CONTROL INTERFACE OF NEW WHITE CIRCUIT FOR SRRC 1.5GeV BOOSTOR SYNCHROTRON

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Abstract

To meet 1.5GeV full energy injection object, the SRRC booster system has been upgraded from 1.3GeV to 1.5GeV recently. High performance IGBT switching power supplies replace old GTO based power supplies. The main magnet family configures as three independent White Circuits and resonance excite at 10 Hz. Each White Circuit is drive by a DC and AC power supply. AC power supply is a four quadrant current amplifier. Control system need to provide a precision, low harmonic content 10 Hz sinusoid reference for this power supply. VME form factor 10 Hz reference generator was implemented. This module includes Numerical Controlled Oscillator (NCO) based sine-wave generator, amplitude regulator and synchronization circuitry for phasing control of three families White Circuit.

1 INTRODUCTION

The booster of SRRC has been upgrade recently to provide 1.5 GeV full energy injection for the 1.5 GeV storage ring. Major component of the White Circuit has been upgraded including the control of the White Circuit. Since the field tracking of magnet families is directly reflect to the performance of the booster, the control of the White circuit is an important issues [1,2,3]. There are three families of magnet drive by White circuit. Each circuit has two regulation loops to keep its amplitude and phase parameters constant. Each White Circuit is drive by a DC and AC power supply. The DC power supply is simple which will not discuss more. While AC power supply control is the core mission of the upgrade which are focus in this report.

2 FUNCTIONAL DESCRIPTIONS

The main magnet families configure three independent White Circuits and resonance excite at 10 Hz. Each White Circuit is drive by a DC and AC power supply. The controls system need provide amplitude and phase adjustable precision and high purity 10 Hz sinusoid reference for this power supply. The block diagram of White Circuit power supplies interface is illustrated in figure 1. The White Circuit power supplies interface consists of amplitude/phase detector module, High purity 10 Hz generator and amplitude regulator module, Digital Delay Generator (DDG), Time to Digital Convert (TDC), interlock and protection module, 16bits DAC and ADC module.

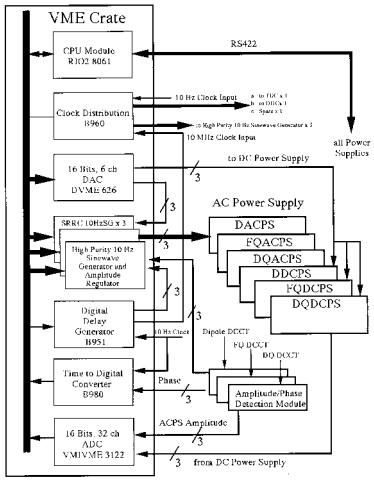

Figure 1: Block diagram of the booster power supplies control interface

3 DETAILS OF BUILDING BLOCK

This White Circuit power supplies control system major function includes amplitude and phase regulation [4]. The phase regulation loop purpose to keep constant phase difference between two quadruple families with dipole. Amplitude regulation loop purpose to keep magnet current with constant amplitude. the DAC module setting amplitude reference of DC/AC power supply, high purity 10 Hz sine-wave generator module to base on amplitude reference generate 10 Hz sine-wave for AC power supplies to control amplitude of White Circuit. The amplitude/phase detection module measures peak of magnet current for analog PID amplitude regulator of high purity 10 Hz sine-wave generator.

3.1 Amplitude and phase detector

The Amplitude/Phase detection module place in temperature controlled oven to ensure its long-term stability. This module directed to detect amplitude and phase of magnet current. There are several stage of filter on the module to eliminate various error source, 10 Hz band-pass filter to extract desire signal, 60 Hz notch filter to reduce the effect of power line interference. The measured magnet current by DCCT is via 10 Hz band-pass filter and peak-detection circuit to generated

amplitude information for amplitude regulator of high purity 10 Hz sinewave generator. The measured magnet current by DCCT is via 10 Hz band-pass filter and zero-crossing detection circuit to generated phase. The TDC module is used to measure magnet current phase.

