UPGRADE TO THE SRS 10 Hz BOOSTER POWER SUPPLY

S A Griffiths, P Dickenson, S J Hands and R J Smith
CLRC, Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, UK

Abstract

The Synchrotron Radiation Source (SRS) at Daresbury Laboratory has a 600MeV, 10Hz Booster, with magnets fed by an energy storage power supply configuration (White Circuit). The design consists of two power supplies, an AC inverter to supply the losses to the high 'Q' parallel resonant circuits and a DC supply to fully bias the AC sinewave. The high stability power supplies are now 30 years old and employ roller regulator transformer technology. They have become increasingly unreliable, with fault diagnostic and calibration difficulties. This paper describes the upgrade to the AC power supply, in particular the new control electronics and its comprehensive monitoring and fault diagnostic system. The proposed re-design to the DC supply is also summarised.

1 INTRODUCTION

Although the booster AC and DC power supplies may look 30 years old, with their original exteriors, they bear no resemblance to their initial design. The last upgrade was 12 years ago, when their control electronics were redesigned; they both still operate with roller regulator units, but with series transistor bank regulation for the DC supply and thyristor rectifier and inverter for the AC supply. Their poor documentation, obsolete components, minimal spares and the old technology, with limited fault diagnostics have affected their reliability in recent years, with the number of faults and downtime increasing as a consequence.

A low cost solution to improve reliability, performance and stability is necessary to guarantee operation for the remaining lifetime of the SRS, a predicted 7 years. The majority of the power supply failures are in, or as a direct result of, the control electronics, either component failure or calibration error. The power electronic circuits are old and improvements in efficiency, reparability and simplification of design can be achieved. Despite this, the power electronics are reliable and with a limited budget the most significant benefit will be gained from a control electronics upgrade.

2 AC POWER CONVERTER OPERATING PRINCIPLES

The AC power converter supplies the resistive losses to the 10Hz parallel resonant circuits via an energy storage choke. The output current stability is regulated by the control of the thyristor rectifier, with the resonant frequency governed by the circuit components. To start the system the power supply initially forces the 'White Circuit' to oscillate at a frequency slightly higher than the resonant frequency. This is achieved with a start-up oscillator and the system operating in open loop. Once a significant signal is obtained from the 'White Circuit', frequency and amplitude feedback can be applied.

The choice of start-up frequency is critical to a successful turn-on of the supply. The results in Table.1 show that due to the high 'Q' of the resonant circuit, the internal frequency must be within a band of 0.118Hz accuracy, to guarantee turn-on. An operating window of 0.024Hz is available to change to frequency feedback. The 'delay' is the phase difference between the internal oscillator signal and the feedback signal from the 'White Circuit' during forced operation. The delay is zero when the internal and resonant frequencies are equal. The power converter will become unstable and fail on overcurrent if the wrong frequency is selected.

Table 1: Range of selectable start-up frequencies.

Internal Frequency	Delay (ms) Resonant - Internal	Turned ON Internal Oscillator	Changed Over To Resonant
9.810	0.0	x	x
9.822	1.0	x	x
9.834	2.0	x	x
9.846	3.0	x	x
9.860	4.0	x	x
9.866	4.5	v	v
9.871	5.0	v	v
9.879	5.5	v	v
9.885	6.0	v	v
9.890	6.5	v	v
9.896	7.0	v	x
9.910	8.0	v	x
9.924	9.0	v	x
9.945	10.0	v	x
9.970	11.0	v	x
9.984	12.0	v	x
9.998	13.0	x	x

The turn 'ON' procedure is influenced by changes in ambient temperature and magnet current and their effects on the resonant frequency. The results in Table.2 show the frequency varies by 0.027Hz when the DC bias current is applied. A further 0.02Hz is added when the AC is increased. A fixed start-up frequency is not sufficient to guarantee turn-on at all bias currents.

Table 2: Change of resonant frequency with DC bias.

