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Solid state modulator for klystron power supply XFEL TDS INJ

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Abstract. The transverse deflecting system XFEL TDS INJ for European X-ray Free Electron Laser includes power supply for the CPI VKS-8262HS klystron. It has been designed for pulse high-voltage, cathode heating, solenoid and klystron ion pump. The klystron power supply includes solid state modulator, pulse transformer, controlled power supply for cathode heating and commercial power supplies for solenoid and ion pump. Main parameters of the modulator are 110 kV of peak voltage, 72 A peak current, and pulse length up to 6 µs. The klystron power supply has been developed, designed, manufactured, tuned, tested and installed in the XFEL building. All designed parameters are satisfied.

1. Introduction

Three transverse deflecting systems (XFEL TDS Systems) are developed and manufactured for the European X-ray Free Electron Laser (XFEL). These systems are designed for monitoring of the longitudinal phase space and the slice emittance of the accelerated electron beam in the Injector, after Bunch Compressor 1 and after Bunch Compressor 2. Each system includes deflecting structure, a klystron for RF drive of the structure and the power supply for the klystron. The TDS INJ System located in the Injector employes CPI VKS-8262HS klystron. The TDS Systems located after Bunch Compressors include Thales TV-2002DoD klystrons.

2. Modulator for PITZ TDS – prototype of modulator for XFEL TDS System INJ

The prototype of the transverse deflecting system has been developed, built and installed at DESY PITZ for the test [1]. The PITZ TDS system is an analogue of the XFEL TDS INJ System. The power supply for the klystron CPI VKS-8262HS includes solid state modulator for direct pulse high-voltage, power supply for the heater and commercial power supplies for the solenoid and the ion pump.
Schematics of the modulator is designed on base of the pulse generator invented by V Arkadjev and N Baklin in 1914. The capacitors are connected in parallel to charge and then to switched series circuit. Such a way the resulting voltage on the load is equal to sum of the voltages on each capacitor. V Arkadjev and N Baklin employed contact-mechanical switches. E Marx suggested spark gap switches instead contact-mechanical switches in 1924. IGBT are used as switches in PITZ TDS modulator.
The modulator is shown in figure 1 (lower part is the modulator in oil tank, top part is the klystron surrounded with local radiation shielding). The voltage and current pulse shapes are shown in figure 2.

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Figure 1. Modulator with klystron and local shielding.

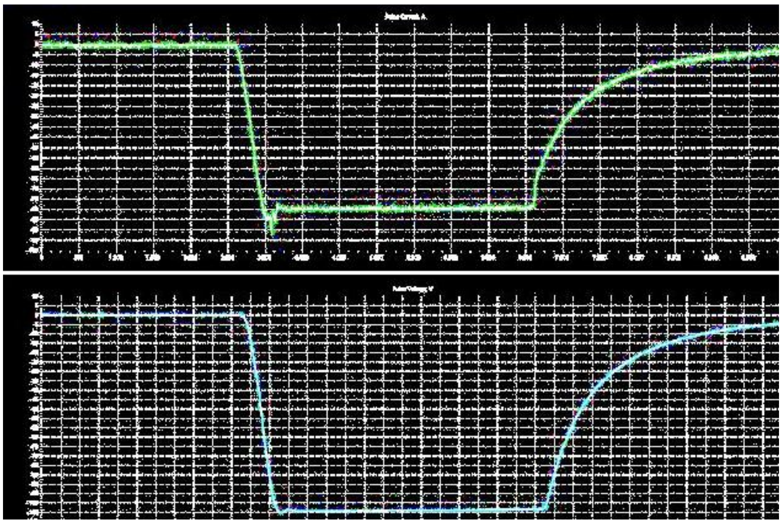

Figure 2. Pulse shape of the current (top) and the voltage (bottom).

The modulator is equipped with fast interlock, interrupting high-voltage pulse in case of break-down. The voltage and current pulse shapes for fast interlock event are shown in figure 3. The fast interlock leads to the voltage interruption and limitation of current.

