POWER SUPPLY SYSTEM FOR THE RIKEN-MUSES PROJECT

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Abstract

The power supply system for the MUSES project has been studied. The present paper describes the overview of the power supply system of the lattice magnet strings, the energy saving system of the synchrotron power station and R&D of the control system.

1 INTRODUCTION

A variable energy linac, ring cyclotron, superconductive cyclotron (SCRC), ion-separator (RIPS) and storage rings (MUSES) are key-components of RI-beam factory. The MUSES comprises an accumulator ring (ACR), a booster synchrotron (BSR) and double storage ring (DSR). The BSR is a slow synchrotron [1] to boost-up the energy of RI-beams from the SCRC or to accelerate an electron beam from the 300MeV linac. The design study of magnet powers supply was focussed on the required specifications and an estimation of dissipation power. A part of the present study has already been reported [2]. The present paper is concerned with overview of the designed power supplies, power station and R&D of the control system. The following points are left as future problems; the compensation of eddy current, correction of hysteresis caused by the repetitive excitation.

2 ACR POWER SUPPLY

The lattice structure of ACR is based on the FODO functions with the wide and narrow dipole magnets. The dc-power supplies drive the magnet family of dipole, quadrupole and sextupole. The switching dc-power supply has been designed for the quadrupole or sextupole magnet strings. The switching dc-power supply is composed of ac-dc converter and sub-dc units. The ac-dc converter is a primary dc-source to deliver the pre-regulated dc voltage to the sub dc-units. Each sub dc-unit is an individual switching-regulator, which is composed of IGBT, ferrite transformer and current control loop with a 12-bit resolution. A power-conversion efficiency of the sub dc-unit is expected at 98% by using a PWM-type switched regulator with an operating frequency of 50kHz. The normal and common mode ripple filters are equipped in the sub dc-unit to suppress a low and high frequency ripples. The electromagnetic shielding of sub dc-unit is subjected to suppress the rf-radiation field from the power supply. The common-mode filter is equipped in the primary of ac-dc converter to suppress the leak-noise into the primary ac lines.

A transistor-type series dropper is equipped in the dipole-magnet power supply to regulate a large and small current level. Specification of power supply of the magnet power supply is tabulated in Table 1.

Table 1: ACR magnet power supply (typ).

Parameter	Dipole (Wide)	QF(Wide)
Total L	105.304mH	207.312mH
Total R	86.2mΩ	120.888mΩ
Max. of Vout	205.786V	178.596V
Max. of Iout	2387.32A	1477.37A
Min. of Iout	77.98A	73.868A
ΔI long	< 10ppm/year	< 10ppm/year
ΔI ripple	<6ppm	<6ppm
Max. of Pout	0.49127 MW	0.2638 MW

Since the cost-performance of thermoelectric devices is higher than the air-conditioning equipment, a peltier device is considered as a temperature controlled reference source of the medium and small sized power supplies. The peltier device is attached to the reference source by the adhesive processing to make it an excellent conductivity. The reference source is controlled within +/-0.5 degree where the current stability of 10ppm is desired.

3 BSR POWER SUPPLY

It is considered that different beam acceleration mode either heavy-ion beam mode or electron beam mode and their combination would be put into operation. The following operating conditions fulfill the combination of different ion species or ion-electron acceleration; 1) Polarity change is no longer required to inject the different ion species. 2) Pulse to pulse operation like the "CERN-SPS super cycle" for different ion species requires complicated current pattern control. 3) Deceleration of accelerated beam is required to decrease the radioactive contamination at a beam damp phase.

The maximum magnetic rigidity of BSR is designed at 8.34Tm for electrons and 14.6Tm for $^{238}U^{92}$ beams. The expected operation modes are listed in Table 2.

Table 2: Typical operation mode of BSR

Parameter	Electron mode	$^{238}U^{92}$
Einj.	300MeV, ($B\rho$=1.00238Tm)	150MeV/u, ($B\rho$=4.7629Tm)
Eext.	2.5GeV, ($B\rho$=8.34070Tm)	$B\rho$=14.6Tm
flat top	1596 A	2785 A
flat bot.	278 A	557 A
ramping	4391.7 A/sec	7426.6 A/sec
Vcoil	1543 V	2623V

A beam extraction using the 3rd order resonance is a main function of the BSR [1]. The power supply of the quadrupole magnet is designed to suppress a ripple current so that the derivative of K [1/m^2] value is similar to the constant. The following table summarizes the rings dedicated for the acceleration or accumulation of the nucleus beam.

Table 3: Comparison of ripple component

Machine	B_{max} (T)	Bmin (T)	Power (MW)	Ripple at Bmin
GSI-ESR	1.6	0.08	7.5	10 ppm
COSY [6]	1.7	0.068	6.5	10 ppm
HIMAC [5]	1.5	0.1	5.4	1 ppm
CERN-PSB[7]	0.7	0.128	NC**	64ppm*
CERN-AC[7]	NC**	NC**	NC**	1.3ppm*
TARN-II [10]	1.5	0.1	1.4	10 ppm

*50Hz, **No reference

The R&D of the ripple reduction of the BSR have been carried out at the cooler-synchrotron TARN-II [10]. The old DCCT of TARN-II was disabled and new one is installed in the power supply. The drift of new one with a specification of 1 ppm was measured during the past 1.5 years. It was observed that long-term drift is appeared, which is fulfilling the data from the factory.

The 2Hz operation with a saw-tooth waveform has been studied to accelerate short-lived RI beam. The voltage-mode operation method [8] gives fast beam acceleration batch. This method is applied after the current-mode control in which the various kind of energy ramping. The DSP module calculates the non-linear feedback quantities in place of the PID feedback loop.

