OPERATION PERFORMANCE OF THE WHITE CIRCUIT FOR THE BOOSTER SYNCHROTRON IN NSRRC

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Abstract

Three independent White circuits, resonating at 10 Hz, drive the main family of magnets in the booster synchrotron of NSRRC. Each White circuit is excited by an IGBT based DC and AC power supply. The control system provides précised, low harmonic 10 Hz sinusoid reference to excite four quadrant AC current amplifiers. A VME form factor 10-Hz reference generator was implemented. This module includes numerically controlled oscillator, which is based on the sine-wave signal generator, an amplitude regulator and synchronized circuitry to control the phases of three families of White circuit. This report summarizes the operation performance of the White circuit.

INTRODUCTION

The electrons are generated by an electron gun and accelerated by the linac to 50 MeV. The energy of those injected 50 MeV electrons beam in the booster synchrotron increases from 50 MeV to 1.5 GeV by the ramping cycle. At the same time, the three families of White circuit power supplies provide the stability of phase and amplitude to help the ramping of the electron beam. Therefore, the performance of the White circuit is very important to the operation of the booster synchrotron. The performance of the White circuit power supply must be monitored in order to understand the current amplitude and phase stability. By doing so will help to find the strategy for reducing the fluctuation of the beam current. The purpose is to make the White circuit magnet current controllable.

SYSTEM CONFIGURATION OF THE WHITE CIRCUIT

There are three families of magnet systems in the booster synchrotron. These are the dipole, the focusing quadrupole and the defocusing quadrupole magnets. Each group includes 12 magnets. The White circuit comprises two coupled resonant circuits. A bypass capacitor and a DC power supply connect two resonant LC circuits. Each White circuit has the same configuration; those AC, DC power supplies are independent sources. Figure 1 schematically depicts the White circuit.

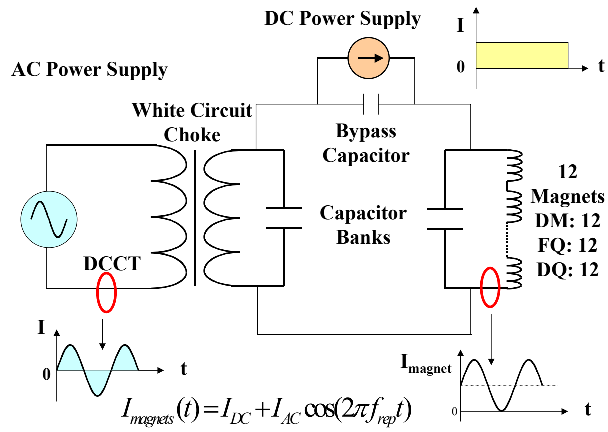

Figure 1: Schematic of the White Circuit.

REGULATION LOOP

Field Regulation

All of the main systems of magnets in the booster synchrotron have three families. They all have the same regulation loop. A proper controller is required to control the output current. The output is a highly purified 10 Hz sinusoidal wave, generated by utilizing the direct digital synthesis techniques. The amplitude of the 10 Hz output signal is proportional to the DC reference input. The feedback value is compared with the amplitude reference and those different inputs to the PID controller. The PID control law built into 10-Hz sinusoidal wave generator is to improve the regulation of the field. Figure 2 shows the field regulation loop of the AC power supply.

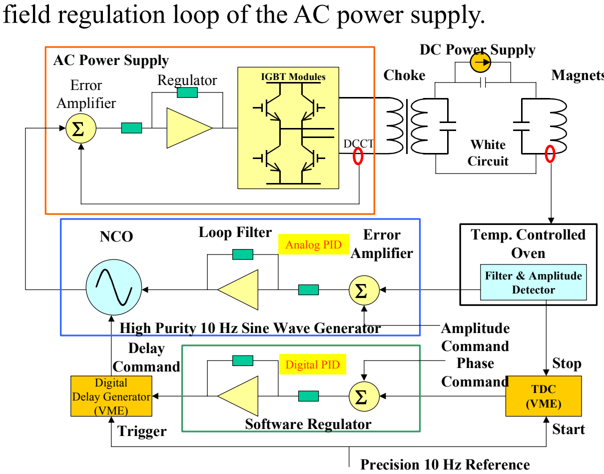

Figure 2: Current and phase regulation loop of the AC power supply.

