Generator

Project Fact Sheet

What are its Primary Applications?

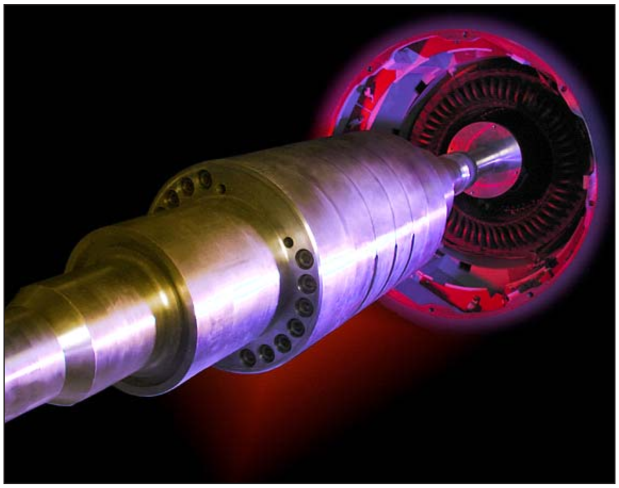
Large generators are typically installed at power generation plants. High Temperature Superconductivity (HTS) generators have the potential to improve efficiency in new power plants as well as through the retrofitting of existing plants.

What are the Benefits to Utilities?

The major benefit of the adaptation of HTS generators into power plants is increased system efficiency. Generators lose power in the field windings and the armature bars. By using superconducting wire for the field windings, the losses in the rotor can be practically eliminated. Other losses can also be reduced because of increases in power density and the reduction in the required cooling capacity. HTS generators will produce electric power with lower losses than their conventional equivalents. Even small efficiency improvements can produce big dollar savings. A half of one percent improvement in generation efficiency provides a utility or independent power producer with additional capacity to sell energy with a value of nearly $200,000 a year per 100 MW generator, assuming electricity prices of five cents per kWh and 8,000 operating hours per year.

Generator designers follow two distinctly different approaches to the design of an HTS generator. One approach, followed by GE, retains the conventional stator core and frame with its magnetic structures and adds an HTS rotor that contains an iron core. This approach completely eliminates any risk associated with the design of the stator and provides a magnetic structure in the rotor to enhance torque transmission. It offers immediate efficiency benefits, compatibility with the turbine drive train, and the ability to retrofit HTS rotors into existing generators.

Alternatively, "air core" designs can eliminate much of the structural and magnetic steel, obtaining a generator that can be smaller and lighter than an equivalent conventional generator. In applications where size or weight reduction is an advantage, such as ships or locomotives, superconducting generators could increase generating capacity without using additional space. Construction, shipping, and installation may be simplified and perhaps less costly as a result of the smaller dimensions and lighter weight. However, the challenges to producing air core HTS generators include the transmission of torque within the generator and the potential for amplification of fault torques on the turbine-generator drive train.



Rotor assembly for the 1.5 MVA HTS generator prototype. (GE Global Research Center)

Another benefit of HTS generators can be lower generator reactances. This benefit can impact utility transmission and distribution stability considerations. One implication is a reduction in the amount of spinning reserve (unused but rotating generating capacity) needed to ensure a stable overall power system. Another benefit is that an HTS generator can be built to be significantly overexcited more easily than can a conventional generator, permitting power factor

What is the Status of the Project?

This partnership was awarded in late 2002. A 1.5 MVA demonstration machine was built and tested successfully. Conceptual designs for 100 and 250 MVA generators were developed, and a preliminary design for a 100 MVA rotor is largely complete. Components of the rotor are now being fabricated and tested.

http://electricity.doe.gov

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Office of Electric Transmission and Distribution, TD-1

U.S. Department of Energy – 1000 Independence Avenue, SW – Washington, DC 20585.

Goal:
Develop and test a 100 MVA prototype High Temperature Superconducting generator.

Team:
GE Corporate Research and Development (team leader)

GE Power Generation Technology (generator technology)

American Electric Power (technology evaluation)

American Superconductor (HTS wire)

Oak Ridge National Laboratory (related studies)

Los Alamos National Laboratory (related studies)

Period of Performance:
2002 – 2006

Cumulative Project Funding:
Private $14.40 Million (54%)
DOE $12.30 Million (46%)
Total: $26.70 Million

What is it?
Generators convert mechanical energy into electrical energy. This project will develop a generator that uses high temperature superconducting windings, which will increase the unit's efficiency and reduce its size.

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correction without adding synchronous reactors or capacitors to the power system. This improved system stability could result in improvements in reliability.

What is the Market Potential?
Generators represent a large, established worldwide market. The U.S. Energy Information Administration estimates that demand for new generation in the USA between today and 2025 will be 428 gigawatts (GW), or over 4,000 units the size of the generator that will result from this project. Additionally, hundreds of gigawatts of existing generators will face replacement in the next two decades. The worldwide market is expected to be even larger. Forecasters predict electricity demand to nearly double by the year 2020, with new generation facilities coming on-line in virtually every corner of the globe.

What are the Project Accomplishments to Date?
The current project was awarded in mid 2002. Initial efforts focused on building and testing a 1.5 MW demonstration rotor. Following successful demonstration of that rotor, conceptual designs for 100 and 250 MVA HTS generators were developed. The preliminary design for the 100 MVA generator is largely complete and some components are currently being fabricated or on order. Lessons learned on the 1.5 MW demonstrator are being factored into the current 100 MVA design. The 100 MVA rotor will be installed in a conventional generator and will be fully tested. In addition, GE will develop conceptual designs for generators as large as 250 MVA based on the knowledge gained in this project.

GE and DOE originally formed a partnership to investigate HTS generators in 1993, and sample generator windings were produced (see picture). Conceptual designs for larger HTS generators were also developed and contributed to the current project.

The GE project will use knowledge gained from earlier superconducting generator projects, but will differ in several important ways. GE will use the same stator core and armature winding. The frame, as well, will not be altered, so that the unit's geometry is compatible with turbines and other power plant equipment for retrofit applications. However, the new project will involve a new cryogenic refrigeration system, cryogenic transfer coupling, and rotor coil and support scheme. The unit will have a rotor diameter of up to a meter, and at that size the support structure must be able to withstand centripetal forces on the surface of the rotor of up to 10,000 g. GE has also stressed demonstrating HTS generator technology that will meet or exceed the established generator industry performance of 99 percent availability.

Alignment with Administration Priorities:
National Energy Policy: " …expand the Department's research and development on transmission reliability and superconductivity"

National Transmission Grid Study: " … accelerate development and demonstration of its technologies, including high-temperature superconductivity…

Secretary of Energy: "… focuses R&D dollars on long-term, potentially high-payoff activities that require Federal involvement to be both successful and achieve public benefit."

Energy Information Administration: "of [advanced power delivery] technologies, superconductivity holds the most promise for yielding significant efficiency gains."

How Does it Work?
A generator converts rotational mechanical input energy, such as that from a steam or gas turbine, into electricity. It does this by rotating a rotor field, which produces voltage in stationary armature conductors. The generator field can be produced with copper windings or permanent magnets. In large machines, mechanical considerations and the desire to vary the level of field produced typically favor the use of copper windings over permanent magnets.