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PROJECT OF HIGH-VOLTAGE SYSTEM WITH FAST CHANGING POTENTIAL FOR DR EXPERIMENT

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Abstract

A storage ring equipped with an electron cooler is an ideal platform for dielectronic recombination (DR) experiments [1]. In order to fulfil the requirement of DR measurements the system of the precision control of the relative energy between the ion beam and the electron beam should be installed in the electron cooler device. This report describes the project of such system that is designed with section approach like COSY electron cooler. Each section consist of the section of cascade transformer and two power supplies for low and fast detuning of potential of high-voltage terminal. This project can be used in CSRe [2] and future HIAF storage rings [3].

MODULATION SYSTEM

The idea of the fast modulation of the electron beam energy is based on idea of two power supplies connected in series as it is shown in Figure 1. The power supply 300 kV produces the constant voltage (CPS) for the accelerating of the electron beam to the fixed energy. The pulse power supply (PPS) +/- 30 kV produces the fast switching between two values of the electron energy and realize the pulsing energy of the electron beam near the fixed value (see Fig. 2). Because of the high value of the pulse +/- 30 kV it is difficult to realize it as single unit power supply (PS). Such solution was used at design of the detuning system in EC-35 cooler (CSRm storage ring). Because of this, the PPS should be divided on the several sections with typical pulse voltage +/- 3 kV and CPS with typical continuous voltage + 30 kV also. So, the detuning system looks as a few section connected in series. Each section provides the DC voltage + 1 – + 30 kV and pulse voltage +/- 3 kV. Each section should have independent energy source isolated from ground and other sections. This energy source may be realized as section of the cascade transformer. Thus the construction of new detuning system for CSRe looks as the acceleration section of COSY electron cooler device [4].

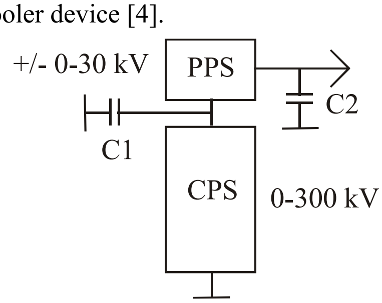

Figure 1: Idea of two power supply connected in series.

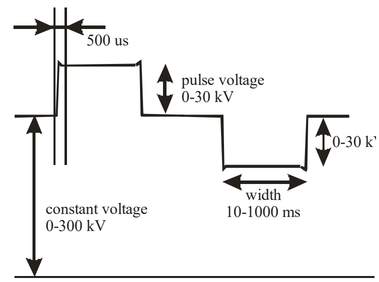

Figure 2: Shape of the detuning system.

The sketch of detuning system for CSRe is shown in Figure 3. It consists of 10 section connected in series. Each section contains CPS, PPS and section of cascade transformer. The high voltage terminal (HVT) contents all power supplies for the electron beam operation. The main problem of such system is inevitable presence of the slow feedback system of CPS (see Fig. 1). The fast change of potential is connected with the capacitance divider with parasitic capacitance C1, C2 of the HVT and 300 kV PS to ground. So after pulse not only the potential in the point B is change, but also the potential in the point A is change too. After that the CPS modules with slow feedback system of 300 kV set the potential of the HVT to the previous value. The parasitic capacitance C2 cannot be decreased from technician point of view. So, we have system with simultaneously operation of two feedback system - fast and slow and both systems see the action of each other.

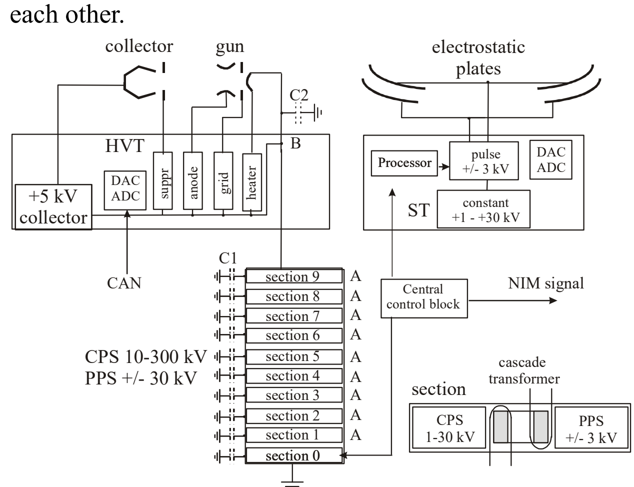

Figure 3: Pulsing system for fast changing of the electron beam energy.

