DEVELOPMENTS IN MAGNET POWER CONVERTERS AT THE SRS

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Abstract

A project to upgrade the magnet power converters of the SRS has commenced to ensure its efficient operation for its remaining operational lifetime. A recent risk analysis of the facilities equipment identified that the main areas for concern were the Storage Ring magnet power converters, kicker and septum pulse power supplies and the Booster Dipole "White Circuit" and associated power converters. This report details the development and replacement programs currently active at Daresbury Laboratory, including future work identified to support and improve SRS utilisation.

INTRODUCTION

Power converters in the areas identified as being vulnerable have, over the lifetime of the Synchrotron Radiation Source (SRS) been generally reliable. However, it is recognised that some of the equipment is reaching the end of its operational life and reliability, obsolescence and environmental issues need to be addressed along with consideration of associated costs.

This paper discusses the approach taken for the areas identified as being at risk and the solutions applied. The paper will also discuss future work identified to further improve SRS reliability.

AREAS OF POWER CONVERTER DEVELOPEMENT

Main Storage Ring Power Converters

Availability of the Main Storage Ring power converters currently in use at Daresbury Laboratory is crucial to maintaining high quality user beam. Any failure of these units must be rectified in the shortest possible time to enable prompt return to operational conditions.

There are 5 main storage ring power converters operating in the range 90KW to 750KW. These power converters were installed in 1994 replacing the original roller regulators [2]. Thyristor topology using phase-shift control regulates current to the main storage ring magnets. It is important that the current is controlled to very tight tolerances to meet the requirements for precise control and positioning of the stored electron beam. Current stability is required to be >100ppm (10^{-4})A and is achieved by use of precision DCCT's and 16-bit DAC/ADC.

The 5 power converters can be divided into two categories. Three units are fed from 3-phase 400-volt supplies and have internal isolation transformers for load matching and operate in the range 90KW to 250KW. The other two have separate extended delta transformers fed at 11KV with dual secondaries at 485 volts phase-shifted by ± 15°.

Daresbury have utilised power converters which became available from the LEP decommissioning at CERN which closely matched the ratings and technology of the existing SRS main magnet power converters.

To take full advantage of these standby units a rapid and reliable changeover system was incorporated as shown in Figure1.

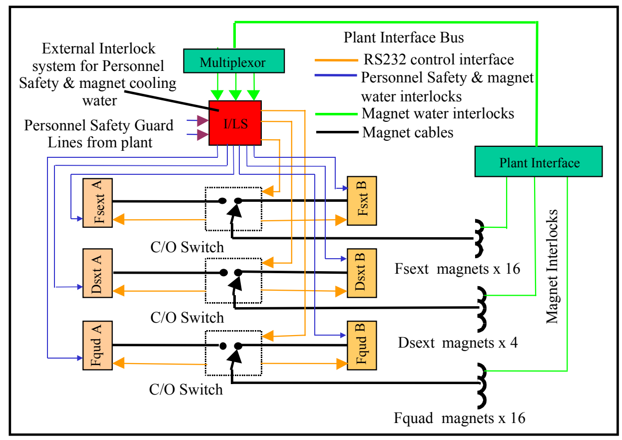

Figure1: Outline of changeover scheme

The existing Dquad and Dsext units have the same ratings. The Dsext unit was tapped on the isolation transformer to provide the correct voltage and current ratio for the load impedance. Re-tapping the existing Dsext power converter enabled this unit to become the standby for the Dquad. Two of the new units then became Dsext and Dsext standby. The new power converter designated for Fsext operation had correct power rating but was designed for half the load impedance. This unit was modified to match the Fsext load by replacement of the transformer, filter choke and capacitors, thyristors, free-wheel diodes and DCCT's providing a low cost solution for a standby system.

Table1: Power Converter Specifications

Magnet family	Existing Units		New Units	
	Amps	Volts		
Dipole	1500	500	Future Project	
Fquad	1500	500		
			Amps	Volts
Fsext	600	400	510	315
Dquad	450	200	450	200
Dsext	450	200	250	360

To enable power converter testing a "dummy load" was required. An existing but out of commission water-cooled unit, capable of sinking 450kW was identified, recommissioned and cooling water flow and temperature interlocking added.

Improvements to the external interlocking system were implemented, with a new system being designed. A detailed risk assessment was carried out to ensure no possibility that the on-line or standby power converters could be operated without the Personnel Safety System, (PSS), being healthy. The design allows for off-line testing into the dummy load and improved indication of interlock status via front panel LED's. Key switches provide power converter external interlock testing.

Auxiliary changeover switches operated simultaneously with the main DC changeover switch connect the selected power converters to the main control system and magnet water interlocks.

