CONNECTION MODULE FOR THE EUROPEAN X-RAY FEL 10MW HORIZONTAL MULTIBEAM KLYSTRON

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Abstract

For the European XFEL project horizontal multi-beam klystrons will be installed in the XFEL tunnel and will be connected to the double tank pulse transformers. Both, the klystron and pulse transformer need for the normal operation to be filled with oil. To avoid the possible oil leakage during connection of the klystron and transformer tank inside tunnel, the connection module (CM) was proposed. The CM will be mounted on the support platform of the klystron and by the wires connected to the guns electrodes outside of the tunnel and will transported into the tunnel together with klystron. The connection to the pulse transformer tank will be done only with one HV cable, because the CM has inside the filament transformer. To reduce the weight and volume of the oil the design of filament transformer was done as high frequency coaxial one with coupling factor of 0.58 and working frequency about 1.5 kHz. The CM has the built-in current and voltage monitors. In this paper we give an overview about design and test result of CM coupled with horizontal multibeam klystrons.

INTRODUCTION

Power system for the klystron cathode heater power supply has been developed to transfer 800 Watts up to 130 kV potential based on the high-voltage gap transformer[1]. Power transfer has been implemented by resonant way on the frequency of 19.5 kHz using coupled LC-circuits with further transformation to DC. Transformer coupling factor is of 0.58, high-voltage gap is 49 mm, and maximum calculated electric field intensity is 35 kV/cm. To increase the reliability of system it was decided late to remove the rectifier and match capacitors from HV side of gap transformer. In this case the working frequency can be reduced to 1.5 kHz and it will be possible to heat up the cathode of klystron using AC voltage. Primary winding of gap transformer is powered by the full bridge inverter [4] using phase shifted pulse modulation. High stability (0.3%) of the output power has been reached using proportional regulation in the feedback circuit. The achieved power conversion efficiency of inverter is more than 0.95 in the regulation range.

KLYSTRON TEST STAND

The reconstruction of existing test stand for testing horizontal RF power sources for XFEL was finished in 2009 [3]. Fig. 1 shows MBK test stand. The test stand has two independent X-ray shielded testing rooms. Each of them has high voltage power system, water cooling system, RF distribution system, measurement, control and interlock systems.

Figure 1: Multibeam klystrons test stand in DESY, left Toshiba MBK connected directly to the pulse transformer tank, on right side Thales MBK with CM connected to the pulse transformer through HV cable.

DESIGN OF FIST PROTOTYPE OF CM

Fig.2 shows a view of CM. Inside cylindrical oil tank, are placed two windings; primary that fixed on the wall of oil tank and secondary fixed on the flat HV insulator.

Figure 2: High voltage gap transformer.

Windings are coaxially positioned one inside another and both have halves of ferrite rings around. Ferrites increase magnetic coupling ratio between primary and secondary and reduce leakage fields. Fig.3 shows waveform of voltage and current of the cathode heater for one of the testing klystrons. The connection of primary to the HF power supply is done through hatch that is located on the upper part of CM. Inside this hatch are located sensors to measure oil temperature, oil level, oil humidity and output connectors for HV and cathode current measurement. The voltage measurement is done by using a capacitor divider, metal flat ring located on the tank wall on klystron side of CM. Current measurement is done by using "Rogovskiy" coil that is located around HV input to the CM.

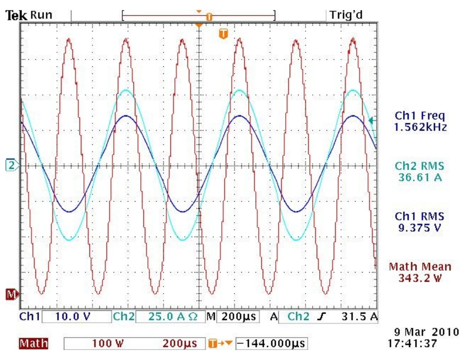

Figure 3: Waveforms of voltage and current on the cathode heater of TH-1802.

Fig.4 shows a high voltage flexible coaxial cable and HV feedthrough. To reduce the leakage current that can go through the normal grounding between klystron and pulse transformer additional screen and ring cores with magnetic conductor section of 28 sq. cm, around HV cable were installed.

Figure 4: ESSEX X-ray 250 kV cable

Fig.5 shows waveform of HV, current and leakage current measurement. The maximum value of leakage current was measured as 0.5A and can be reduced if necessary, by increasing a number of magnetic cores.

