300KV HIGH-VOLTAGE SOURCE WITH UP TO 15 kW OUTPUT POWER

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Abstract

The presented report contains the description of high-voltage source with output voltage up to 300 kV and output current up to 50 mA. The source consist of the chopper with IGBT switches working with a principle of pulse-width modulation and the full H-bridge converter with IGBT switches, both working on programmed from 15 to 25 kHz frequency, and the high voltage transformer powering the eight-stage multiplier with the additional capacity filter at output. The transformer and multiplier both are made in common volume separated on oil tank part with silicon oil for transformer and SF6 part for multiplier. The additional capacity filter provides low ripple and noise level in working range of output currents. The source can operate in normal mode with series of high-voltage breakdown in output voltage. In the high-voltage breakdown the released in load and matching circuit energy is less than 40 J at maximum operating voltage 300kV. The efficiency of system is more than 80% at the nominally output power 15 kW. The description of the source and the test results are presented.

Description

The presented source was designed for accelerator electron gun of Siberian Synchrotron and Terahertz Radiation Centre. That was reason for some specific terms like: strong reliability to high-voltage breakdown, low energy dissipated in high voltage breakdown, low voltage ripple for maximal power operation. The energy is dissipated in components of source and in the load during the high voltage breakdown less than 30J for 260 kV operations. The basic characteristics of high-voltage source are shown in Table1.

Parameter	Unit	Min	Nom	Max
Output voltage	kV	10	260	300
Output current	mA		15	50
Output power	kW			15
Voltage ripple	%			0.2
Voltage stability	%			0.1
Transient time	ms		50	
Converter frequency	kHz	15	20	25

Table 1. Basic characteristics of high-voltage source.

Overview

The circuit diagram of power part of high-voltage source is shown in Fig.1. The high-voltage source consists of the 20 kHz power converter with insulated gate bipolar transistors (IGBT) as switches (part A) and high-voltage transformer with the four-stage multiplier (part B). The power converter consists of 3-phase rectifier VD1, electromagnetic (EMI) filter F1, switch SW1, rectifier's filter capacitors C1-C2, 20 kHz chopper with IGBT switch Q1, 20 kHz inverter with IGBT switches Q3-Q6, output filter circuit L2 C5 C6, and isolation transformer T1.

Design

The converter is made in one 4U and three 6U crates in the rack of 19" Euromechanics standard. There are distilled water is used to cool IGBT switches and other elements.

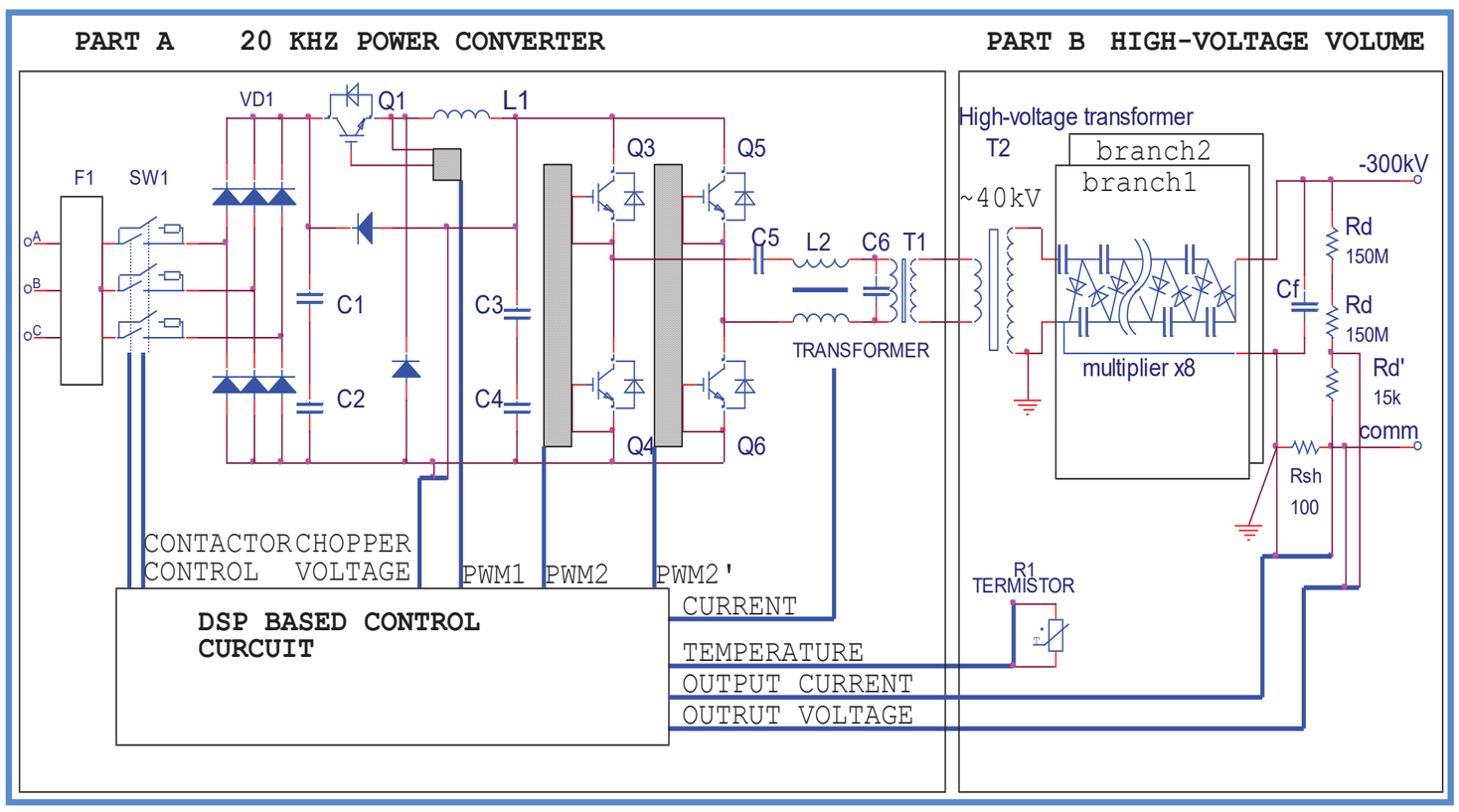
The EMI-filter, input switch and input rectifier are positioned in the first 4U crate. The input filter capacitance, chopper's switches and choke are located in second crate. The chopper's capacitors, inverter and control circuit are located in the third case. And at last, there are capacitor and inductors of matching circuit located in the fourth crate. The high-voltage transformer and multiplier designed in the mixed oil/SF6 tank. The transformer is located in silicon oil and multiplier in the SF6 volumes.