Kicker & Septum Pulse Power Supplies

10 pulse power supplies are currently in operation within the booster and main storage rings of the SRS, 3 for septum and 7 for Kicker applications. A project was initiated to replace the booster extraction and SR injection Septum pulse power supplies. This work will enable future development of the Kicker units.

Using the CX1154 thyratron device to switch high current pulses to divert the electron beam, Septum power supplies typically provide 25µS pulses of 8kA @ 3.6kV. Kicker power supplies switch significantly faster, 2.5µS pulses of 3.5kA @ 10kV both at a 5Hz repetition rate.

Triggering of the Septum and Kicker power supplies is synchronised to the booster 10Hz cycle. At maximum booster field the Septum is "triggered" and at peak Septum field the Kicker is "triggered". See figure 2.

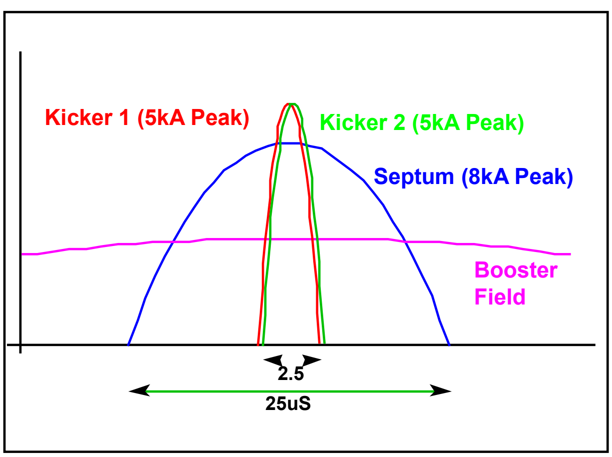

Figure 2: Timing of typical Kicker and Septum Pulses

Reasons for Change

All SRS pulse power supplies are currently in-house designs their reliability is reasonable but repair times can be excessive. The thyratron valves are expensive and require replacement approximately every 3 years. Obsolescence, maintainability and cost issues have driven the search for replacements.

A low cost modular solution was procured with thyristor switching technology. The units were modified to meet EU standards [5], on safety and wiring regulations and the control interface redesigned for compatability with the SR control system.

Solid-State Circuit Operation

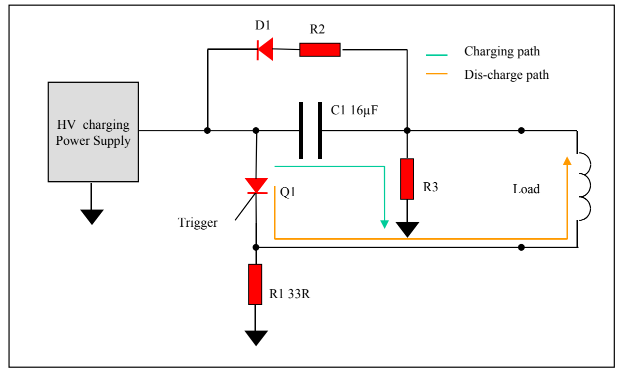

Figure 3: Outline of Solid-State Pulse Power Supply

At initial switch on thyristor Q1 is turned off. Capacitor C1 charges from the HV power supply through R1. On receipt of the trigger pulse thyristor Q1 turns on rapidly discharging capacitor C1 into the load inductance. Once discharge current reaches its peak and C1 is fully discharged the freewheeling diode D1 becomes forward biased dissipating the stored energy in the load inductance. Current stops flowing through thyristor Q1 and it turns off.

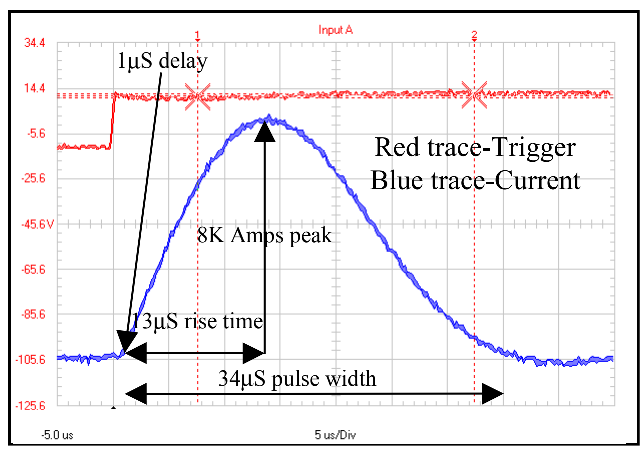

Figure 4: Output Current Response of Solid-State Pulse Power Supply

2 of the first 3 pulse power supplies procured will replace the existing booster extraction Septum and SR injection Septum units. The third unit will be used as a prototype for further development and will be available as a spare if required.

