3-CHANNEL CURRENT SOURCE WITH CHANNEL OUTPUT CURRENT UP TO 180 A AND OUTPUT VOLTAGE UP TO 180 V

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Abstract

The presented report contains the description of 3-channel current source with channel output current up to 180 A and output voltage. Each channel can be operated and controlled independently. The source consists of 2 part. First part is charging source with capacitance bank at output. And the second part is 3 current sources powered by a capacitance bank. The charging source is converter with IGBT switches, working with a principle of pulse-width modulation on programmed from 15 to 25 kHz frequency, with high power rectifier at output. The source output voltage is up to 180 V, peak power is 40 kW and average power is 20 kW. Capacitance bank has 120 kVA storage energy. Second part contains 3 independent current sources with up to 180 A output current each. Each current source consists of H-bridge 2-quadrant convertor with MOSFET switches working on 50 kHz frequency and the output LC filter. The controllers of the sources are developed with DSP and PLM, which allows optimizing operations of the sources. The controllers are connected by internal control network for more flexibility and efficiency. The description of the source and the test results are presented.

DESCRIPTION

The presented current source was designed for supply of quadrupole magnets with 2 Hz ramping 180A current. There are three group of quadrupole magnets is used BF BD BG. That way three current sources are needed. Parameters Current scenario for quadrupole magnets is shown in Figure1. In the beginning there is a few-millisecond injection plateau - the current should be 1/15 from the maximum current and have the stability not worse than 0.05 %. It is followed by a 0.26-second controllable rise of current . The current stabilization accuracy at rising should be better than 0.1 %. Then there is a short flat-top for extraction of the particles with the fixed energy – followed by fall. The repetition period is 1 or 2 Hz.

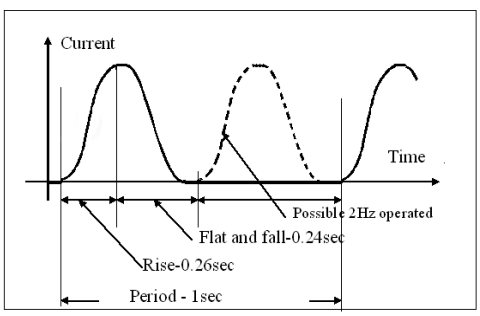

Fig.1. Current scenario.

The load parameters are the same for each channel. Load inductance is 0.14Hn. Load resistance is 0.3Om. At the specified current scenario, the average power of active losses is 2.5 kW for channel, the energy accumulated in inductance is 2 kJ. Time constant of the magnets is approximately 0.5 sec, thus, to provide the current fall during the necessary (<0.2 sec) time, the current source should be two-quadrant and the part of current from inductance at fall should be recuperated to the source buffer capacitor. The capacitance value is 0.1F per channel for 40V over voltage and 200V operating voltage. The selected diagram of power source is shown on Fig.2. The common 30kW bulk power supply with 200V output voltage and common 0.3mF capacitance bank are used. Three separate current sources are powered from capacitance bank. Each of the Output sources has their own channel of computer control via PSC and PSI controllers. Bulk Power supply is controlled current sources by local bus. The circuit with the single bulk PS and the common capacitance allows optimizing the magnet energy recuperation for asynchronous operation or for different values of maximum currents in channels.

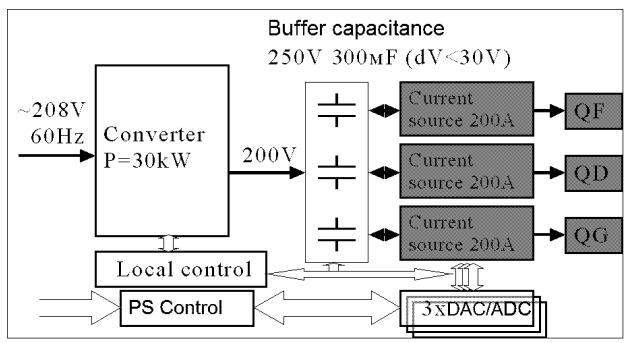

Fig. 2. Power source block diagram.

Overview

The current source circuit diagram is shown in Fig.3. The bulk power supply consists of 3-phase rectifier VD1, electromagnetic (EMI) filter F1, switch SW1, rectifier's filter capacitors C1-C2, 20 kHz inverter with IGBT switches Q1-Q4, isolation transformer T1 output rectifier circuit VD1-VD3, and the capacitance bank C4. The current sources are identical. Current source consists of input capacitance C5, 50 kHz two quadrant H Bridge with MOSFET switches Q5-Q12, filter circuit L1 C6 C7 and DCCT circuit.