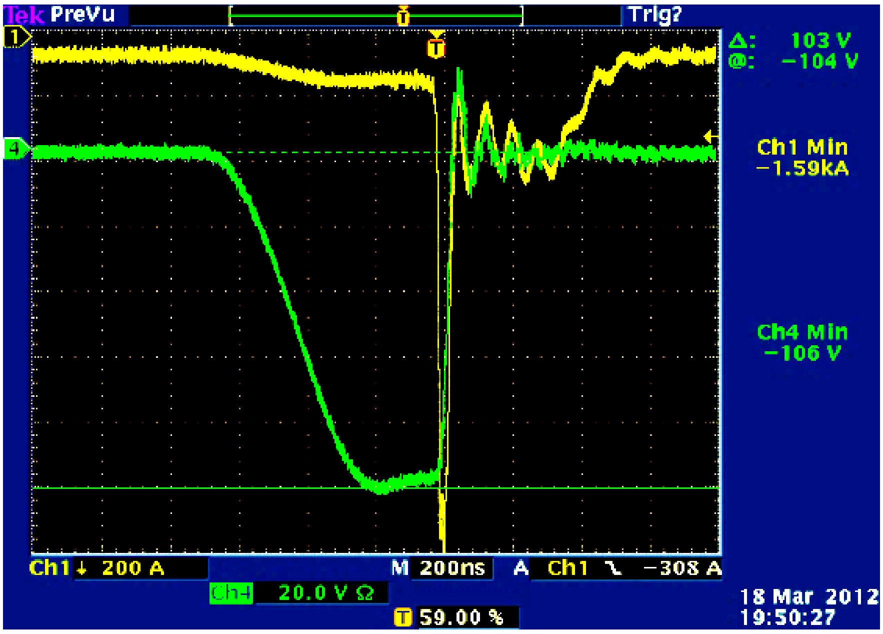

Figure 3. Measured pulse shape of the current (yellow) and the voltage (green) in case of fast interlock event.

Main modulator parameters are 110 kV voltage, 80 A current, 8 V heater voltage, 35 A heater current, pulse length up to 6 µs, 3.1 µs nominal flattop, 0.2 µs rise time, 2.0 µs fall time, voltage fluctuation (pulse-to-pulse, rms) <0.16%, 0.4% long-term stability (peak-to-peak), voltage unflatness (peak-to-peak) <1%, beam current limit at break-down 1500 A & 35 nsec and 350 A & 300 nsec, beam voltage fall time at break-down 35 ns, total charge for breakdown 160 µC.

3. Modulator for XFEL TDS Systems

Two modulators developed for two type klystron of XFEL TDS Systems are based on on the same principle as PITZ TDS modulator, but built with additional pulse transformer. The modulator for

XFEL TDS INJ System has been manufactured and tested. The modulator for XFEL TDS BC1 System is under construction.
The output voltage in the modulator XFEL TDS INJ can be set in the range from 0 to 110 kV. Max output current is 166 A. The pulse length can be adjusted from 0 to 6 µs.
Figure 4 shows the pulse shapes measured with dummy resistive load (instead the klystron). The presented oscillograms show voltage pulse shapes at a) nominal pulse length 6 µs and nominal flattop 3.1 µs, b) reduced pulse length to 3 µs, c) 300 times zoomed pulses in one oscillogram to realise voltage stability, d) zoomed pulse top to see unflattness 0.8 V for 3.1 µs flattop. Achieved value for rise time is of 730 ns and for fall time is of 600 ns.
The pulse transformer is shown in figure 5. It is submerged for operation in the oil tank.
The measured current in function of the modulator voltage at operation for resistive dummy load is shown in figure 6.
Main parameters of the klystron power supplies are summarized in Table 1. The klystron power supply for the XFEL TDS System INJ is shown in figure 7.

