NEW POWER SUPPLY OF THE INJECTION BUMP MAGNET FOR UPGRADING THE INJECTION ENERGY IN THE J-PARC 3-GeV RCS

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Abstract

With the energy upgrading of LINAC (Linear accelerator) to 400 MeV in the J-PARC (Japan Proton Accelerator Research Complex) [1, 2], a new power supply of the injection bump magnet [3 - 6] has been designed for the 3-GeV RCS (Rapid Cycling Synchrotron) [7, 8]. The new power supply of the shift bump-magnet (SB magnet) [9, 10] is composed with the capacitor bank which has function to form the output current pattern. This power supply is a commutation strategy using the electrical charge and discharge of the capacitor, and the frequency of the switch that becomes the source of the noise is a little. Comparing to the conventional switching-type power supply, this power supply is switched only three times for the pattern formation. Thus, the ripple due to the switching can be expected to be much lower. The 1/16 scale model was manufactured and the characteristics was evaluated. This paper summarizes the design parameter and the experimental result of the new power supply.

INTRODUCTION

In the injection bump system of the J-PARC 3-GeV RCS [3 - 6], both of the increase of the power supply capacity and the performance improvement of the output accuracy according to the upgrade of the LINAC to 400 MeV injection beam energy are required. And so, the generating the high intensity beam of 1 MW is the primary goal in the RCS [7, 8]. To do so, to reduce the unnecessary beam loss in the term of the injection and the acceleration is an important issue. In order to reduce the unnecessary beam loss of the injection period, the improvement of the deviation to a setting current is required for the injection bump system. The power supply produces the injection trajectory with good accuracy whose deviation to a programmed pattern becomes to be less than ± 0.2 %. Moreover, the high-intensity beam test in the previous commissioning, the second harmonic vibration of a 48 kHz ripple currents due to the IGBT chopping on the present SB power supply excitation current waveform, and there is the problem that the betatron tune resonance (about 96 kHz) [11]. Therefore, the present level of the current ripple of the flat top is necessary to decrease to half or less.

The power supply system of the SB magnet will be changed to the commutation system of the capacitor with an electrical charge and a discharge, which decreases the switching noises and the ripple current.

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DESIGN OF THE NEW POWER SUPPLY FOR THE SHIFT BUMP MAGNET

Overview

The SB magnet produces a fixed main bump orbit to merge the injection beam from the LINAC into the circulating beam of the RCS. They are realized with four magnets connected in series, which are located at the long straight section [3, 4]. Both specifications of the present design and new design of the SB power supply are shown in Table 1. In the new power supply for 400 MeV beam injection, the capacity is required 1.6 times output current and about twice output voltage. The typical output current waveform of the SB power supply is as shown in Figure 1. The rise time and the fall time are able to change between 150 µs and 500 µs in the situation of the foil temperature [3]. In order to keep the good accuracy during the beam injection at 500 µs, the flat top time is setting over 550 µs. The current waveform is the same specification regardless of the injection energy.

Table 1: Specifications of the SB Power Supply

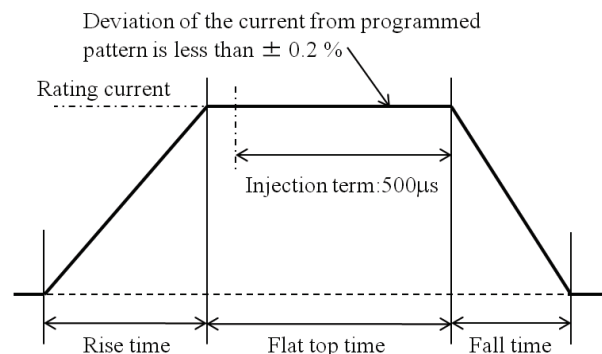| Contents	181MeV	400MeV
Maximum current [A]	20.000	32.000
Maximum Voltage [V]	6.400	14.400
Rectification circuit	PWM	24 Pulse
Main component	IGBT assembly	Capacitor bank
Output accuracy [%]	1.0	0.2

Figure 1: Schematic view of the waveform of the SB power supply.

Composition

The rectification circuit of the new SB power supply is alternated to the 24 pulse commutation system from the PWM (Pulse Width Modulation). The control unit is simply and the switching noise can be degreased. Moreover, the new design of the power supply has been planned to use the commutation system of the capacitor with an electrical charge and a discharge [9, 10]. This system is composed by many electrolytic capacitor banks. The outline of the operation mode is shown in Figure 2. The waveform pattern of the output current at the trapezoidal shape has been created by the three switching timing, which are the start-up mode, the flat-top mode and the falling-down mode.

