1.3.2 TRANSMISSION AND DISTRIBUTION TECHNOLOGIES

Technology Description

The electric utility industry is restructuring itself from a regulated environment to operation under competitive wholesale electricity markets. However, the electric transmission and distribution (T&D) systems remain regulated entities that connect deregulated generation to the end-use customer. Construction of U.S. transmission above 230 kV is expected to increase by only 6% (in line-miles) during the next 10 years, while demand is expected to increase more than 20%. The resulting increase in the intensity of use of existing facilities will increase energy losses and transmission congestion, and is likely to cause grid reliability problems and threaten the continued growth of wholesale electricity trade. Energy losses in the U.S. T&D system were 7.2% in 1995, accounting for 2.5 quads of primary energy and 36.5 MtC. Losses are divided such that about 60% are from lines and 40% are from transformers (most of which are for distribution). Technologies that can improve efficiency and reduce carbon emissions are high-voltage DC (HVDC) transmission, high-strength composite overhead conductors, and power transformers and underground cables that use high-temperature superconductors (see related technology profile). High-efficiency conventional transformers also could have significant impacts on distribution system losses. In addition, energy storage and real-time system monitoring and control systems could improve system reliability and customer access to competitive generation, including renewable power producers. There is no active U.S. program for HVDC development or improved distribution transformer technologies.

System Concepts

- Composite-core, low-sag transmission conductors can transport two to three times as much power as conventional conductors over the same rights-of-way and with no tower modifications.
- Energy storage will facilitate more optimal use of existing infrastructure and increase the dispatchability of renewable resources.
- Real-time grid operations using measured data and automatic, intelligent controllers can improve T&D reliability – and lead to a smart, switchable future network that can anticipate and respond automatically to system contingencies.

System Components

- One advanced composite overhead conductor consists of an aluminum metal matrix composite core (replacing the steel core of a conventional cable) surrounded by temperature-resistant aluminum alloy wires.
- Several large- and medium-scale energy-storage systems, using different electrochemistries, have been developed.
- Real-time control uses wide-area measurement systems, synchronized by global positioning system (GPS) satellite clocks that feed system information to artificial neural net controllers. The controllers reconfigure the system in real time, preventing outages and allowing maximum use of available transmission capacity.

Technology Status/Applications

- Aluminum composite-core conductors, terminations, and suspensions have been developed by 3M Company and demonstrated in the field by leading U.S. and European utilities. Additional field trials in the United States and accelerated thermal cycling tests are planned in 2003-2005. This extensive mechanical

and electrical testing is required to predict the 40-year life responses of this new conductor technology. Niche applications including long-span river crossings and short lead-time reconductoring over congested existing rights-of-way are now cost-effective. In addition, the conductor's core has 25% lower electrical resistances than steel, enabling higher transmission efficiencies.
- Large-scale energy-storage systems are entering field demonstrations.
- Wide-area measurement systems used for monitoring, event analysis, and system model studies have been deployed in the Western United States power grid to help analyze system disturbances.

Current Research, Development, and Demonstration

RD&D Goals
- Accelerated thermal-cycle testing for 3M's composite conductor in 2003-2005. Field-testing of this conductor began in 2002 on a 230kV transmission line on DOE's Western Area Power Administration grid. Other advanced conductors are expected to undergo similar high-current and field tests in 2003-2006.
- Demonstration of the reliability of energy-storage systems, and reduction of the cost of such systems by 30%.
- Operation of a prototype smart, switchable grid on a region on the U.S. transmission grid by 2010. The market for conventional utility-control systems approaches $300 M/year.

RD&D Challenges
- Development of large-diameter composite conductors for high-voltage transmission lines that are both low-cost and high capacity, so as to yield the highest payoffs in grid reliability and competitive market efficiency.
- Energy-storage systems with reduced costs that can meet several applications while using a single system.
- Neural net networks that can be trained in parallel to perform control functions in real-time control systems.
- A regulatory framework that will allow investors to make credible projections of the return on investment in new transmission capacity.

RD&D Activities
- For composite conductors, 3M Company cost-shared on a DOE effort in FY2002 and FY2003 to perform field tests and accelerated, controlled thermal tests on several conductor sizes.
- DOE is cost-sharing an energy-storage effort with industry. EPRI has a newly reformed energy storage target.

Recent Successes
- DOE's *National Transmission Grid Study*, released in May 2002, examined issues surrounding U.S. transmission system upgrades and expansion, and contains 51 recommendations for actions to remove constraints on the U.S. transmission grid.
- Real-time monitoring tools have been developed by DOE and installed in California with funding by the California Energy Commission, and at the North American Electric Reliability Council (NERC) to monitor and display voltage and frequency over wide areas.
- Demand response (DR) projects are assisting independent transmission system operators (ISOs) with DR program design, and identifying DR capabilities to respond to markets for energy and contingency reserves.

Commercialization and Deployment Activities
- Commercial deployment of high-current composite conductors awaits U.S. field trial results, and manufacturing cost reductions for all but high-value niche applications.