The MUSES-BSR expects a deceleration of the RI beam from the top to the bottom fields. A magnetic-hysteresis due to an alternative excitation of the laminated magnet core would be appeared. An eddy current effect in the magnet gap and vacuum chamber of the ring gives excess of sextupole excitation to the beam optics. The tune tracking and chromaticity controls depend on those magnetic saturation effects. The magnetic-hysteresis loop should be corrected for the dipole, quadrupole and sextupole family [9].

The new B-dot clock system for the RF acceleration system has been studied. The traditional type is based on the search-coil system followed by the VCO to read-out the B-F table. The new type is composed of the DSP to calculate the rf-acceleration frequency from the detected B-dot signal. An excess number of dipole magnet for the B-dot detection could be disabled since the DSP gives the function of signal-conditioning of the B-dot signals detected from any dipole magnets in the ring.

4 POWER STATION AND CONTROL

A line voltage fluctuation named flicker would be deduced by the induced reactive power due to the pulse operation of BSR. A BSR-power station is subjected to stabilize the line voltage of the RI-beam factory so that the interference between the power line of BSR and the outside of BSR power line should be minimized. Induced reactive-power is compensated by using a hybrid-power saving system located in the BSR-power station. The hybrid-power saving system (HPSS) comprises a Static-Var. Compensator (SVC) and motor-generator (MG) to stabilize the primary-line voltage of 6.6 kV and to suppress the 3rd, 5th and 7th or higher harmonic currents. The dipole-magnet power supply is branched directory to the HPSS. The power supplies of quadrupole-magnet group are blanched to the HPSS through the sub-power station with local SVC. The power supply of sextupole-magnet group is branched to the power line of BSR-Q magnet group because of small-dissipation power. The line voltage oscillation caused by the coupling between the SVC and any electric devices should be considered. An estimated parameter of the MG is described as follows: The power rating of induction motor is 1.65MW, AC generator power rating is 12.95MW. The inertial moment of flywheel is designed at 7.2 [ton m^2] to achieve the frequency stability of 0.5% at a rotation speed of 600rpm. An image of the power station is shown in figure 1. Using MATLAB has carried out a simulation study of energy saving system. The simulation flow calculates the fluctuation of the line voltage and rotation frequency as a function of the inertial moment of the flywheel system.

The power line accident will be occurred due to any reason. The diesel engines are also used during peak electricity days to reduce the energy bill. The solution of redundancy, adapted directly onto the 6.6 kV line of the 10 MVA peak-power requirement, is a new way of supplying electricity to all the sensitive equipment of the RI-beam factory with MUSES. Thus the RI-beam factory considers the power plant that is composed of 2 sub units of 1MVA each connected in parallel in a N+1 redundant way. The parallelism is performed at the 6.6kV level. This means that the system is composed of two 6.6kV bus bars one for the input and one for the output. The motor generator mentioned above is mechanically connected to those diesel engines with the magnetic-crutch.

The excitation current and operation status are controlled through the ARCNET (ANSI/ATA IEEE878.1) based on the LAN technology. The industrial-standard modules are equipped in the power-supply cabinet and connected with LAN cables in each other. The commercial based programming language and the operating system develop the control program of power supply. The Internet live using the WWW server has been tested to monitor the power supply status. The collected data is transferred to the HTML file in every few minutes. The collected data is also saved in the text file with a time stamp.

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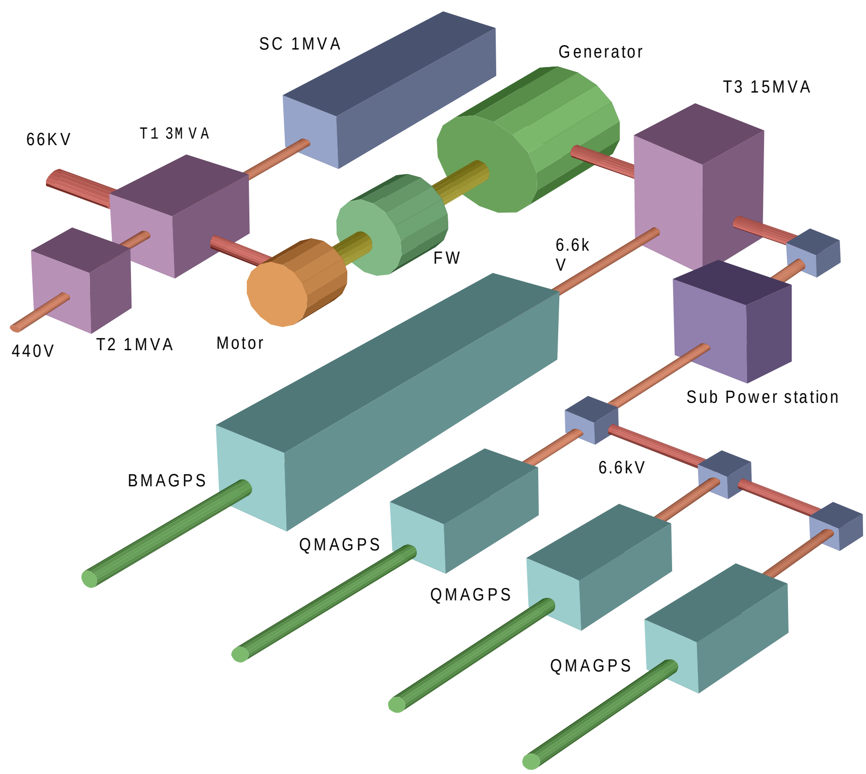

Figure 1. Overview of the power station of the MUSES-BSR