POWER SYSTEM FOR QUADRUPOLE MAGNETS OF NSLS-II 3 GeV BOOSTER

Erokhin A.I., Kolmogorov V.V., Medvedko A.S., Potapov S.I.,
Pureskin D.N., Senkov D.V., BINP SB RAS, Novosibirsk, 630090, Russia

Abstract

Power system for quadrupole magnets of NSLS-II 3 GeV booster designed, manufactured and tested in BINP, Russia. The power system consists of 2 parts. 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 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.

This report considers the details of current sources design, their parameters and results of inspection test in BINP.

Finally, the first results of injection and extraction section commissioning at BNL site are reported.

INTRODUCTION

The presented current source was designed for supply of quadrupole magnets of NSLSII booster. The parameters of quadrupole magnets power system are shown in Table1. There are three group of quadrupole magnets is used BF BD BG. Those way three current sources are needed. Current scenario for quadrupole magnets is shown in Fig.1. In the beginning there is an injection plateau - the current should be about 1/15 from the maximum current and have the stability not worse than 0.01 %. It is followed by a controllable rise of current. The current stabilization accuracy at rising should be better than 0.1 %. Then there is a flat-top for extraction of the particles with the fixed energy – followed by fall. The repetition period is 1 Hz.

Table 1: Quadrupole Magnets Power System Parameters

Parameter	QF	QD	QG
Lenses per channel	8QF	8QD	8QG
Current, A	167	118.3	105.3
Resistance per string, Ω	600	1200	900
Inductance per string, Hn	6.5	108	325
PS max voltage	175	175	175
Rise current error tolerance, %	±0.1	±0.1	±0.1
Long term stability, %	±0.01	±0.01	±0.01
Min Ramp repeat time, ms	500	500	500
Max power loss W	2500	2500	2500

*Work supported by the Ministry of Education and Science of the Russian Federation

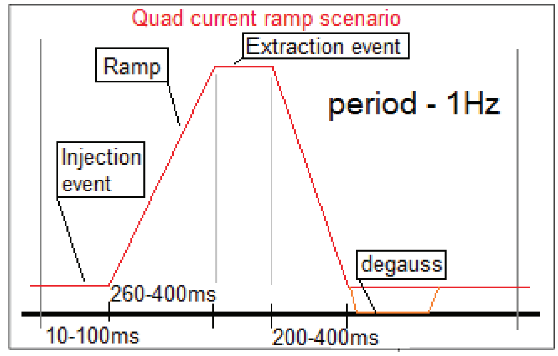

Figure 1: Current scenario.

DESCRIPTION

Overview

The load parameters are the same for each channel. Load inductance is 0.14 Hn. Load resistance is 0.3 Om. 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 0.1 F per channel for 40 V over voltage and 200 V operating voltage. The selected diagram of power source is shown on Fig.2. The common 30 kW bulk power supply with 200 V output voltage and common 0.3 mF 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.

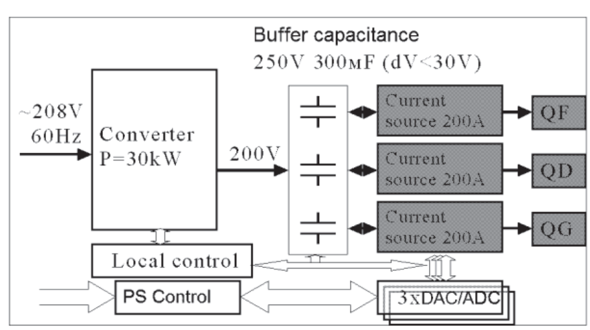

Figure 2: Power system block diagram.