Phase Regulation

Another input to 10-Hz sinusoidal wave generator is the phase control signal. In the phase regulation loop, the zero cross detector, time digital converter monitor the dipole AC power supply. The timings of the focusing quadrupole and the defocusing quadrupole AC power supply reference to the dipole and compared with the phase reference and the result is sent to the PID controller. The PID controller implemented in the software system to make the system more stables. Figure 2 shows the phase regulation loop of the AC power supply.

PERFORMANCE MEASUREMENT OF THE WHITE CIRCUIT

Performance of the Measurement System

A high performance measurement system was established using a Keithley 2701 6-1/2 digits digital multimeter (DMM) with the Ethernet interface to characterize the performance of the White circuit. This DVM equips with a multiplexer integrated in the control system. A Keithley 263 calibrator/source is used to simulate the signal form power supply to ensure the performance of the measurement system. Figure 3 shows 14 hours of typical test result. All channels have been gone through the same test and obtain the same results. The measured long-term and short-term performance is approximately 1 ppm in root-mean-square. Therefore this measurement system is reliable.

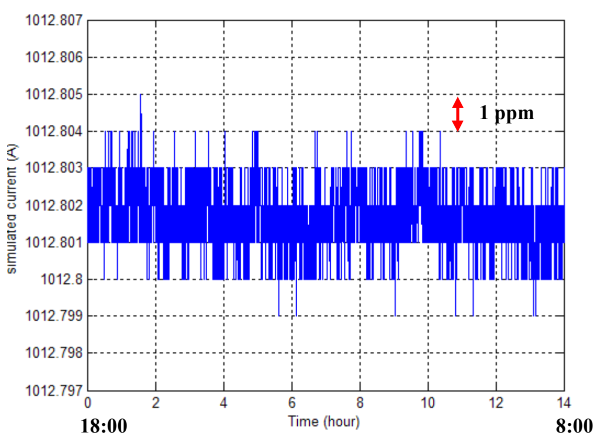

Figure 3: Performance of the measurement system.

Current Stability of the White Circuit

The DC dipole power supply increases the output current slowly; steady state output is achieved after one hour. However overall the DC dipole power supply peak-to-peak fluctuation is less than 20 ppm (p-p) after half an hour as shown in Fig. 4. DC current fluctuations of FQ and DQ magnet are less than 30 and 45 ppm (p-p) respectively.

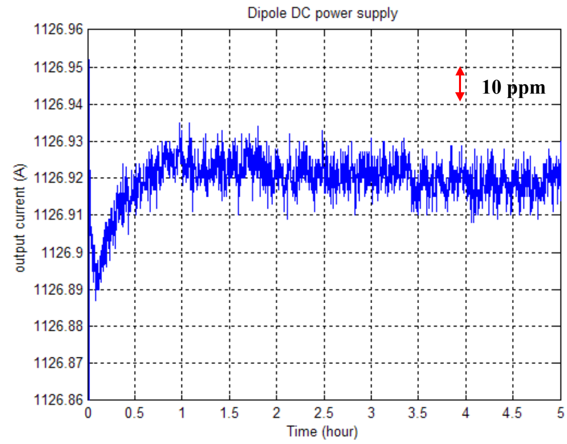

Figure 4: Performance measurement of dipole DC current.

Figure 5, 6 and 7 present the current stability performances of the AC dipole, FQ and DQ magnets. AC current fluctuations of the dipole, FQ and DQ magnets are less than 100, 80 and 130 ppm (p-p) respectively.

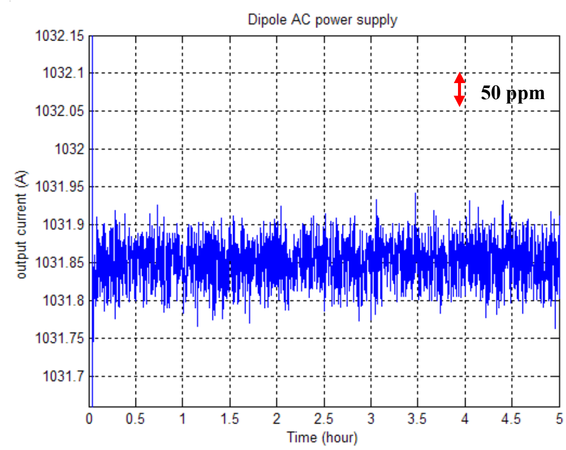

Figure 5: Performance measurement of the dipole AC current.