3.2 High purity 10 Hz generator and amplitude regulator

Block diagram of the high purity 10 Hz generator and amplitude regulator as show in figure 2, it photo shown in figure 3. There are three function units on the board, VME interface, NCO/DAC and amplitude regulator. VME interface function is to provide interface decoder of status and control register for this module configures.

VME HOST through VME interface configure NCO after generate sinusoidal wave data via optical isolator to DAC, this optical isolator have a function to forestall interaction of digital and analog grounding. NCO/DAC is used to generate sinusoidal wave with very stable in frequency. The clock for the NCO is a oven-controlled 0.1ppm clock source, frequency stability is superior.

An analog PID regulator does the amplitude control. Amplitude reference to control multiply DAC output amplitude. Output phase of the 10 Hz sinewave reference is done to reload phase accumulator of NCO.

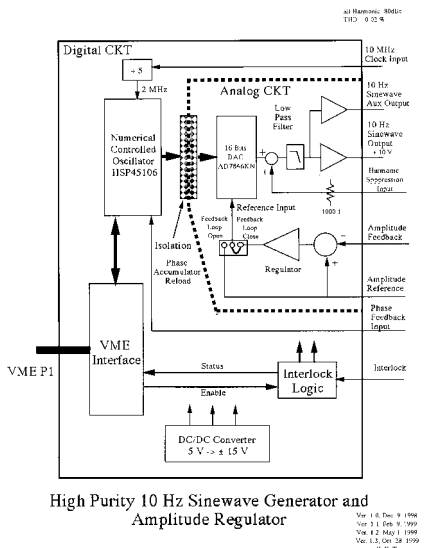

Figure 2: Block diagram of the 10 Hz high purity sine-wave generator and amplitude regulator.

Figure 3: Photograph of the 10 Hz sinusoidal generator and amplitude regulator.

3.3 Time to digital converter

Time to Digital Converter (TDC) is used to measure arrive time of the magnet current zero-crossing time difference with 10 Hz fiducial reference. Three families White Circuit use three TDC channels. The phasing control software keep make the TDC reading of QD and QF reading relative dipole constant by adjusting the delay generator output to adjust of the 10 Hz reference that drive power supply of both family quadruple White circuit. Commercial product TDC was use for this purpose.

3.4 Digital delay generator

Digital delay generator is use to provide a delayed output relative to precision 10 Hz fiducial reference and provide the phase control of three 10 Hz reference sinewave output.

3.5 Phase regulation

The DDG module setting 10 Hz trigger signal phase for high purity 10 Hz sine-wave generator module produce related to 10 Hz sine-wave output of the 10 Hz trigger phase. The DCCT device to sense output amplitude of magnet current for amplitude/phase detection module direct detection output phase of magnet current feedback to TDC module to proceed software PID phase regulation and supply to rectify phase for DDG module.

A software PID regulator is used to keep constant phase difference between two quadruple families with dipole circularity. Input of the regulator is TDC reading and output is delay value of digital delay generator.

3.6 Interlock and protection

There is several interlock to protect form the operation fault except the self protection function of power amplifier, and the other mechanical protection. Since there are several element within the feedback loop, the protection use DCCT output, DC power supply output Polarity.

4 TEST RESULTS

The performances of White Circuit have test, the White Circuit amplitude tracking and phase tracking between dipole and quadrupole field.

4.1 Signal purity

In TLS case, the 10 Hz source generator spectrum as show in figure 4. Higher order harmonics is about -85 dBc compare to 10 Hz fundamental peak. The 10 Hz source

spectrum quality limited by DAC glitch. The Dipole ACPS output spectrum higher order harmonics is –80 dBc compare to 10 Hz fundamental peak (see figure 5). Dipole current spectrum higher order harmonics is –50 dBc compare to 10 Hz fundamental peak (see figure 6). Dipole Field spectrum higher order harmonics is –60 dBc compare to 10 Hz fundamental peak (see figure 7). Nonlinearly of White Circuit choke is prominent the spectrum of magnets current.

