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Environmental advantages of superconducting devices in distributed electricity-generation

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Abstract

Distributed generation (DG) is emerging as an alternative to a centralized electricity-generation system. The goals of DG include the minimization of the environmental impacts of energy production and introduction of new renewable energy-sources to the distribution network. Superconducting devices are also proposed for DG because of their high efficiencies as well as smaller size and more stable operation during peak loads. This study concentrates on the environmental benefits of superconducting machinery by comparing suitable devices with their competitors in DG-networks. Exploitable superconducting devices in DG include superconducting magnetic energy-storage (SMES), flywheels and cable systems. Life-cycle assessment (LCA) is used as a tool in comparisons of energy-storage devices suitable for DG: SMESs, flywheels and batteries. In LCA, all material inputs, energy consumptions, wastes, and emissions are assessed over the life-cycle of the product. Finally, a commercialization schedule for HTS-cables is presented and an unconventional concept for a DG-network is suggested for further examination.

Keywords: Distributed generation; Environment; Life-cycle assessment; Superconductivity

1. Introduction

Environmental issues have become increasingly important in decisions about energy policy. However, these issues are often phrased in ambiguous terms such as "environmentally-friendly technology", "green products", and "sustainable development". Superconducting

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technology is eagerly praised as environmentally friendly, but fair comparisons are missing which would show whether certain technologies are environmentally superior. Here, this issue is addressed by comparing superconducting devices with their rivals in distributed-generation networks.

Distributed generation (DG) can be defined as electricity generation connected to a distribution network or a customer site with less than 10 MW of power delivered [1,2]. DG should not be confused with renewable energy-generation. Renewables can be exploited in DG and are very much encouraged by certain lobbying groups, though non-renewable technologies are also considered in DG-systems [3]. Traditionally, electricity is generated in large power-stations, located near resources or at logistical optima, and delivered through a high-voltage transmission grid and locally through medium-voltage distribution grids. DG aims to add versatility of energy sources and reliability of supply and reduce emissions and dependence on fossil fuels. In addition, DG can contribute to the reduction of transmission losses and help introduce new developments such as fuel cells and superconducting devices [1]. Fig. 1 illustrates the differences between a central plant and a DG model.

Superconductivity means zero electrical resistivity below the critical values of current density, external magnetic-flux density, and temperature. In classical metallic superconductors, T_c is lower than −250 °C. These low-temperature superconductors (LTSs) can be drawn into wire and wound as regular conductors. During operation, LTSs are typically cooled by liquid helium at 4.2 K (−269 °C) and therefore need a special insulation vessel called a *cryostat*.

Classical superconductors have been commercialized in magnetic-resonance imaging (MRI) devices and in industrial magnetic separation. Unfortunately, as electrical machinery is considered, LTSs become economically viable only at powers exceeding 1000 MVA. The so-called high-temperature superconductors (HTSs) were discovered in 1986, and they renewed interest in network appliances. The possibility of operating at liquid nitrogen (LN_2) temperature (77 K) considerably simplifies cryostat design and lowers cooling

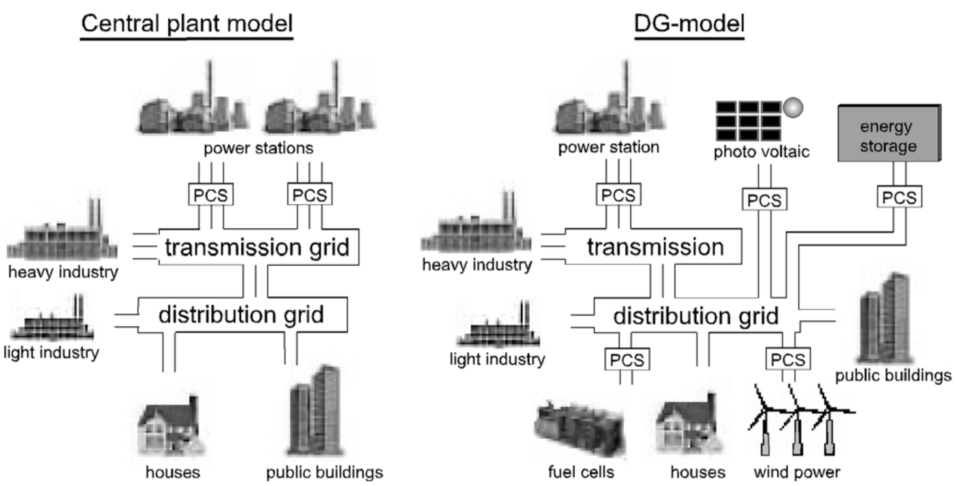

Fig. 1. Schematic diagram of traditional central-plant model and one referred to as DG-model. PCS stands for power-conditioning system.