ISBN 978-3-95450-122-9

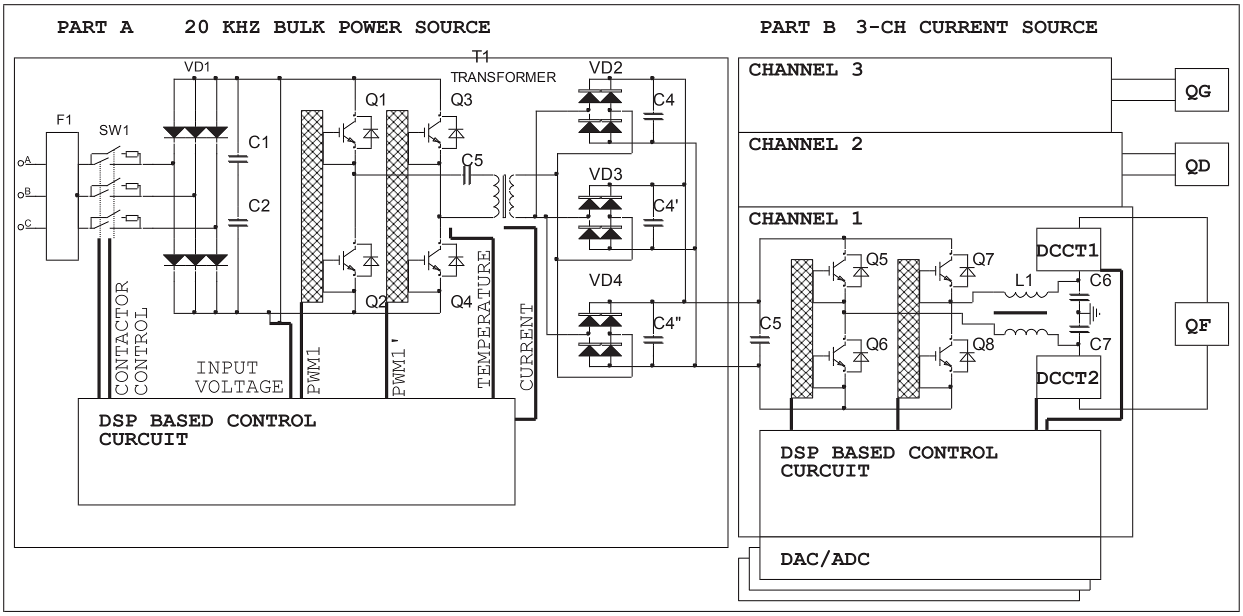

Figure3: 3-channel current source circuit diagram.

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.

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 208 V 60 Hz to DC 300-350 V 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 10 A current. When the voltage on filter is up to 250 V 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 capacitors C1,C2 to AC voltage with 20 kHz frequency. When the short circuit or overcurrent 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 350 V down to 200 V 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 0.15 F capacitance is located near rectifier and another C5 48 mF 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 20 kHz frequency. The bridge is made on IGBT 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 IGBT bridge output the PWM signal is sent to LC filter L1, C6, C7 filtrating a 20 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

ISBN 978-3-95450-122-9

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, inverter and Bulk PS control circuit are located in the second case. And at last, there are rectifier 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 [2].

The current source control circuit is realized 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.

All the IGBT 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 current source switches has overvoltage active clamping. The current source IGBTs are switched ON if switch voltage exceeded 250 V.

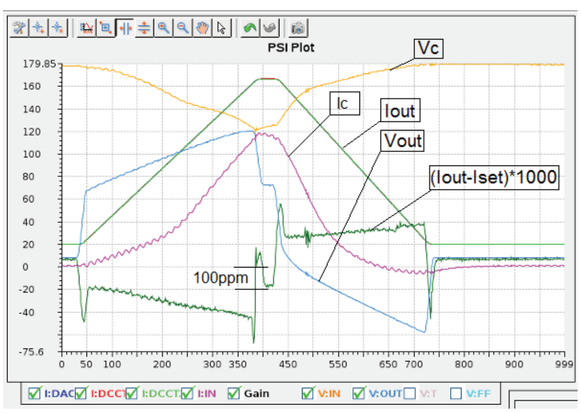

Figure 4: 1Hz 170A ramp QF source waveforms.

RESULTS

The current source have been completely constructed and assembled at the NSLS-II booster. Integrated tests were carried out and gave good results The long time stability of output current was better than 0.1% for 8 hours. Current setup accuracy was better than 0.1% on the ramp and is about 0.01% on the injection and extraction plateau.

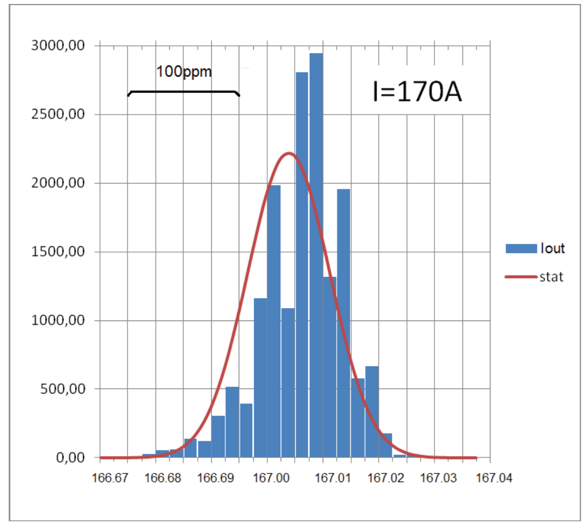

Figure 5: 170 A extraction plateau long term stability.

REFERENCES

[1] T.Shaftan et all, "NSLS-II Booster Design", NSLS-II Technical note, 0061, BNL, USA, 2009.

[2] I.A.Gusev, A.S.Medvedko, A.Yu.Protopopov, D.N.Pureskin, D.V.Senkov "High-voltage source with output voltage up to 60 kV with power current up to 1A", Proceedings of RuPAC 2010, Protvino, Russia, 2010, HPSC017,p.357; http://www.JACoW.org

ISBN 978-3-95450-122-9