B1. PS1 CABLES FOR FUTURE POWER SYSTEMS. Innovative cables and systems

Comprehensive tests of the 1200 m HTS DC cable system for Saint-Petersburg

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The report presents the results of the development of a DC superconducting line for the power system of St. Petersburg. The main attention is paid to the study of possible emergency conditions associated with malfunctions in the cryogenic system. The analysis of the data obtained during the tests of emergency regimes of two-circuit cryogenic system of the cable line is presented. The report demonstrates schematic diagram of the cryogenic supply system and the maximum allowable parameters of HTS DC cable line cryogenic system during emergency regimes of operation determined during the tests. The possible time of transmission of rated power in the event of various failures of the cryogenic system was estimated. Recommendations for improvement of the reliability of operation in different regimes were given.

Experience of operation of experimental and demonstration HTS cable lines (HTS CL) showed that the reliability of the operation largely depends on the stability of maintaining a predetermined temperature range along the length of the cable line. This leads to the need to solve such problems as: the reliability of the cryogenic system of the cable line, maintaining the specified parameters of the liquid refrigerant, maintaining the parameters of vacuum insulation, monitoring the level of heat load. As part of the project of creation of a 2.5 km long HTS DC cable line for the power system of St. Petersburg, the analysis of the most likely emergency conditions of the cryogenic system was carried out and a hardware and software complex with a system of lockouts and protections of the cryogenic system of the cable line built into the overall structure of the automatic process control system was developed.

Complex tests of all components of the HTS DC cable line were carried out within the framework of the National project for the creation and implementation of a superconducting cable line with a capacity of 50 MW in the power system of St. Petersburg. The tests were carried out at the Research and Development Center of Federal Grid Company of Unified Energy System, Moscow.

The experimental stand consisted of several lengths of cable lines with couplings and current leads, reverse cryostat (no cable inside), dual-circuit cryogenic system with rated power of 12 kW at 77 K, the integrated rectifier-converter device and the automatic process control system (Pic.1). The total length of the cryogenic circuit of the line exceeded 1200 meters.

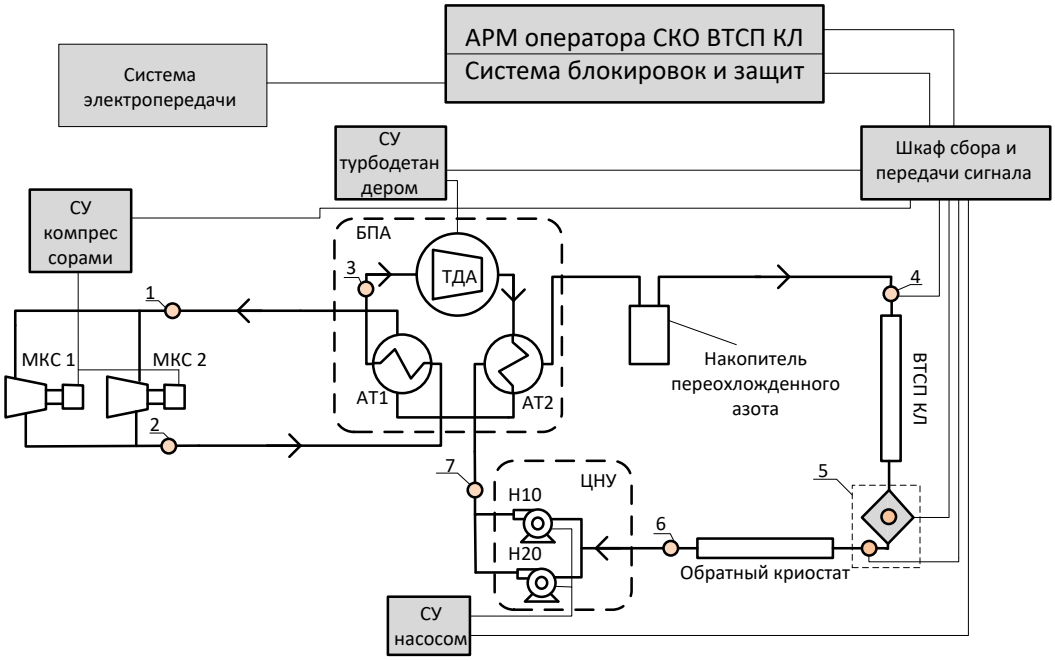
Picture 1 – Scheme of integration of system of lockouts and protections into the control scheme of HTS DC cable line cryogenic system

The report presents the results of vacuum, cryogenic and electrical tests conducted over several months. The temperature and flow rate of liquid nitrogen varied widely during the tests. The electrical and hydraulic characteristics of the HTS cable line were determined, some emergency conditions of the cryogenic supply system were studied, and the possible operating time of the cable in various accidents in the cryogenic system was estimated.

