PERFORMANCE OF THE NEW WHITE CIRCUIT IN UPGRATED 1.5 GeV BOOSTER SYNCHROTRON

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Abstract

To meet 1.5 GeV full energy injection requirement, the booster synchrotron of SRRC was upgraded from 1.3 GeV to 1.5 GeV. Its magnet system was power from the White Circuit operating on 10 Hz resonant excitation. Because the limitation of old magnet power supplies rating prevents the booster synchrotron from carry out 1.5 GeV full energy injection, the White Circuit system were modified and new high performance IGBT based switching power supplies were installed to replace the old GTO based power supply. A PID control algorithm was implemented to regulate amplitude and phase to remove the thermal effect and another environment disturbance. Operating performance will be presented in this paper.

1 INTRODUCTION

Three independent White Circuits were install in the injector for dipole, focusing quadrupole and defocusing quadrupole magnets. 10 Hz-repetition rate and White Circuit were chosen for decreasing the energy load demands [2].

In the White circuit, a DC power supply was need to provide a DC bias, and two capacitor banks were installed in parallel to bypass the AC voltage. A White choke is a AC inverter coupling the excitation current from the AC power supply output. AC power supply is an AC current converter, its reference was provided from a high purity 10 Hz sine-wave generator [3].

White Circuit was excited 10 Hz sine-wave current, its both phase and amplitude of the sine-wave current in the magnet should be controlled. In order to improve the phase and amplitude stability, a proper controller is need. The task of the phase and amplitude regulation loop is to monitor and control the both phase and amplitude of current between the dipole magnet AC power supply, defocusing quadrupole magnet AC power supply, and focusing quadrupole magnet AC power supply.

2 OPERATING PRINCIPAL

The injector has three same White Circuit schematics. The current behavior in magnets follows the equation [1].

$$I_{magnet}(t) = I_{dc} + I_{ac}\cos(\omega t)$$

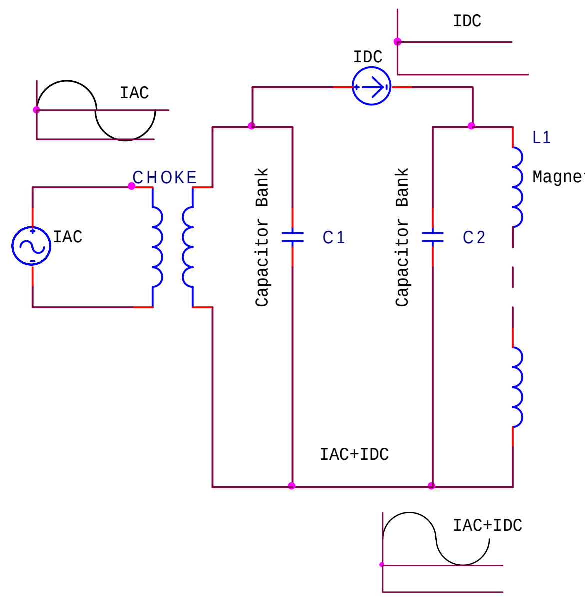

Figure 1. White Circuit

Magnet system in SRRC has 12 dipole magnets, 12 focussing quadrupole magnets and 12 defocusing quadrupole magnets, each magnet group was excited by the White Circuit.

Each White Circuit consists of two resonant LC circuits with the same nature frequency, the two circuits are connected by a bypass capacitor bank and DC converter. It superimposes the DC current from DC power supply on the AC current from AC power supply. It provides a sine-wave current swinging between 0 and maximum current, the amplitude and phase of both AC and DC components can be controlled. Field and phase regulations were implemented in injector control system.

3 SYSTEM CONFIGURATION

The power supply control interface provides amplitude reference to DC power supply and provides phase and amplitude regulated high spectral purity 10 Hz reference to AC power supplies in the new injector control system.

3.1 Field Regulation

In the injector magnet system, it includes three family main power supplies, one is dipole AC power supply and the other is focussing quadrupole AC power supply, the third is defocusing AC power supply. In order to keep constant current ratio between the dipole magnet and quadrupole magnets while the White Circuit resonant excitation, a magnet AC current compensation function was need. In the figure 2, it presents one of three families AC power supplies control interface and magnet AC current regulation loop. Which a high purity 10 Hz sine-wave generator and also is an amplitude regulator was implemented in the regulation loop to compensate the AC power supply current output.

In order to improve the performance of AC power supply, a PID controller was built in the AC power supply control interface to avoid the environment disturbance and thermal effect. For the base requirement, a measurement about magnet fields amplitude spectrum from a DCCT and peak detector less then -80db.