Dc current (Amps)	Frequency (Hz) AC = 127A	Frequency (Hz) AC = 600A
0	9.812	9.8
283	9.815	9.805
300	9.816	9.806
350	9.819	9.809
400	9.823	9.812
450	9.827	9.817
500	9.83	9.824
550	9.834	9.834
600	9.839	9.85
Change	0.027	0.05

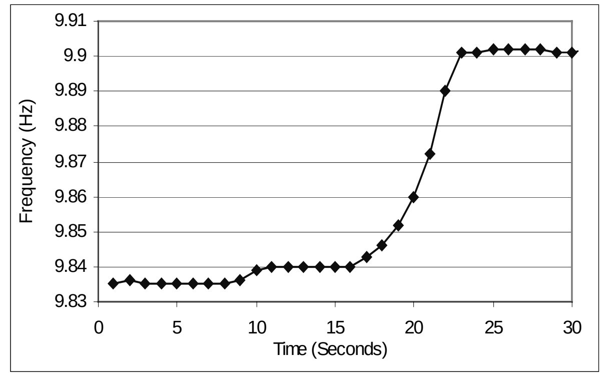

Figure 1: Change in resonant frequency with DC bias

3 AC POWER CONVERTER DESIGN SOLUTIONS

3.1 Overview

The preliminary design solution is to provide a system, with comprehensive monitoring and fault diagnostic facility, which is capable of identifying the optimum start-up frequency. The simplest design is to set a fixed internal frequency and program the start up sequence so the AC supply is turned-on with the DC off. This is not ideal and the alternative is to use an intelligent controller which can measure the resonant frequency, allowing the internal oscillator to be set to its optimum. To achieve this the system is operated in open loop (to prevent change over to the frequency feedback) to provide a broader range of turn-on frequency as shown in Table.1. The phase displacement between the internal and feedback signals can then measured. The new start-up frequency is then calculated and set manually.

The design uses a Programmable Integrated Circuit (PIC) 16C715 - 20 to generate the internal frequency; this can be adjusted by thumbwheel switches to 1mHz resolution with 100 selectable frequencies. The internal and resonant frequencies are displayed on a liquid crystal display, along with the time delay during forced operation.

3.2 Protection

To help prevent synchronised firing of adjacent thyristors, the present system differentially monitors the voltages generated across diodes in each leg of the H-bridge. During diode conduction the electronics uses these signals to inhibit the firing of the opposite thyristors. The operation of these signals is critical during changeover from internal to frequency feedback, but voltage transients within the power electronics can be transmitted to the control board and cause component failure. The facility is then lost and the window for turn-on is reduced. This is resolved by the introduction of two low resolution DCCTs, which provide galvanic isolation to the control electronics. The pulses from the DCCTs are initially inhibited to prevent incorrect firing of the thyristors due to noise during low current conduction.

3.3 Amplitude Stability

Currently amplitude stability of the supply is provided by a complicated in-house designed 'sample and hold circuit', which relies on accurate control of a capacitor charging time and temperature coefficients during each cycle as shown in Figure.2.

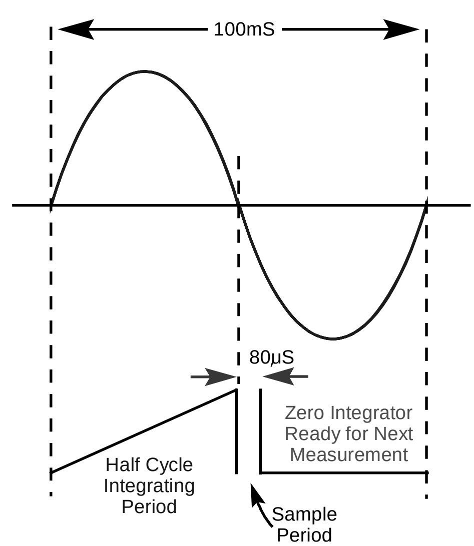

Figure 2: Present Sample and hold circuit.