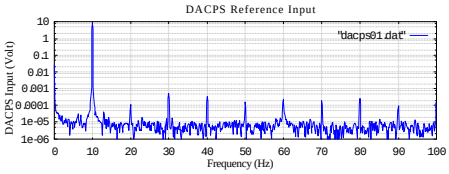

Figure 4: Output spectrum of 10 Hz signal generator.

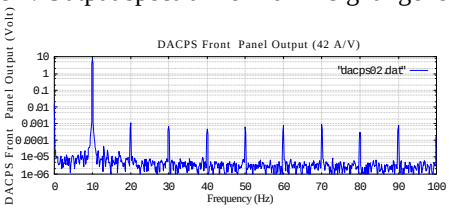

Figure 5: Spectrum of DACPS front panel output.

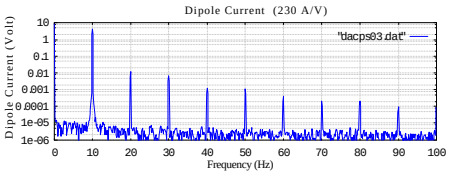

Figure 6: Spectrum of Dipole Current.

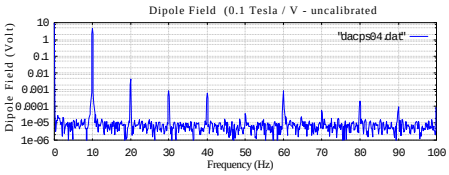

Figure 7: Spectrum of dipole field.

4.2 Amplitude regulation performance

The performance of the amplitude can be seen from the step response of the feedback loop as show in figure 8. The amplitude regulation settling time about 2 sec.

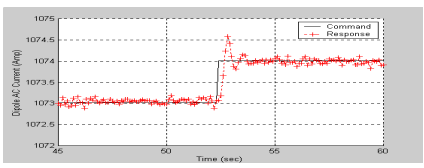

Figure 8: Amplitude regulation step response.

4.3 Phase regulation performance

The performance of the phase regulation can be seen from the step response of the feedback loop as shown in figure 9. On the figure 10, the difference of zero crossing time difference of dipole and focus quadruple is shown.

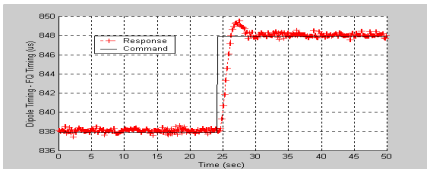

Figure 9: Phase step response

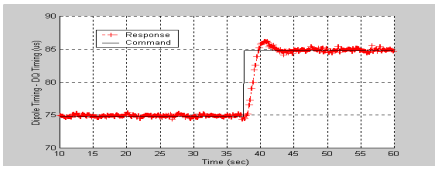

Figure 10: Phase step response

5 SUMMARY

Using amplitude regulation loop and phase regulation loop to control amplitude and phase of White Circuits. Amplitude regulation loop purpose to keep constant magnet current amplitude. Phase regulation loop purpose to keep constant phase difference between two quadruple families with dipole. Tracking of magnet families is done by above two regulation loops. The high purity 10 Hz generator VME module is to provide a high purity 10 Hz sinusoidal source and provide amplitude regulation. Higher order harmonics is about -85 dBc compare to 10 Hz fundamental peak. The spectrum quality of 10 Hz source limited by DAC glitch. The Dipole ACPS output spectrum higher order harmonics is –80 dBc compare to 10 Hz fundamental peak. Dipole current spectrum higher order harmonics is –50 dBc compare to 10 Hz fundamental peak. Dipole Field spectrum higher order harmonics is –60 dBc compare to 10 Hz fundamental peak. Nonlinearly of White Circuit choke is prominent the spectrum of magnets current. In spite of current situation enough basic requirement of the booster, but continued to promote signal purity is very important.

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