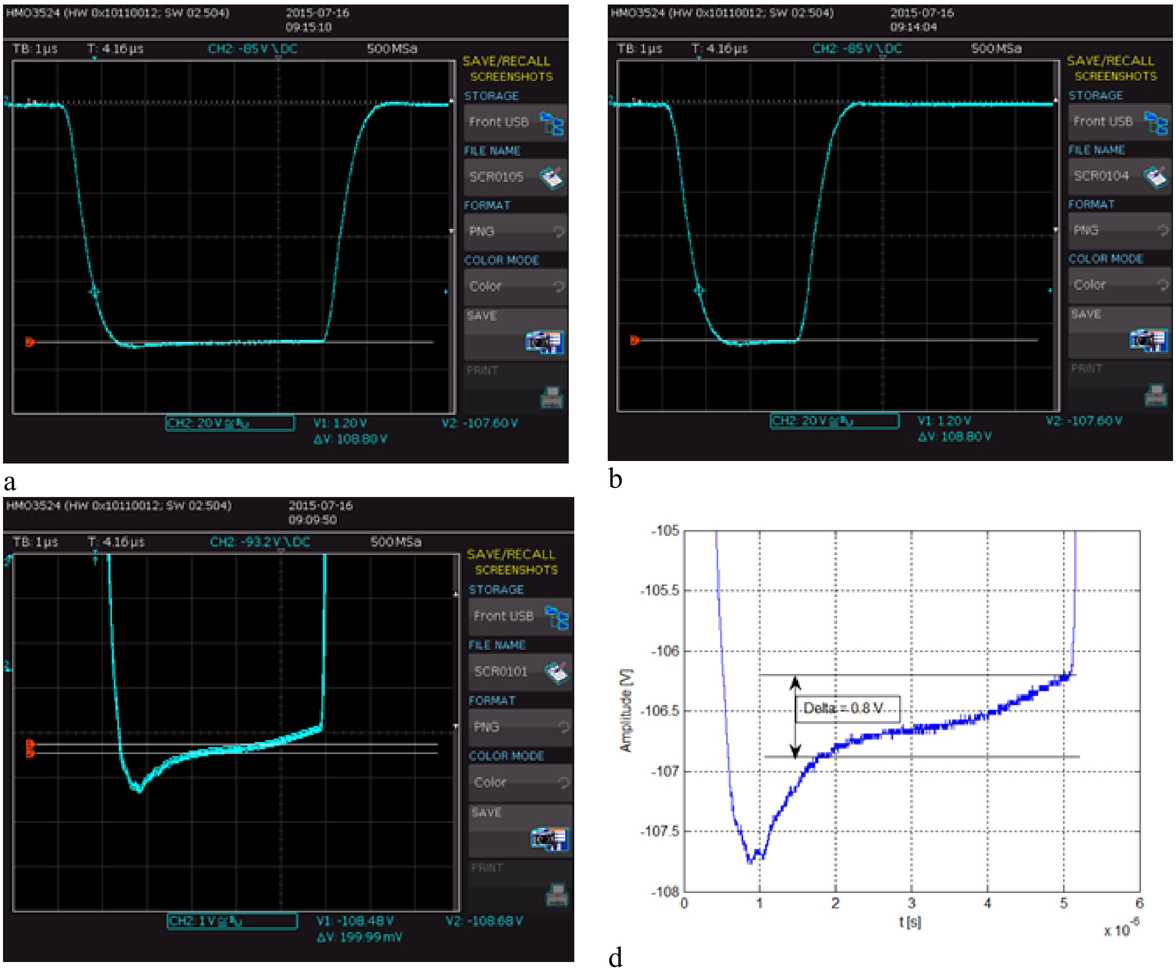

Figure 4. Measured pulse shapes.

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Table 1. Main parameters of the klystron power supplies

	Unit	XFEL TDS INJ	XFEL TDS BC1
Number of modules in the modulator		6	2
Max voltage of the module	kV	8	22
Max voltage of the modulator	kV	48	44
Max voltage in the modulator with respect to the ground	kV	24	22
Max current of the modulator	A	166	1422
Ratio of pulse transformer		2.3	5.68
Max voltage of the klystron	kV	110	250
Nominal voltage of the klystron	kV	101	230/232
Max current of the klystron	A	72	250
Nominal current of the klystron	A	66.4	214/219

Figure 5. Pulse transformer.

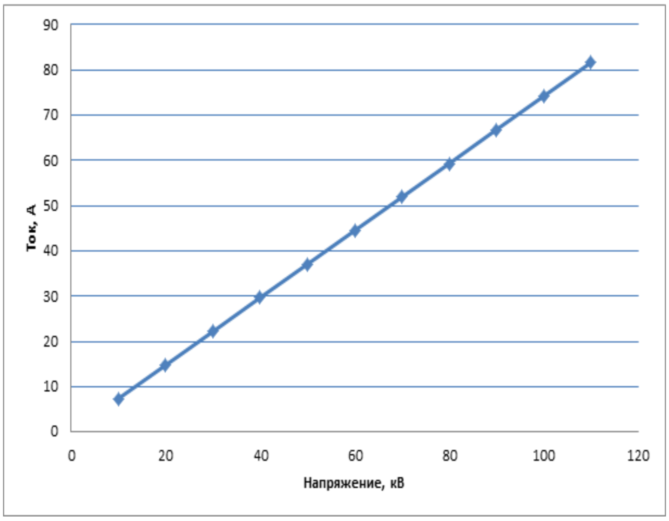

Figure 6. Current (A) v.s. voltage (kV) in the modulator with resistive load.

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Figure 7. Klystron power supply XFEL TDS INJ: left – pulse transformer in oil tank with klystron and local shielding on the top; middle – modulator; right – control unit in power supply cabinet.

The transverse deflecting system XFEL TDS System INJ including the klystron power supply has been installed in the XFEL building and tested. All requirements are met.

References

[1] Kravchuk L *et al.* 2010 Layout of the PITZ Transverse Deflecting System for Longitudinal Phase Space and Slice Emittance Measurements *Proceedings of Linear Accelerator Conference LINAC2010 (Tsukuba, Japan)* 416-418

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