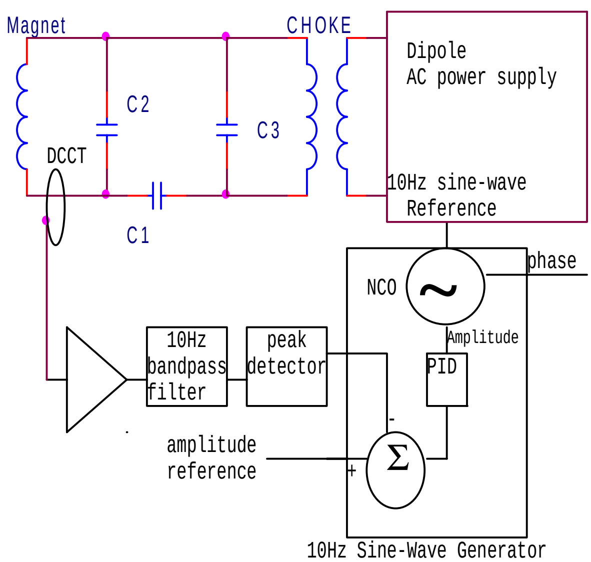

Figure 2. Dipole magnet AC current (magnet field) regulation

3.2 Phase Regulation

In the phase regulation loop, dipole AC power supply is free running with a 10 Hz sine-wave generator, its phase was monitored by zero crossing detector and time to digital converter. The figure 3 show that dipole AC power supply is a master for all the quadrupole power supply. An application program controlled the current phase relations to the dipole magnet of both two quadrupole magnets in the control system.

A proper PID control algorithm was implemented in the software phase regulation loop. The timing of the focusing quadrupole magnet and the defocusing quadrupole magnet are calculated with the dipole magnet current phase and a set point reference. For the injector overall stability and a great phase tracking, less than 1 µs phase shift was demanded.

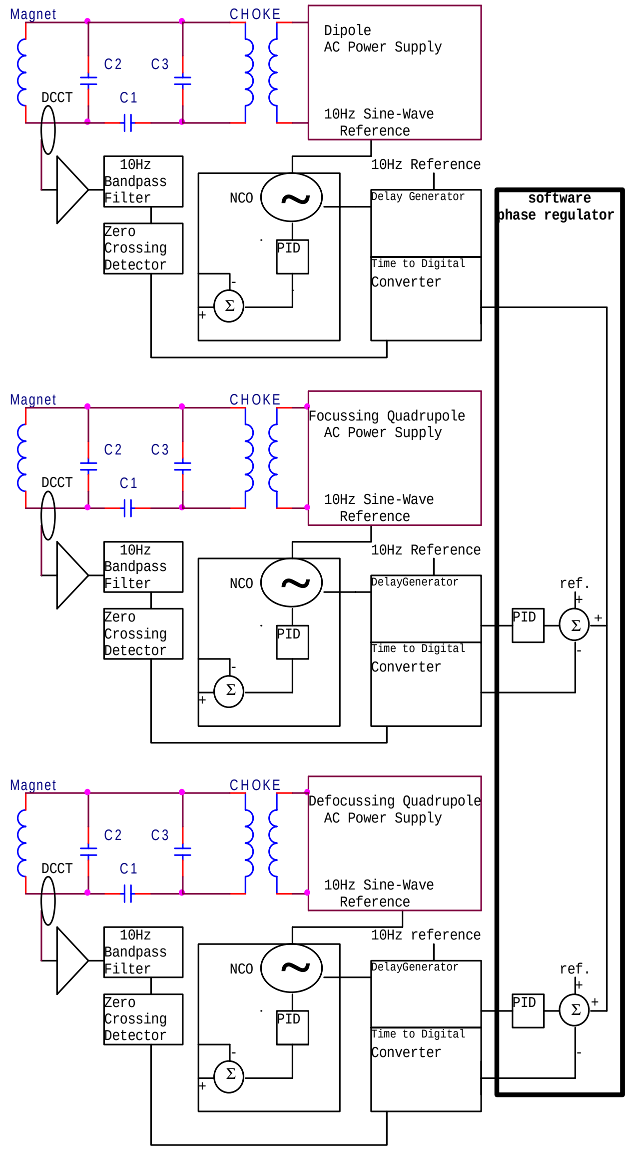

Figure 3. AC power supply phase regulation

4 PERFORMANCE OF THE WHITE CIRCUIT

4.1 Phase Tracking Stability

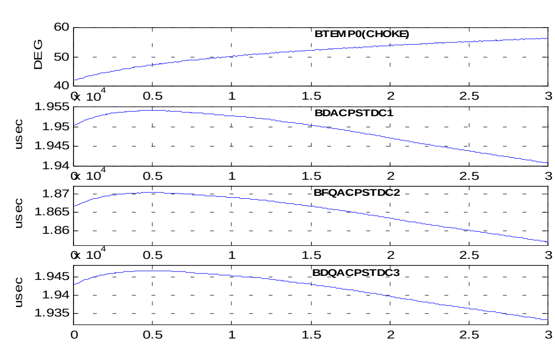

Figure 4. Dipole White choke temperature history and three family AC power supplies phase tracking

In the figure 4, it shows the dipole White choke temperature increases from room temperature to fifty-seven degree after a cold start. But the overall phase tracking stability still keeps under 1μs. Owing to the dipole White choke and capacitor bank temperature increasing, first the dipole White Circuit phase increase, when it cross the dipole White Circuit resonant frequency point, and then the phase decrease. A proper phase regulation implement can reject the thermal effect during the injector operation [4].