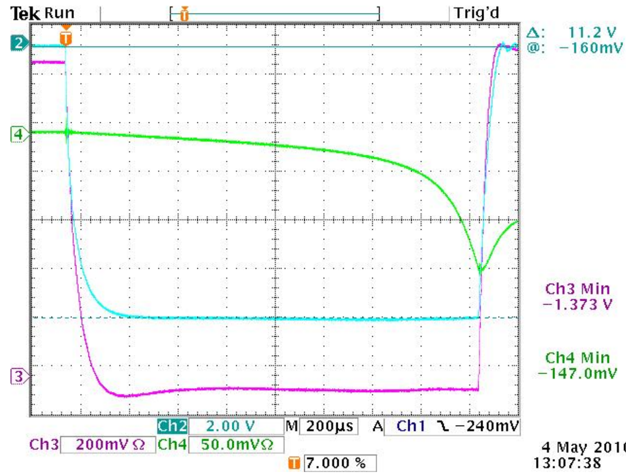

Figure 5: Pulse shape of cathode current, high voltage and leakage current measurement.

TEST RESULT

In the technical specification of 10 MW 1.3GHz MBK the maximum frequency of cathode heating is written as 60 Hz. From literature it is known, [1], [2] that some of klystrons were operating with high frequency heating of cathode. To examine possibility of operating of 10 MW MBK with high frequency cathode heating the CPI VKL-8301B 10 MW klystron was fully tested on the DESY test stand without CM and after that the test was repeated with CM. The total time of operation VKL-8301B with CM was about 100 hours, it was not observed any deterioration of klystrons parameters, including amplitude and phase stability. Fig.6 shows 10MW CPI klystron on the test stand. In March 2010 on the test stand was installed the Thales TH1802 klystron, that had already been fully tested at the factory. The klystron was connected to the pulse transformer through CM. All parameters of klystron didn't show any difference to the

Figure 6: February 2010, CPI VKL 8301B with CM on the klystron test stand in DESY.

parameters that had been measured at the factory. Up to now we have got about 250 hours of operation and will keep this test setup until few thousand of operation hours.

NEW DESIGN OF CM

In the new design of CM the priority target is to reduce the weight of CM and volume of oil inside CM and klystron gun tank in order to make easier and safer transportation horizontal MBK with CM into the XFEL tunnel. To avoid possible oil leakage on the floor of the tunnel through the connection flange between klystron and CM oil collector tank under CM will be installed. This collector will protect the connection between klystron gun tank and klystron body also. To reduce the surface temperature of CM, what is very important for the tunnel installation, it will be installed new water cooling system directly in the oil tank. Fig.7 shows the sketch of new CM. We expect to have weight of CM about 100 kg and about 100 liters of oil inside CM and klystron gun tank. The connection of CM to the klystron gun tank will be done by 600 mm diameter flange and in addition, CM will be supported by two metal rods connected to the main klystron frame. In September 2010 we will install new CM on the klystrons test stand and start testing it together with Toshiba 10MW MBK E3736H. In the new design of CM the coupling factor between primary and secondary winding in the gap transformer will be increased up to 0.607 and we expect to get efficiency of power transfer for the cathode heating about 90%. For the purpose of data acquisition and control high frequency power supply (HFPS) of CM has its own microcontroller with Ethernet link. Although direct cathode power heating control is implemented in FPGA and there is manual mode also. To prevent against high frequency influence of HFPS on measurement system the connection between HFPS and CM will be done as coaxial.

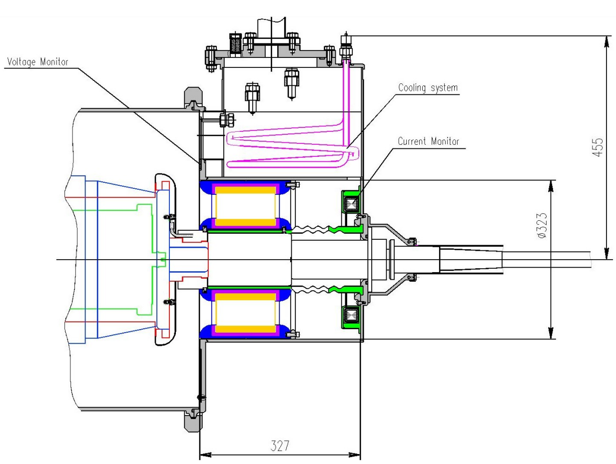

Figure 7: New design of CM, left side gun tank of klystron, on the right HV cable connection.

CONCLUSION

Since February 2009 the 20 kHz version of CM had been installed on the MBK test stand [3], In November 2009 the CM was modified to 1.5 kHz option, after that CM was connected to the pulse transformer through 250 kV ESSEX X-ray cable and tested with two types of klystrons, CPI VKL-8301B and Thales TH1802. In case of VKL-8301B it was required 660W for the cathode heater and in case of TH1802 300W. Up to now we have got about 350 hours of operation at the level of voltage about 117 kV and current 140A, high voltage pulse duration 1.7 ms and repetition rate of 10 Hz. There were several arcs in the gun of klystrons. During this time we didn't observe any sign of degradation of CM parameters, and any influence of high frequency cathode heating to the phase and amplitude of klystrons' output.

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