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CASCADE TRANSFORMER FOR HIGH VOLTAGE COOLER

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Abstract

Experience of using the different systems for powering the high voltage coolers are discussed. The acceleration and deceleration tube need the electric power for operating. At BINP several different power transferring systems were used. The multistage cascade transformers, and the system based on the turbo generators powered by the compressed gas flow.

HIGH VOLTAGE COOLER

The electrons in the electron cooling section should have the low temperature in the rest frame of the electron beam. For this we use strong focusing by the magnetic fields not only in the cooling section but in the entire transport channel of the electron beam, in the acceleration tube and near the electron gun. The last two parts of the electron cooling systems require to supply enough electric power in order to create the necessary magnetic field and also to power the gun and collector electronics.

Figure 1 shows the design of the cascade transformer which will be used for the high-voltage electron cooling system for the NICA collider [1].

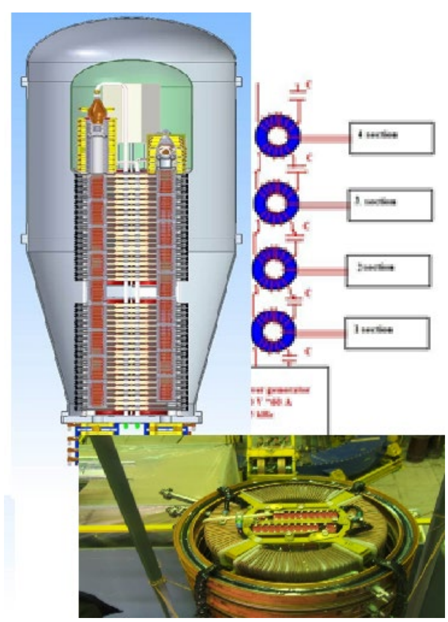

Figure 1: The design of cooler and power supply.

The cascade transformer design is similar to the design of the acceleration tube. The transformer consists of alternating ceramic and metal rings. Inside the metal ring there is a magnetic circuit with two high-voltage sectioned windings and one winding under the potential of the magnetic core to power the electronics of the high-voltage section. One high-voltage winding serves to transfer power to the next stage up, the other winding for communication with the lower section of the transformer [2].

The parameters of the cascade transformer section are presented in the Table 1.

Table 1: Parameters of a Single Section of the Cascade Transformer

Parameter	Value
Diameter of the magnetic core (outer/inner), mm	280/200
Thickness, mm	20
Mass, kg	4.8
Operational magnetic field, T	0.25
Power losses in the yank, W/kg	12
Coils current (r.m.s.), A	≤ 50
Voltage (r.m.s.), V	≤ 700
Transferred power, kW	≤ 35
Power losses, kW	7
Number of turns	28
Mass of the wires, g	230
Wires cross section, mm^2	5.8
Wires resistance, Ohm	0.015

A NEW DESIGN OF THE CASCADE TRANSFORMER

A prototype of a new cascade transformer consists of three magnetic core rings connected by eight parallel turns for communication was obtained from the manufactory and tested (Fig. 1). When making measurements (according to point 2), the input winding W1=32 turns, the first lower magnetic circuit is powered by a voltage generator (U gen)with a frequency of 25 kHz. The output winding W2=32 turns, a load with a resistance R=62 ohms is connected to the third upper magnetic circuit, and with an overall dissipation power of up to 3000W.

To calculate the coupling coefficient of two pairs of connected cascades, the input inductance of the transformer was measured in two modes-with the secondary winding of the transformer open and shorted: Inductance Lopen=15.5 mH Inductance Lshort=56 uH. The calculated coupling coefficient for one pair of cascades is equal to: Kc=0.9991.

Measurement of the voltage transfer coefficient to the load: A measuring current transformer with a current transfer coefficient of 75/1 is included in the loads circuit.

The voltages on the input W1(Ugener)and output W2 (ULoad) windings of the cascade transformer are measured using an oscilloscope in the rms cycle voltage measurement mode for a period.

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During the operation (about 40 minutes) of the cascade transformer in the power transfer mode of 2.7 kW to the load, the transformer cores were heated to 30 degree Celsius. The ambient air temperature was 23 degrees Celsius.

Later, a new transformer was manufactured in a complete set and delivered for the Chinese project CSRe (see Fig. 2).

Figure 2: A photo of the prototype of the cascade transformer based on a distributed windings.

TRANSFERRING THE POWER USING TURBO GENERATORS

Compressed gas is an ideal carrier of stored power from the ground potential to the high-voltage parts of the electron cooling system. We use a turbo generator to convert the power stored in the compressed gas into the electrical power which we can further use [3].

The same concept is utilized in the Accelerator Mass Spectrometer (AWS) facility, and it has been operating successfully for years. The photo of the turbo generator used in the AWS is in the Fig. 3.

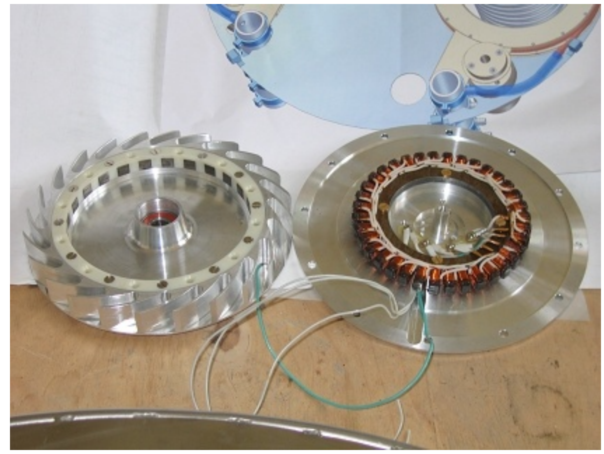

Figure 3: A photo of the internals of the turbo generator.

CONCLUSION

The methods of energy transfer from ground potential to high voltage are under active development in the Budker INP. All methods have both advantages and disadvantages and should be chosen in dependence of system requirements.

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REFERENCES

[1] M. I. Bryzgunov, *et al.*, “High voltage electron cooling system in the NICA collider”, presented at COOL’21, Novosibirsk, Russia, November 2021, paper S102, this conference.

[2] Mao Lijun, ”Development of Electron Cooler Components for HIAF Accelerator”, presented at COOL’21, Novosibirsk, Russia, November 2021, paper S103, this conference.

[3] Kurt Aulenbacher *et al.*, “Future developments for the HESR Cooler prototype at Helmholtzinstitut Mainz”, presented at COOL’21, Novosibirsk, Russia, November 2021, paper S501, this conference.