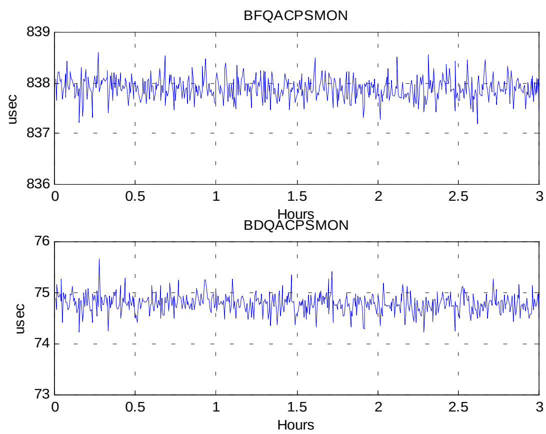

Figure 5. Phase tracking of FQ and DQ to Dipole

In the figure 5, it presents the performance about the phase tracking, either the focusing quadrupole magnet current phase reference to dipole magnet current phase or the defocusing quadrupole magnet current phase reference to dipole magnet current phase always keep below 1 μs during a three hours period.

4.2 Stability of Magnet Current

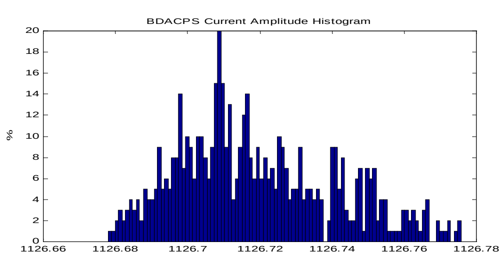

Figure 6. Histogram of the dipole magnet AC current amplitude, (Three hours)

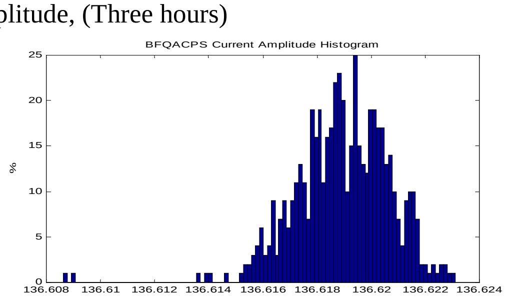

Figure 7. Histogram of the focusing quadrupole magnet AC current amplitude, (Three hours)

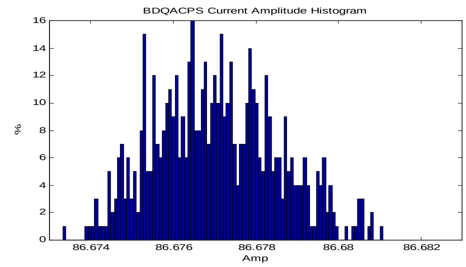

Figure 8. Histogram of the defocusing quadrupole magnet current amplitude, (Three hours)

From the figure 6, 7, and 8, these histograms describe the performance of the AC power supply output current in the White Circuit. An amplitude stability measurement below 20 ppm for all AC power supplies in three hours period.

5 DISCUSSION

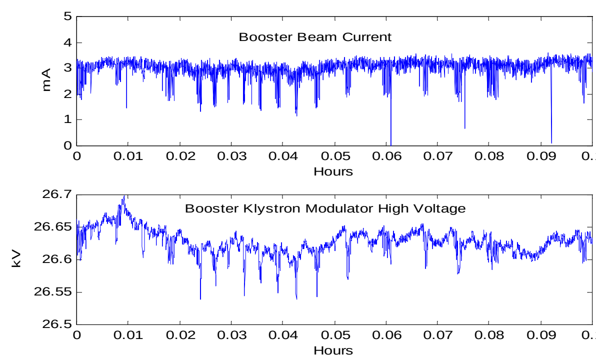

Figure 9. The correlation of booster beam current fluctuation and klystron modulator high voltage.

The figure 9 shows that there are strong correlation between the booster beam current and the klystron modulator high voltage. Improvements of the klystron modulator high voltage stability and other upgrade project are under going.

REFERENCES

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