Results of an experimental study of measuring the current-voltage characteristics of an HTSC cable on a model setup

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Abstract. The volt-ampere characteristics experimental study results of the HTSP cable in hybrid high power transmission systems presented. These systems use a superconducting cable to transmit energy. The liquid hydrogen or LNG (liquefied natural gas) simultaneous transportation leads to an increase in power transmission and energy flow density in the system.

1. Introduction
The high-power energy transmission requires the application of new approaches to energy systems. The hybrid systems using is one of the ways to solve this problem. The htc hybrid cable has higher bandwidth and higher efficiency compared to traditional forms of power transmission.

The liquefied natural gas or hydrogen as refrigerants using is both a transported energy medium and a refrigerant that can provide power cables superconductivity and electric drives [1-3].

The experimental model was created at the moscow aviation institute. The transport channel length is 10 m, the operating pressure range is from 1.5 to 5 mpa, the liquid nitrogen mass flow rate is up to 7 kg/s. The installation uses a high-temperature superconducting cable with an operating current of up to 2 ka. Liquid nitrogen is used as a refrigerant.

The general view of the layout of the hybrid system is shown in figure 1, and figure 2 shows a diagram of the flow path of the layout of the hybrid system.

Figure 1. The hybrid system general view.
2. Results

The critical current is significantly influenced by the cooling conditions of HTSC conductors (coolant flow rate, pressure in the channel, presence of a vapor phase, liquid temperature and distance from the entrance to the pipeline). One of the tasks of the study was to optimize the processes of cooling down the transport channel and bringing the electrical load of the cable to the nominal mode.

The parameters in the channel of the model varied in the experiment: the volumetric flow rate of liquid nitrogen from 0.5 to 6.3 l/s; pressure from 0.2 to 4.6 MPa; liquid temperature from 80 to 87 K, flow rate varied from 0.45 to 5.7 m/s.

Figures 2 ... 8 show some results of measuring the current-voltage characteristics of the HTSC cable.

In figure 2 shows the influence of flow conditions on the current-voltage characteristic and the value of the critical current (determined by the criterion of 1 μV/cm or 100 μV/m). It can be seen that the critical current does not depend on the flow conditions along the channel length, and it is 435 A at a pressure of 13 bar and a temperature of 82 K. The current of occurrence of hyperconductivity for sections located at a distance of 1 m from the entrance is 390 A, and for a section located at a distance of 7.8 m 300 A.
Figure 3. Design of the layout of the hybrid system: 1 - current lead; 2 - the main transport channel; 3 - circular transport channel; 4 - cryostatting channel; 5 - screen-vacuum thermal insulation: a - liquid injection scheme, b) - liquid drainage from the model.

The greatest influence on the value of the critical current and the current for the occurrence of hyperconductivity is exerted by the temperature of the liquid in the channel of the model. As seen from figure 5, an increase in the temperature of the liquid from 81.5 K to 84 K leads to a decrease in the critical current from 440 to 410 A, practically all other things being equal. The greatest influence is exerted by the increase in the temperature of the liquid practically to the saturation temperature (mode 1.12). It can be seen that an increase in the temperature of the liquid to 87 K led to a decrease in the critical current to 270 A, and the current of the onset of hyperconductivity decreased from 350 to 200.

In figure 6 shows the results of experiments carried out at different fluid temperatures, flow rates and pressures. It can be seen that the main influence on the critical current is exerted by the temperature of the liquid, and the pressure in the channel has little effect on the value of the critical current.

In figure 7 shows the results of experiments depending on the distance from the entrance to the channel carried out at different fluid temperatures, flow rates and pressures. It is seen that the critical current decreases downstream.

In figure 8 shows the results of experiments illustrating the influence of the conditions of cryostatting of an HTSC cable on the value of the critical current (cooling conditions). Experiments carried out with other things being equal (liquid temperature, pressure, flow rate) show that the absence of liquid flow in the central channel leads to a decrease in the critical current. So modes 1.17 and 6.17 were carried out for the case when the liquid moved along the central and peripheral channels. It can be seen that, despite a significant increase in the fluid flow rate in the peripheral channel, a decrease in the critical current from 430 to 420 A [4-6].
Figure 4. Current-voltage characteristic of the HTSC cable depending on the distance from the entrance.

Figure 5. Volt-ampere characteristic of the HTSC cable depending on the temperature of the liquid in the channel.
Figure 6. Volt-ampere characteristic of the HTSC cable depending on the pressure and temperature of the liquid in the channel.

Figure 7. Current-voltage characteristic of the HTSC cable depending on the distance from the channel entrance.
3. Conclusion
The results of the experiments show that the temperature of the medium has the greatest influence on the value of the critical current. At temperatures above 81.5 K, the critical current begins to decrease. The cooling conditions of the HTSC cable are less affected. The magnitude of the change in pressure from subcritical to supercritical does not affect the value of the critical current.

Experimental studies of the effect of cryogenic flow parameters (pressure, mass flow rate, etc.) on the current-carrying capacity of the HTSC cable in the layout. It is shown that at temperatures up to 81.5 K, the HTSC conductor retains its current carrying capacity. The greatest influence on the decrease in the critical current value is exerted by the temperature of the medium. The magnitude of the pressure in the SPTM tract has practically no effect on the magnitude of the critical current. The influence of the HTSC cooling conditions on the critical current is noted.

Acknowledgments
The work was supported by the Russian Science Foundation, grant 19-79-10206.

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