The composition of the new SB power supply is 16 banks. One bank has the performance which outputs the exciting current of 2 kA/± 7.2 kV. Each bank is connected in parallel and the maximum exciting current of 32 kA is outputted. Figure 3 shows the schematics view of the whole circuit of the 16 banks. One bank is composed by twelve up-down units, two flat-top units and one control unit. One up-down unit has the function as the starting-up and the falling-down. Twelve up-down units and two flat-top units are connected in series. And so, the units connected in series are divided into the P side and the N side on the basis of the midpoint earth. The schematic view of the one bank is shown in Figure 4.

The outline drawing of one bank is shown in Figure 5. The power panel size is 2800 mm in width, 3150 mm in height and 2200 mm in depth. There is a pile of units in the power panel and the height of the power panel is decided by the unit's number.

No actual production of high current and high voltage specifications corresponding to the new SB power supply with this system. In addition, to use many capacitors, the capacitors with a small enclosure and a high capacitance has been developed.
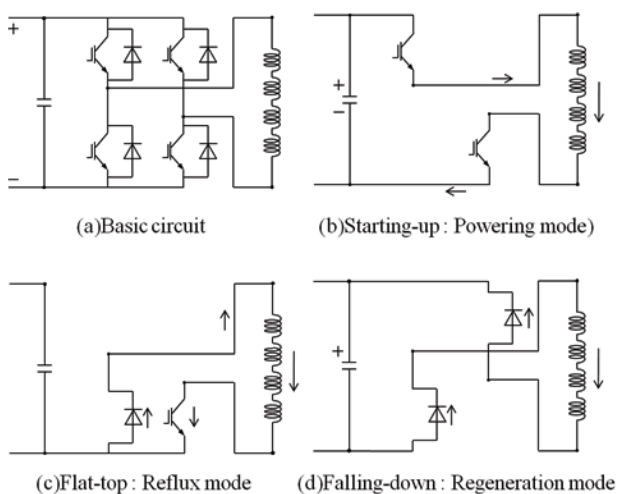

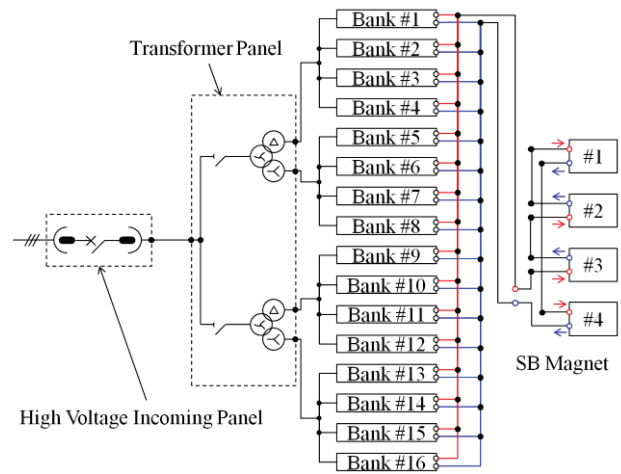Figure 2: Schematic view of the outline of the operation mode for the new SB power supply.

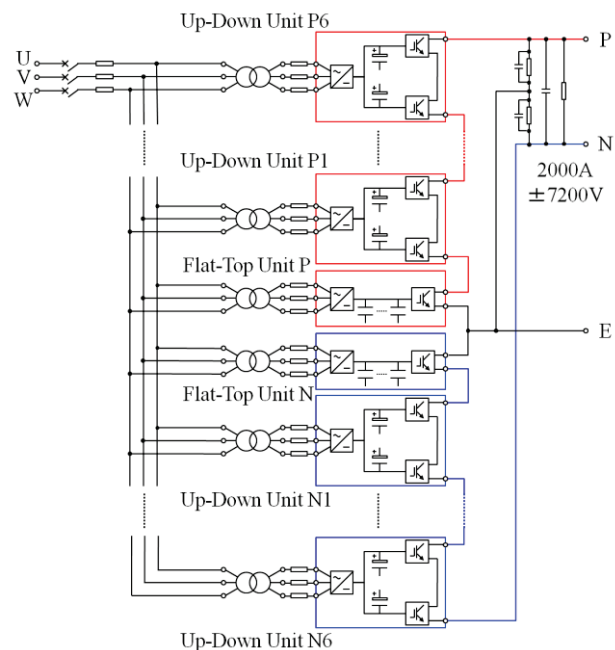Figure 3: Schematic view of the whole circuit of the new SB power supply which has 16 banks.