Control circuit

The control circuit is realised in digital signal processor (DSP), programming logic matrix array (PLM), and analogue input buffers. The control and analogue grounds are isolated from external signals and grounds and, that way, in control circuit has obtained low noise level. It allows operation with better then 0.1% accuracy. All the IGBT switches are protected from short circuit and over current. The controller measured seven analogue channels with 12-bits resolution. These channels are shown in Table 2. The controller has CAN-bus interface which is used to link with an external control system. The used data rates are 125, 250 and 500Kbits in second. The protocol of CAN-bus interface is compatible with devises produced in the BINP. This controller circuit is an improved development of previous version used high voltage source .

Protections and interlocks

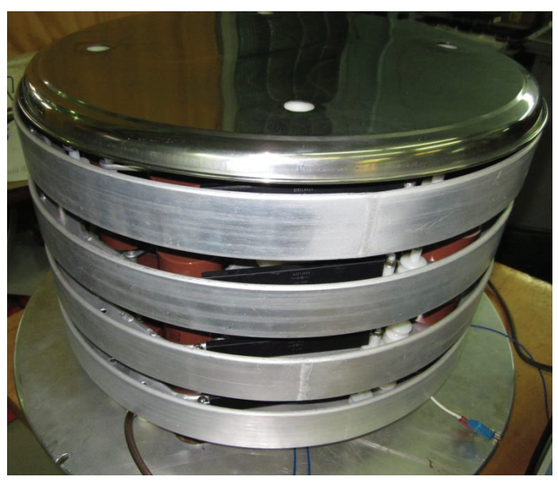
There are two level of overcurrent protection: programmable and circuitry one. Rigid protection has a 140mA threshold level, if the output current increases up to 140mA or higher the all converter switches OFF. The programmable threshold level is tunable. If output current is higher then programmable threshold level (from 5 to 55mA) the converter first tries to limit current on this level than in case of failure all converter switches OFF. Switching OFF time is less then 50 microseconds. The converter tries to switch on output voltage after 100 milliseconds with rise speed 100V/msec. High-voltage transformer protection measures the temperature of transformer and the transformer's input current. In case the input current of transformer rises up to 250A that matter the short circuit in transformer. In this case the converter is OFF.



Results

The high-voltage source was designed tested and now it operates with 300keV electron gun at Siberian Synchrotron and Terahertz Radiation Centre. The tests are shown high reliability, efficiency better than 85% for full load operations. The long time stability of output voltage was better than 0,1% at 260kV output voltage.

Converter rack



4 multiplier sections at tests