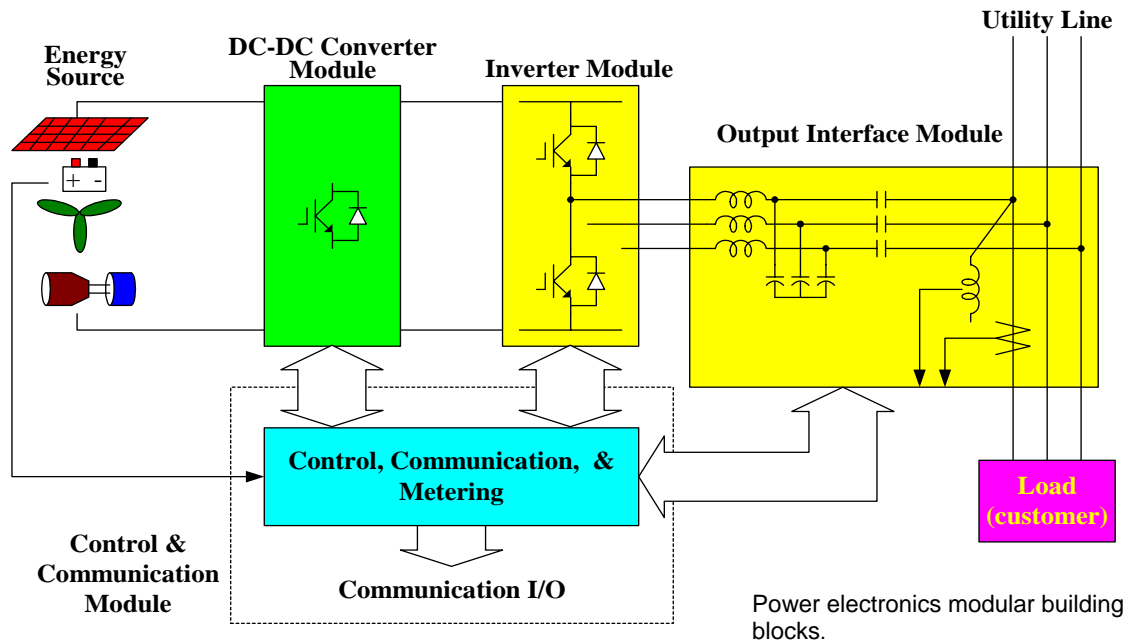
- Transportation: Displacement of internal combustion engines and enabling power electronic components



for alternate approaches to standard systems (traction drives, flywheels, auxiliary drives, alternators).

- Industrial: Enabling components for more efficient motors and introduction of adjustable speed drives to match drives to loads for fans, pumps, and compressors.
- Utilities: Power-quality systems, high-voltage DC power transmission systems.
- Renewable energy: Inverters to convert DC power from photovoltaics and wind turbines to AC power.
- Power supplies: Converters embedded in systems to alter the electrical power from one type to another.
- Defense: Grid and equipment interfaces to allow for mobile and emergency backup of transmission and distribution infras.

### Current Research, Development, and Demonstration



### RD&D Goals

- The research program goal in this area is to build a power electronic system on a base of modules. Each module or block would be a subsystem containing several components, and each one has common power terminals and communication connections.
- The figure represents a strategy in which the interface is partitioned into four basic blocks with each one performing a different system function: (1) DC-DC converter; (2) power electronics, (3) output interface and filtering; and (4) control, communication, and metering. Each of the power blocks will have their own control and communication interface such that a group of modules can coordinate their actions to act as an ideal interface to interconnect distributed energy resources to the utility system. Also, with each block having its own control and communication interface, these modules can be combined to form a multilevel configuration as well as other series/parallel connections as necessary to meet the voltage and current requirements for the particular installation. In addition, this approach will allow for future capacity increases, enhancement to functionality, redundancy, and reconfiguration.

### RD&D Challenges

- Smaller, lighter, more efficient, and lower-cost inverters.
- Increase reliability and lower cost.
- Improved materials and devices: Solders, capacitors, ferrite semiconductors, low-loss drivers, thermal management, passive devices, DC disconnects, connectors, and new semiconductor materials such as silicon carbide.
- Increase modularity of power electronic components.
- Present-day power electronics exhibit a number of serious problems and limitations. Some of the most

significant of these are (1) the need for difficult-to-meet switching device ratings (and associated reliability issues), (2) the need for transformers (and associated design limitations), (3) high cost, (4) control limitations, (5) limitations on voltages that can be attained, (6) creation of high levels of harmonic distortion.

- USCAR is pursuing the development of electric devices as an enabling technology.
- Developing power electronic building blocks.
- The Federal initiatives in transmission and distribution system long-range R&D were canceled.

**RD&D Activities**

- The DOE Energy Storage Program supports research in power electronics for megawatt-level inverters, fast semiconductor switches, sensors, and devices for Flexible AC Transmission Systems (FACTS). Projects in these areas recently won two R&D 100 awards.
- Office of Naval Research and DOE have a joint program to develop power electronic building blocks.
- The military is developing more electricity-intensive aircraft, ships, and land vehicles, providing power electronic spin-offs for infrastructure applications.
- The Superconductivity Technology Program funds R&D of more efficient motor technology under the Superconductivity Partnership Initiative.

**Recent Progress**

- Soft-switching inverter topologies have been recently developed for improved inverter efficiency, reliability, and performance.
- High-power solid-state inverters with improved efficiency and reduced cost and size have been developed.
- A multilevel inverter has been developed, which when deployed will allow 26% more energy to be extracted from photovoltaic or other renewable energy sources.

**Commercialization and Deployment Activities**

- Major U.S. motor and drive manufacturers are beginning to expand their product lines to include improved power electronics.
- U.S. power semiconductor manufacturers are expanding product lines and facilities to regain market position from foreign competitors.