The HTS DC cable line is a D-link, in which the transfer of a large flow of energy at the distribution voltage level is carried out by a superconducting cable. AC-DC-AC conversion, fault currents limiting and the regulation of power flows is carried out by converter substations. The DC-link provides mutual reservation of two power districts powered from substations "RP-9" and "Tsentralnaya" and, consequently, increase of reliability of power supply of consumers.

Conducted electrical tests of HTS DC cable line with a total length of 1200 meters confirmed the achievement of all design characteristics of cable line. Thus, when the temperature varied from 67K to 81K, the critical current varied from 5700 A to 3200 A.

The principle of operation is the supercooling of liquid nitrogen circulating in the HTS cable line by heat exchange with cold gaseous helium. The schematic diagram of a closed dual-circuit cryogenic system is presented at Picture 2.



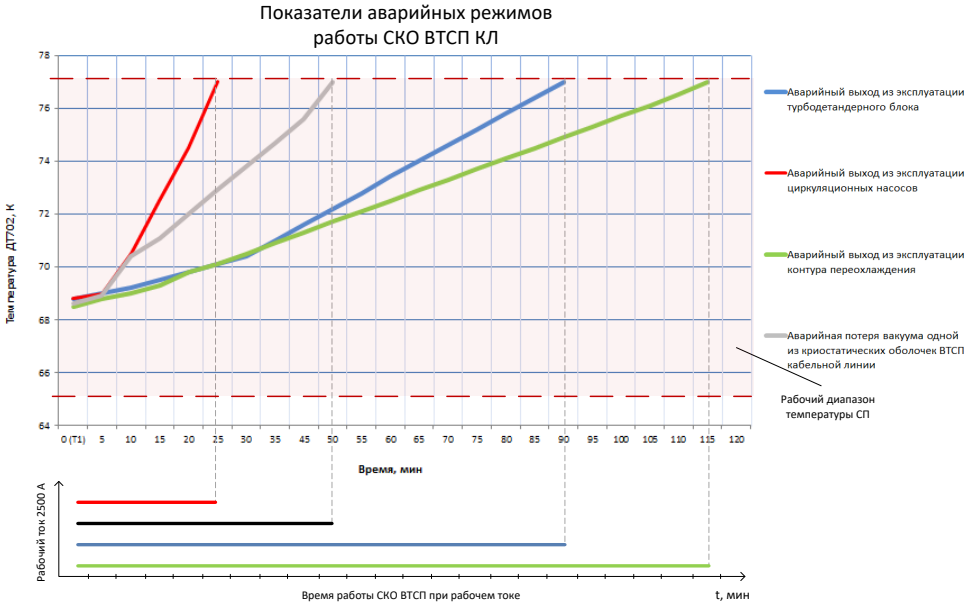
Picture 2 – Schematic diagram of a closed dual-circuit cryogenic system

The scheme includes two circuits.

The first main circuit is the circulation circuit, where the superconducting cable is cooled and liquid nitrogen is supercooled after it is heated by pumping cold helium gas through the cable line in the heat exchanger.

The second circuit is a refrigerator designed to cool helium gas by compressing it in a compressor, followed by expansion in a turbo-expander unit.

Emergency processes in HTSC DC cable line cryogenic system are the result of the occurrence of damage to the equipment, increase of level of leakage in the circulation loop of liquid nitrogen, the false alarm rate of devices and machines, incorrect human actions. The summary of test results of the HTSC DC cable line cryogenic system in emergency conditions are shown at Picture 3.



Picture 3 – Dependence of temperature change of the most heated points from emergency mode period

The results of the analysis of emergency operation modes HTSC DC cable line cryogenic system will ensure the safety of the technological process of cryogenic supply of HTS DC cable line, and make adjustments to the system of lockout and protection, and increase the control and automatic control of dual-circuit cryogenic system in given regimes.