The main parameters for a solid-state design are as follows:

- Half sinewave current pulse waveform
- Output pulse duration of 25µS – with rising edge to peak of 13µS
- Delay between trigger and output pulse <1µs

- Output pulse jitter <2nS between consecutive pulses

Booster White Circuit

The SRS White Circuit consists of two tuned LC circuits with a resonant frequency of 10Hz. A DC power converter provides full bias to offset the AC current. The AC power supply replaces losses in the circuit through an auxiliary winding on the energy storage choke.

The SRS booster contains 16 dipole magnets with a total inductance of 96mH. The peak stored energy is given by $\frac{1}{2}LI^2$ = 87.5 kJ, cycled at 10Hz. If a direct mains source was used the input power required would be 875kW. The White Circuit allows the energy to be cycled between the inductance and the capacitance so that the AC power supply has only to overcome losses in the circuit. These are approximately 147 kW.

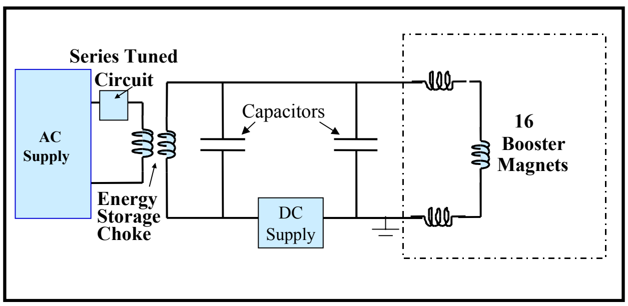

Figure 5: Outline of SRS Booster White Circuit

The booster is essential to the SRS performance and possible risks to reliability must be minimised

Energy Storage Choke

The SRS white circuit used 5 recycled magnets of the same specification, 4 in the energy storage choke and 1 in the series tuned circuit. Failure of one of the 4 magnets in the energy storage circuit could cause major downtime and be extremely expensive to repair or replace. The magnet of the series tuned circuit has been replaced with a new purpose designed unit. This magnet is now available as a spare for the 4 used in the energy storage circuit.

Energy Storage Capacitors

The capacitors used in the energy storage circuit have been operational since the SRS started in the early 1980's, considerably exceeding their expected lifetime of 15 years. Although there have not been any electrical or leakage failures their age presents an increasing efficiency risk.

An electrical failure would cause a short shutdown whilst a spare unit is fitted. However a leak of the dielectric fluid, in the form of PolyChlorinated Biphenyls (PCB's) could cause a major shutdown due to contamination of the area and other equipment. This is also an environmental issue as equipment identified as containing PCB's now have to be removed from service under EU legislation [3]. Any project that involves the replacement of PCB contaminated components must allow for the disposal costs. These can be nearly 30% of the new capacitor costs.

A program was initiated to review circuit performance following which the AC and DC power converters have recently been upgraded, [1].

FUTURE DEVELOPMENTS

Main Storage Ring Power Converters

Contingency plans to cover a failure in the 2 remaining main storage ring power converters are currently under review. Two options are available. Option 1 would provide a shared backup power converter and switching system whilst option 2 would ensure that all necessary spares are available in the event of a breakdown. Option 1 would minimise downtime but will be more expensive to provide, whilst option 2 would extend downtime but would be cheaper to implement.

Pulse Power Supplies

Future development in implementing solid-state switching for faster pulsed Kicker power supplies relies on availability of switching devices capable of handling 5kA at several kV. Development of IGBT and higher speed thyristor devices is ongoing at the major manufacturers, [4].

White Circuit

Using a DCCT and suitable software to develop firmware to improve stability and reduce non-linearity of the current feedback control loop.

Other Areas of Development

Switch-mode modular MCOR units from BiRa Incorporated are being installed to provide improved performance, <100ppm, at lower cost for bi-polar applications in Pole-face windings and Trim magnet power converter applications. Consideration is being given to the use of these units in upgrading steering magnet systems where improved current stability near zero current is essential.

REFERENCES

[1] S.A. Griffiths, P. Dickenson, S.J. Hands and R.J. Smith. Upgrade to the SRS 10Hz Booster Power Supply

[2] D.E. Poole, S.A. Griffiths and M. Heron. New Magnet Power Converters for the SRS at Daresbury.

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[4] A. Welleman, J. Waldmeyer, E. Ramezani, ABB Switzerland Ltd, Semiconductors Solid Sate Switches for Pulse Power Modulators.

[5] The Low Voltage Directive 73/23/EEC