The Influence of Operating Conditions on the Parameters of Superconducting Materials Intended for Use in Superconducting Fault Current Limiters

The modern power system requires continuous expansion and modernization. The connecting new local energy sources entails an increase in the short-circuit power at the connection point and, consequently, higher short-circuit currents. These currents may exceed the permissible level of short-circuit currents for the installed elements of the network infrastructure. Therefore, there is a need to modernize the system or use current limiting systems, such as short-circuit chokes or is-limiters. An alternative to the need for modernization and costly investments can be superconducting Superconducting Fault Current Limiters (SFCL). SFCL uses the phenomenon of a sudden transition of the superconducting material from the superconducting state to the resistive state, in which they are able to limit short-circuit currents. SFCL protect the sensitive circuit against the dynamic effects of short-circuit currents. SFCL has almost zero impedance in the state of normal operation of the system, and the ability to spontaneously return to the state of superconductivity.

The superconducting tapes used in the SFCL, made in mulitlayers technology, may degrade as a result of the operation of the device. The paper presents the results of research on high-temperature superconducting tapes of the second generation (HTS 2G) intended for SFCL. Tests carried out for the HTS SF12100-CF tapes with a silver layer of 4 μm and 2 μm thickness indicate that the parameters of the tapes provided by the manufacturers are insufficient for the design and analysis of SFCL operation in MV networks. The parameters of HTS tapes were tested:

- surge currents I_{0max},
- minimum limited currents I_{min},
- maximum voltages on the tape U_{max},
- energy E released on the tape,

as a function of the operation of prospective short-circuit currents.

Also made:

- testing changes in the value of the critical current of HTS 2G tapes caused by their repeated transitions from the superconducting state,
- the influence of electrical insulation on the change in the value of the critical current,
- studies on the impact of the duration of expected short-circuit currents on the degradation of HTS tape parameters, including tests of changes in the value of the critical current, surge current, minimum limited current and voltage on the tape,
- tests of the time of return of HTS tapes to the state of superconductivity as a function of the load current value,
- and microstructural studies.

The paper proposes two methods for determining the value of the critical current I_C.

The research results presented in the paper have shown that repeated transition of superconducting tapes from the superconducting state by the expected short-circuit current causes a decrease in the value of the critical current I_C, which is affected by the number of leads, the value of the expected short-circuit current and its duration. The process of I_C value degradation is also affected by the course of the strip cooling process in liquid nitrogen. Changes in the I_C value of the HTS tape are not taken into account at the design stage of the SFCL, and may affect the cooperation of the SFCL with the PSP systems and may be the reason for the accelerated replacement of the arrester. The value of the surge current I0max also changes.

The ranges of energy emitted in the tape and the safe range of voltage drops for which the HTS tape is not damaged and the value of the critical current does not change have been determined. An analysis of the cooperation of the SFCL with the protections of the PSP power automatic protection in the event of a reduction in the critical current of the HTS tape was carried out. Due to the necessity of cooperation between SFCL and auto-reclosing systems, the times of tape return to the superconducting state and the ranges of load currents at which it is possible to quickly return the tape to the superconducting state were determined. The possibility of protecting wind turbines with dual power supply based on the DFIG induction generator by NOZP during voltage dips, in the time resulting from the grid code, was analyzed. Microstructural tests of HTS tapes were carried out in order to

identify changes that may affect the changes in parameter values. It has been shown that the basic parameters of the tapes provided by the manufacturer are insufficient for the design of SFCL.