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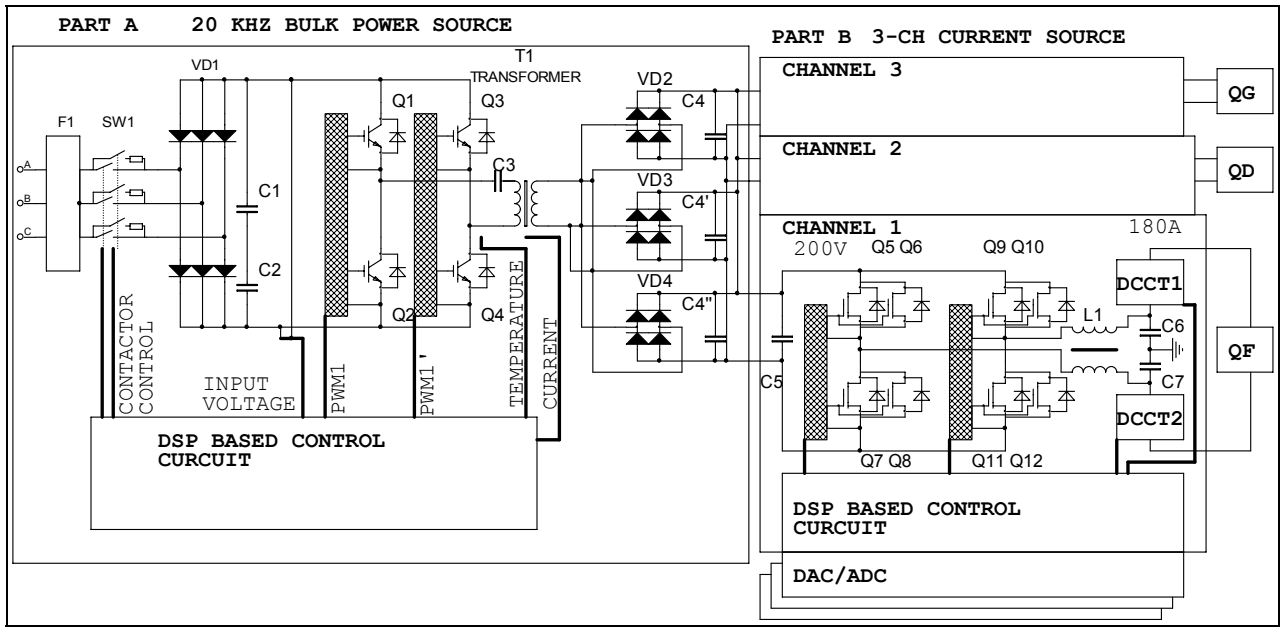

Fig.3. 3-channel current source circuit diagram.

Input rectifier

EMI filter is used to eliminate high-frequency noise to the power line from the source. 3-phase rectifier and filter C1-C2 is used to convert input AC 3-phase voltage 208V 60Hz to DC 300-350V voltage. Contactor SW1 consists of 2 groups of contact: the first is used for soft start of converter and another is used for normal operations. First group of contacts is switched ON and the filter's capacitors C1-C2 are charged with 10A current. When the voltage on filter is up to 250 volts level the second group of contacts is switched ON and the rectifier is connected directly to 3-phase AC line.

Inverter

Full-bridge inverter Q1-Q4 converts DC voltage from chopper's capacitors C3-C4 to AC voltage with programmed from 15 to 25 kHz frequency. When the short circuit or over current is detected the inverter switches are switched OFF in 10 microseconds to protect power circuit from damage.

Output rectifier

20 kHz voltage is decreased by transformer T1 from 350V down to 200V and is transmitted from three secondary windings to the rectifiers. From the rectifiers, voltage is transmitted for capacitors charging. Capacitance bank is divided on two parts. C4 0.15F capacitance is located near rectifier and another C5 48mF part is located in each current source. Voltage at the rectifier outputs is monitored. The current is already monitored at the current source input.