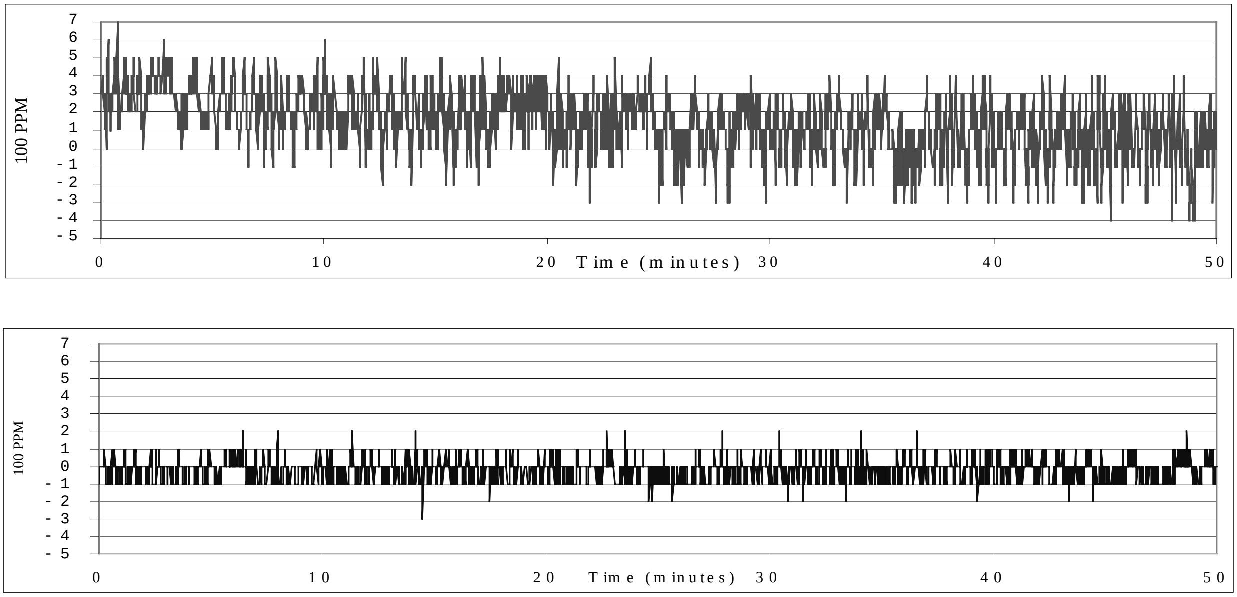

Figure 3: Amplitude stability plots of old (top) and new (bottom) control electronics

This will be replaced with a simple RMS to DC voltage converter and signal conditioning. The stability plots for the old and new systems are show in Figure.3 and demonstrates the improvement in short and long term stability.

3.4 General

The control crate and modules are designed to provide accessibility and reparability. The modules contain built in test and comprehensive fault diagnostic facilities.

4 FUTURE AC POWER CONVERTER UPGRADE

The second stage of the AC power converter upgrade is to enable the PIC to synchronise the firing of the thyristors irrespective of the resonant frequency.
Two Possible Solutions are:

- the electronics initially fires one cycle of the circuit, which allows the frequency of the feedback signal to be measured without overcurrent failure. Once the resonant frequency has been recorded the PIC can automatically set the internal frequency and start the supply;
- alternatively the feedback signal gained from firing one cycle of the circuit as above, is used to synchronise the firing immediately to give instant closed loop control, removing the need for an internal oscillator.

5 DC POWER CONVERTER UPGRADE

The DC power converter is not suited for efficient operation and is susceptible to mechanical failures and requires regular maintenance. To purchase a new unit is not practical and it is intended to develop the supply as follows:

- replace control electronics with a system containing extensive fault diagnostics;
- provide identification of any series regulation transistor failures, interlocked to trip system if 10% fail;
- provide monitoring points for the transistor bank feedback waveform, closed loop error signal and roller regulator voltage output;
- replacement of the DCCT with a high stability equivalent;
- rewire the DC power converter controls cable;
- provision of a complete set of spares.

6 SUMMARY

It is expected that by the summer 2001 the upgrades to the Booster AC and DC power converters will be complete.
As a result there should be a significant reduction in:

- Faults - with the improved control board protection, crate design and modern technology;
- Downtime - due to improved fault diagnostics, availability of spares and full circuit documentation;

The AC supply should be capable of switch-on irrespective of the DC bias setting. There will have been a notable enhancement in power converter performance particularly in stability and accuracy.