High voltage pulse power supply with feedback can be produced with linear wideband transistor. In spite of the progress in semiconductor technique the transistors aren't

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produced on full voltage that is needed for this task. So, the transistor should be connected in series. It leads to the following problems. The first, the voltage applied to each transistor should be less than datasheet value. The second, the transistors located at high potential should be provided by control circuit. The quality of control circuit is very important for obtaining wideband operation. The line of transistors connected in series and operated in linear regime can provide high rate of the switching process between energy levels and the possibility of the fine matching of the voltage for producing high-quality of output voltage. Such circuit can be named as high-voltage (HV) linear operational amplifier (HVA).

The screen shot of the oscilloscope signal from combination HV and HVA is shown in Figure 4. The yellow line is output voltage of the high voltage system, the green line is signal from divider of feedback system and the magenta line is signal of error of feedback system. The edges of pulse are shown in Figure 5. One can see that the transition process of voltage setting is about 400 us.

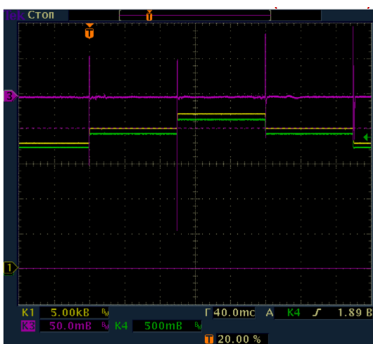

Figure 4: Signal from test-bench, the pulse amplitude +/- 2 kV, the voltage of the main power supply is 20 kV.

Figure 5: Edges of pulse.

CASCADE TRANSFORMER

The important problem of such section design is transfer of the electric power to many electronic consumers kept at a high and different electric potential. Several practical methods for solving this problem are possible. EC-300 (see Fig. 6) cooler is used transformer with large gap that are filled by SF_6 gas [5-6]. The experience of COSY [7] cooler shows that the cascade transformer with 33 sections has many benefits. In this case the high potential for electron acceleration can be received with high voltage power supplies connected in series. In this case the classical multiplier (Cockcroft–Walton generator) may have a large number of section but the problems of the potential sagging and pulsation is decreased significantly because the multiplier section is powered independently. So, the high stability of the electron energy can be obtained.

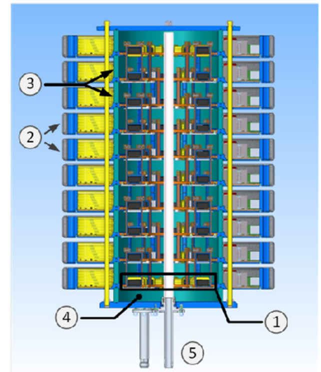

Figure 6: Design of high-voltage system. 1 - section transformer, 2 - electronic section, 3 - section transformer metal ring and ceramics, 4 - vessel filled by oil, input and output of oil.

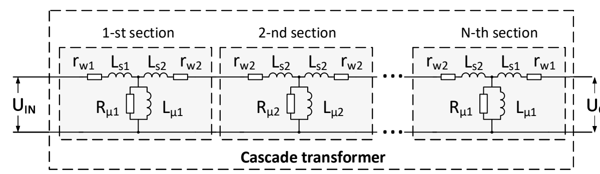

Figure 7: Equivalent circuit diagram of the cascade transformer.

The cascade transformer consists of alternating ceramic and metal rings (see Fig. 6). Inside a metal ring, there is a magnetic core with eight short circuit windings. The potential of the cascade transformer section is specified by the corresponding potential of the high-voltage section for which it acts as the power source. Transformer oil is pumped from the bottom of transformer. The total length of the cascade transformer in design is 0.9 m and the column diameter is 0.74 m. The geometrical sizes of iron (the outer and inner diameters) are 28 cm and 20 cm, thickness is 2 cm, iron mass is 4.8 kg, maximum magnetic induction is 2 kG, magnetic loss at an induction of 2.0 kG is 12 W/kg.

The electrotechnical and equivalent circuit diagrams are shown in Figure 7. It is apparent that the voltage value at the final load strongly depends on the scattering induction Ls. In order to decrease this value the large number of shot-circuit winding to top and bottom is located close to each other (see Fig. 6). This shot circuit is the primary and the secondary windings. So, the leakage of magnetic flux from one winding is compensated by the other. As result the leakage inductance is less than COSY design to factor 2. In this case the compensative capacitors can be installed outside of the cascade transformer. The variant with capacitors located on one side is shown in Figure 8, and variant with capacitor located on both side is shown in Figure 9. The impedance of the capacitors is equal to impedance of leakage current at resonance frequency 25 kHz.