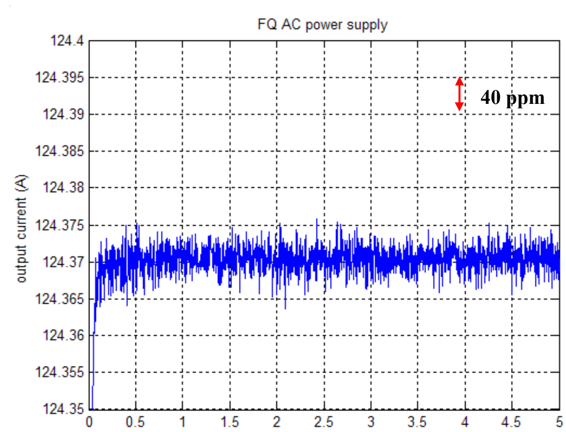

Figure 6: Performance measurement of the FQ AC current.

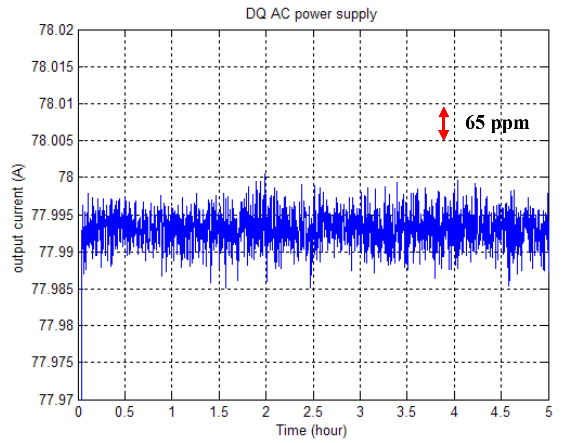

Figure 7: Performance measurement of the DQ AC current.

Phase Tracking Stability of the White Circuit

The tracking of the magnet input current for dipole magnet and quadrupoles is crucial to the operating performance of the booster synchrotron to with less tune variation. The phases of the focusing quadrupole and the defocusing quadrupole are referenced to the current phase of the dipole. Figure 8 and 9 shows the phase of FQ and DQ relative to the dipole current phases. A typical phase can be tracked within 1μs (0.0036°, or 10 ppm of 100 msec cycle time). Drift after the cold start is due to the resonance frequency change of the White circuit. The frequency change is due to the capacitance change with respect to very small ambient temperature increase. Our measurement shows that the temperature coefficient of the capacitor is approximately 150 ppm/°C.

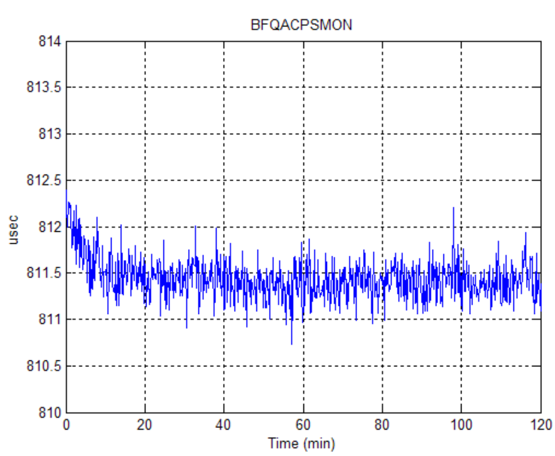

Figure 8: Relative phase of FQ current and dipole current.

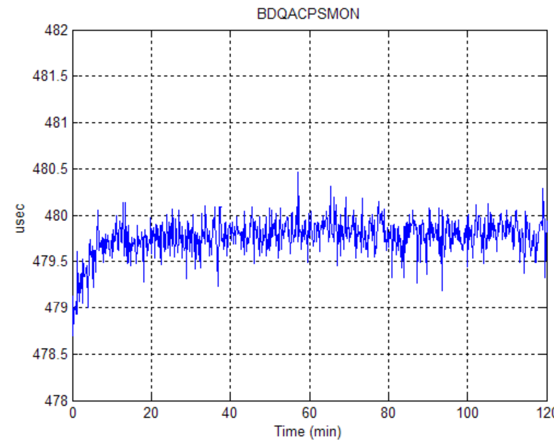

Figure 9: Relative phase of DQ current and dipole current.

FUTURE WORKS

Upgrades to improve the top-up mode operation of the booster synchrotron White circuit will be undertaken.

The following improvements will be implemented:

- A new amplitude and phase detector will be developed to replace the existing one.
- The PID parameters of the regulator will be optimized to improve the performance of the White circuit and find the solution to eliminate thermal effects and environment disturbance.

The goal is to enhance the performance of the White circuit to satisfy the stringent requirements of routine top-up mode operation.

REFERENCES

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