Current source

200 V-voltage from the converter output charges the buffer capacitor C1-C4, from which voltage is transmitted to H-bridge operating at 50 kHz frequency. The bridge is made on the doubled MOSFET transistors. The bridge operating frequency is determined by presence of the beam synchrotron oscillations zone at the frequencies from 20 to 33 kHz. So the converter operating frequency should be out of the given zone in order to avoid the ripple components with the frequencies coinciding with the synchrotron oscillation frequencies in the spectrum of output voltage frequencies.

From the MOSFET bridge output the PWM signal is sent to LC filter L1, C6, C7 filtrating a 50-kHz frequency, then, through two DCCTs, the current comes to the source output terminals. The first DCCT is used for the organizing of the feedback loop, the second one - for independent current measurement. Current source control unit compares the measurements of both DCCTs and, at difference of measurements, set the control circuit fault signal.

Design

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

The EMI-filter, input switch and input rectifier are positioned in the first 4U crate. The input filter capacitance, inverter and Bulk PS control circuit are located in the second case. And at last, there are rectifier

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circuit and capacitance bank are located in the third crate. Three current sources are located in another rack in three 4U crates

Control circuit

The bulk PS controller based is an improved development of previous version of PS controller used high voltage source [1].

The current source control circuit is realised on digital signal processor (DSP), programming logic matrix array (PLM), analogue input buffers and analogue feedback circuit. 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 0.01% accuracy.

All the IGBT and MOSFET switches are protected from short circuit and overcurrent. This protection has 2 levels. First level is the over current protection in driver, the switching OFF switches in case of over current and short circuit is the second level of protection. The MOSFETs has overvoltage protection too. The current source MOSFETs are switched ON if switch voltage exceeded 250V.

RESULTS

The current source was made and fully tested. The tests are shown high reliability, efficiency better than 85% for full load operations. The long time stability of output current was better than 0,1% for 8 hours. Current setup accuracy was better than 0,1% in both mode: ramp mode and continuous mode. The results of long time stability tests with ramp current scenario are shown on Fig. 4. The current was measured on the middle of ramp and on the top Plato.

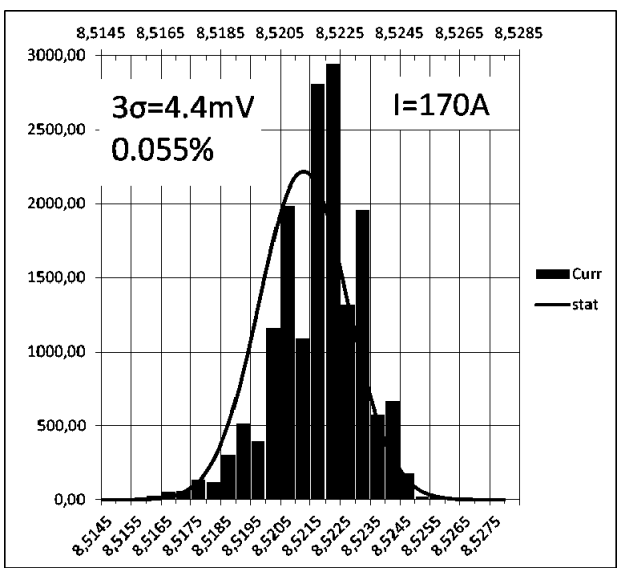

Fig 4a. Long time stability on top Plato.

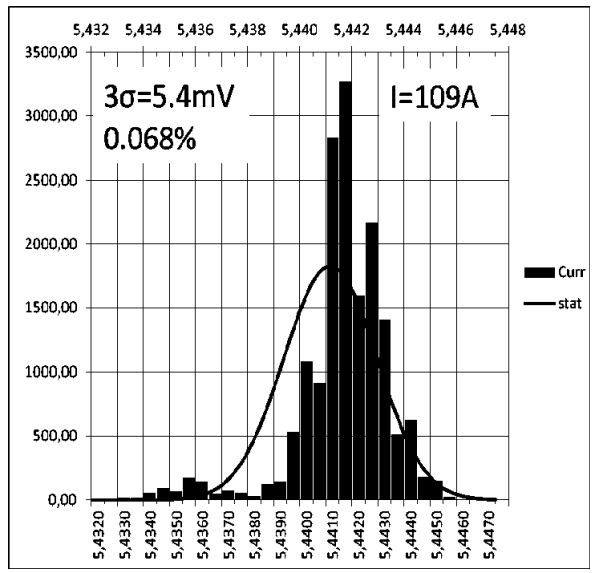

Fig 4b. Long time stability on ramp.

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