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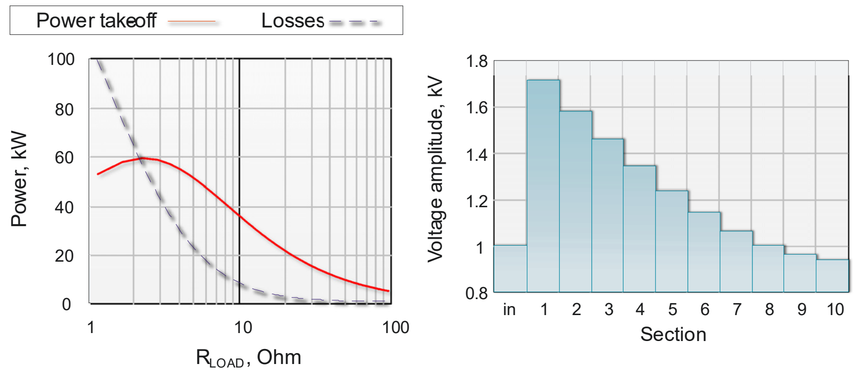

Figure 8: Transfer function of cascade transformer with compensative capacitor Cs = 180 nF from one side.

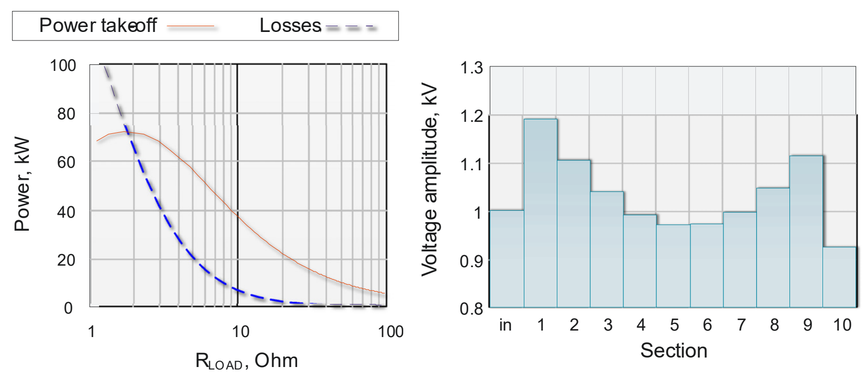

Figure 9: Transfer function of cascade transformer with compensative capacitor from both side.

So, reducing of the leakage inductance gives possibility to install compensative capacitance only outside of the cascade transformer. Such design essentially lighten manufacture and assembling of this device. The variation of voltage level from section to section is good enough (see Fig. 9). The transformer enables to transfer 40 kWt of power with 7 kWt losses according estimation. It is enough for HIAF and CSRe cooler operation. The power consumption of the coolers includes high-voltage modules and the collector power supply (about 15 kWt) for recuperation of the electron beam.

ACKNOWLEDGEMENT

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CONCLUSION

The use of section principle for electron cooling devices has a few benefits. It allow to decide together the problem of energy transfer to collector power supply and obtaining precise energy value of the electron beam. This energy can be stable or changing according specified function. This decision can be used in the electron coolers for CSRe and future HIAF storage rings.

REFERENCES

[1] L.J Meng, X.W Ma, V.V Parkhomchuk, *et al.*, *Chinese Physics C 2013*, 37(1), p.17004:1-17004:8N.

[2] E. Bekhtenev, V. Bocharov, A. Bubley, *et al.*, *in Proceedings of the 9rd European Particle Accelerator Conference (EPAC 04)*, Lucerne, Switzerland, 2004, pp. 1419–1421.

[3] L.J. Mao, J.C. Yang, J.W. Xia, *et al.*, *Nucl. Instr. Meth. A*, 786 (2015), p. 91-96.

[4] V.B. Reva, N. Alinovskiy, T.V. Bedareva, *et al.*, *in Proceedings of the 5th International Particle Accelerator Conference (IPAC 14)*, Dresden, Germany, 2014, p. 777–779.

[5] V.M. Veremeenko, R.V. Voskoboynikov, A.D. Goncharov, *in Proceedings of the RuPAC XX*, Novosibirsk, Russia, 2006, p. 97-99.

[6] E. Behtenev, V. Bocharov, V. Bubley, *in Proceedingsof the RuPAC XIX*, Dubna, Russia, 2004, p.506-510.

[7] M.I. Bryzgunov, A.D. Goncharov, V.M.Panasyuk, *et al.*, *Instruments and Experimental Techniques*. 2015. v.58, No 2, p.9-17.