ISSN 0040-6015, Thermal Engineering, 2012, Vol. 59, No. 13, pp. 994–999.

Superconducting Transformer with a Rotating Magnetic Field

E. P. Volkov and E. A. Dzhafarov

Received January 24, 2012

Abstract—The results of investigations into the physical model of a superconducting transformer with a rotating magnetic field with separate excitation winding are presented.

DOI: 10.1134/S0040601512130095

In electrical power engineering of the present and future, the application of superconductors (SC) with large current densities of the transport current is the method without alternatives of incorporation of high technologies that allows us to increase sufficiently the technical-and-economical and environmental efficiency of electrical power processes and to improve the characteristics of electrical power equipment.

This explains the attention of leading countries to investigations and designs in the field of the development of high-power superconducting equipment for the needs of the electric-power industry.

The sphere of application of low-temperature and high-temperature superconductors envelopes all types of electrotechnical and electric-power devices such as superconducting generators and motors, superconducting transformers (SCT), superconducting inductive energy storages, superconducting dc and ac cables, superconducting current limiters and switches, and cryotron converters [1].

Power transformers belong to elements of power systems connected with other elements not only constructively but also by integrity of processes. They affect the economy of electrical power and its reliable, safe, and environmentally pure transportation from generation places to consuming objects.

The use of SCs in force transformers allows us to increase the current density in windings by several orders of magnitude, to reduce the load losses by 90% with accompanying increase in efficiency and power coefficient, and to decrease weight-and-scale characteristics by a factor of 2–3. The advantages of SCTs are a high overload capacity, the possibility of limitation of short-circuit currents, a decrease in reactive resistance, fire safety, environmental safety, an increase in service life, and transportation facilitation [2, 3].

High-power SCTs can find application as the electromagnetic (induction) power input (output) into superconducting ac cables, and in combination with a controlled superconductor commutator, into superconducting dc cables [2], superconducting inductive energy storage, etc.

Superconducting transformers with a rotating magnetic field (SCTRMF) of the electrical-machine type are also of definite interest for power-producing application [2, 4, 5].

Multiphase SCTs are intended to transform a three-phase voltage system into a multiphase one without applying special transformer converters to a number of phases and to obtain any voltage for the electric-power transmission without using the intermediate transformer.

The development of SCTRMFs with a controlled semiconductor commutator (CSC) based on high-power gate-controlled GTO-thyristors and IGBT-power transistors allowed us to develop new types of static SC electric-machine converters such as rectifiers, inverters, frequency converters, etc.

A dc SCT also belongs to the class of SCTRMFs with a CSC; it is intended for the electric-power transmission from the dc generator into the SC power line or for the connection of two or several SC power lines with various voltage levels, which will allow us to perform electric-power transmission at a constant voltage during stable operation without reactive powers, at minimal voltage drops, and power losses [2].

The SCTRMF is a static electromagnetic energy converter with two or several superconducting ac windings. Its superconducting windings are constructively performed by analogy with closed windings of electrical machines arranged in the grooves of the magnetic core and consisting of sequentially arranged sections.

The constructive structure of the SCTRMF is similar to the structure of the asynchronous machine with a blocked phase rotor. The symmetry of the magnetic system in the SCTRMF provides identical magnetic resistances of all the SCT phases, and magnetizing phase currents are almost equal in it.

The rotating magnetic field can be formed in the SCTRMF not only by the three-phase alternate current but also by the direct electric current for the spatial switching of the elements of superconducting windings based on the contactless semiconductor switch [2].