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Overview of R&D activities on applications of superconductivity to power apparatuses in Japan

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Abstract

R&D priorities of superconducting power apparatuses were investigated by NEDO sending questionnaires to experts in the field of superconductivity applications. As a result of the investigation, superconducting generators with low temperature superconductor superconducting field windings, high temperature superconductor (HTS) power cables, HTS fault current limiters and HTS transformers had high R&D priorities and are expected to come into the real applications in the years of 2011–2015. Based on this result, the government decided to raise three national projects in the year of 2000 to develop those apparatuses together with flywheel energy storage. Beside of those three projects, there are two more national projects for fundamental material technology developments for HTS applications (raised in 1998) and R&D of SMES (raised in 1998). Important results are coming out now, though most of the projects are in early stage of the project term.

Keywords: Superconducting power applications; National project; R&D priority; Overview

1. Introduction

Specific situations of the electric power systems in Japan are very high density of electric demands in metropolitan areas, long distance bulk power transmission, long distance inter-connection of the power systems. In those situations, the electric power companies keep supplying reliable and high quality electricity to consumers. Due to widely spreading information technology and steady electrical shift of energy consumption, the density and amount of electric power demands keep growing especially in highly populated metropolitan areas. However, sites for facilities to reinforce electricity supply to cope with the increases in the demand become more severely limited in large cities by various factors including high cost of land, environmental regulations and public opinions. Beside this, amount of bulk power transmitted from remote areas are increasing. Those situations increase possibilities of deterioration of power quality and instability in operation of the power system. Therefore, there is a fear that difficulties might occurs in the future to maintain the stable operation of the power system and high power quality.

Application of superconductivity can be effective solutions of those difficulties by improving efficiency and compactness, increasing power density, breaking capacity limits of electric power devices and creating new functional devices. Therefore, electric power companies are expecting to solve their problems by applications of superconductivity and major Japan's electric power companies are involved in the R&D activities on superconducting devices as main players.

In this back ground now NEDO (New Energy and Industrial Technology Development Organization) is conducting five national R&D projects related to superconducting power apparatuses including a project of fundamental material technology developments with firm supports from the electric power companies. There are also in-house R&D activities conducted by electric power companies.

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2. R&D priority study of superconducting apparatuses

R&D priorities of superconducting power apparatuses of low temperature superconductor (LTS) and high temperature superconductor (HTS) were investigated by NEDO sending questionnaires to experts in the field of superconductivity applications including engineers of electric power companies, electric wires and machines manufactures, scientists in national institutes and university professors. In the questionnaires, it was asked to score the R&D priority of each of the applications. The results are shown in Fig. 1. In Fig. 1, a high positive point means high priority and a negative point means no priority and years when the apparatuses are expected to come into real applications are also shown based on answers to the questionnaire. Superconducting generators with LTS field windings and copper armature windings, HTS power cables, HTS fault current limiters and HTS transformers have high R&D priorities and are expected to come into the real applications in the years of 2011–2015. Based on the result of the investigations the government decided to raise three national projects to develop those apparatuses together with flywheel energy storages in the year of 2000.

3. National projects conducted by NEDO

Beside of the three national projects mentioned above, there are two more national projects for fundamental material technology developments for HTS applications (raised in 1998) and R&D of SMES (raised in 1999).

In total there are five ongoing national projects related to superconductor power applications which are conducted by NEDO.

3.1. Fundamental material technology developments for HTS applications (Project term: 1998 FY–2002 FY)

This project was established to develop technologies for high critical current density J_c coated conductors, bulk materials and electric devices and the first two technologies are related to power applications. Coated conductors such as YBCO conductors have higher J_c in high magnetic field than Bi/Ag sheathed wires at 77 K but technology to make long conductors is to be developed. Recently a YBCO tape, 10 m long and 1 cm wide with 50 A of critical current, has been made by the ion beam assisted deposition (IBAD) process [1] and this success is considered to lead to development of long coated conductors of hundreds meter with practical critical currents in near future. Details of R&D of the coated conductors are described in the paper in this issue.

Bulk superconductors can be used as permanent magnets with much higher magnetic flux density and also for non-contact bearings. Magnitude of the trapped magnetic field is dependent on J_c and mechanical strength of the bulk. 15 T was obtained at 30 K using a YBCO bulk reinforced by newly developed epoxy impregnation technique (Fig. 2). Other bulk materials (RE123 system) are being developed to obtain high trapped magnetic field at 77 K and technique to increase the size of a bulk is also being developed.

3.2. R&D fundamental technology for superconducting generators—Super GM/Phase II-(2000 FY–2003 FY)

In the previous Super GM project, a 70 MW model superconducting generator with LTS field windings and copper armature windings was successfully developed and tested [2], and the technical feasibility of a superconducting generator has been demonstrated (Fig. 3). However, it has turned out to be clear that a superconducting generator made on the technical basis of the model superconducting generator was not cost competitive to a conventional one. Therefore, it is planed in the phase II of the Super GM project to develop technology for the cost reduction. R&D of fundamental technology for scaling up to 600 MVA class machines is also included in the project because one of the most

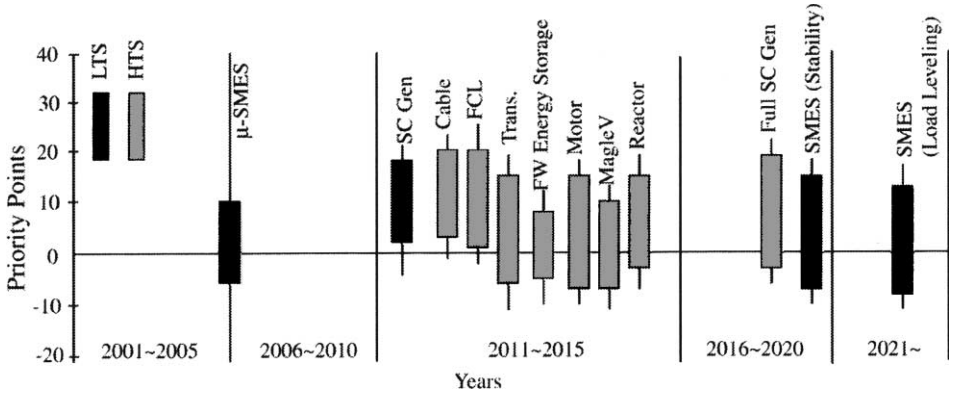

Fig. 1. R&D priorities of superconducting power apparatuses.