Figure 4: Schematic view of the one bank, which is the main circuit of new SB power supply used the commutation system of the capacitor bank.

EXPERIMENTAL RESULT

The examination in one bank has been performed. The preliminary result of the output waveform is shown in Figures 6 and 7, respectively. The setting parameter of the rise and fall time is 500 μs and 150 μs, respectively. The rating current of 2 kA was confirmed. The start position of the flat top is large due to the high impedance load equivalent to four SB magnets and the effect of the eddy current. The flat-top voltage is adjusted using the flat-top unit and the raised current can be suppressed. The continuous current ripple does not occur anymore because there are no IGBT choppers as in the present system.

Therefore, we can minimize the high frequency leakage noise and solve the betatron tune resonance.
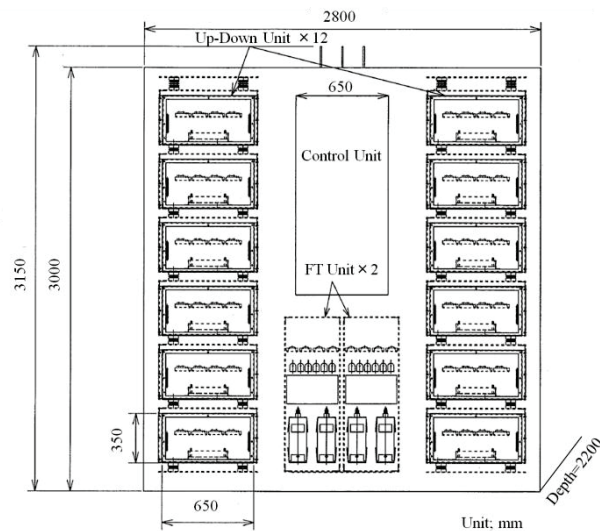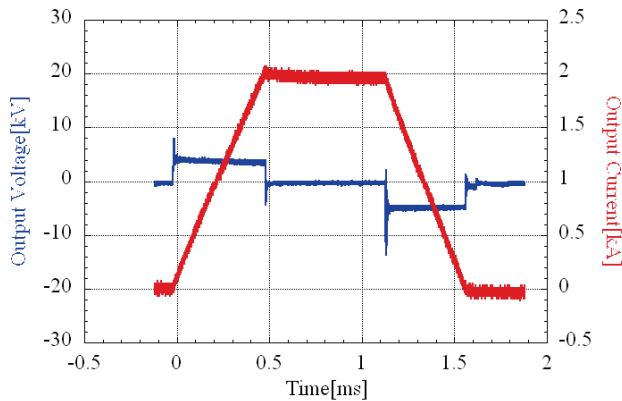

Figure 5: Outline drawing of one bank.

Figure 6: Output waveform of the current and voltage. The setting parameter of the rise and fall time is 500 μs.
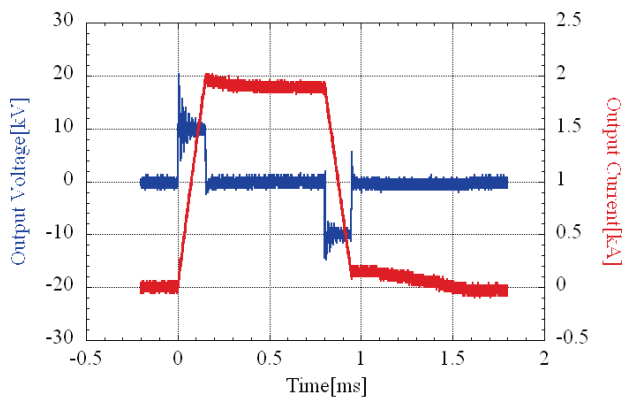

Figure 7: Output waveform of the current and voltage. The setting parameter of the rise and fall time is 150 μs.

SUMMARY

The new power supply system of the SB magnet has been adapted the commutation system of the capacitor with an electrical charge and a discharge. The 1/16 scale model was manufactured and the characteristics was evaluated. Both the rating current of 2 kA per one bank and the reduction of the current ripple due to the switching on the flat-top were confirmed. However, the output accuracy of the deviation is required to adjust furthermore. In this year, the fifteen remaining banks will be manufactured and the rated output examination of 32 kA has been planned. Next year, the long maintenance period of five months is planned from July. And so, the present SB power supply is due to be exchanged to the new power supply in this period. After installation of these machines, new SB power supply will be performed.

The beam commissioning of the RCS using the 400 MeV injection beam will be start in early 2014. Consequently, the 3-GeV RCS will aim at 1 MW beam power.

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