Diagnostic and Protection Systems for the Daresbury SRS Upgrade

J. A. Balmer, M. J. Dufau, D. M. Dykes, B. D. Fell, M. T. Heron, B. G. Martlew, M. J. Pugh, W. R. Rawlinson, R. J. Smith, S. L. Smith, B. Todd.

CLRC Daresbury Laboratory
Warrington, WA4 4AD, UK

Abstract. The UK light source, the SRS, is being upgraded by the addition of two multipole wiggler magnets. The reduced aperture of +/–7.5 mm within the titanium alloy tube has provided the opportunity to incorporate new sensitive electron beam position monitors. Due to investigations into the effects of synchrotron radiation striking uncooled surfaces, software and hardware vessel protection systems have also been incorporated for machine protection.

INTRODUCTION

The 2.0 GeV second generation Synchrotron Storage Ring at Daresbury, the UK's only synchrotron radiation light source, is now a mature machine. It provides facilities for over 2500 users from both academic and commercial backgrounds. The primary source of radiation is the 16 dipole magnets. In order to provide significant improvements, insertion devices have been added. Currently two superconducting wavelength shifters and one undulator have been completed and are now fully exploited. As a continuing policy to develop and improve the existing facility, further upgrades are scheduled to take place later this year. These involve the addition of two identical 2.0 Tesla permanent magnet multipole wigglers (MPWs) to the lattice. Due to the small space available (1.1 m) in the straight section locations, it was necessary to design the devices with as short a period as possible and with a small gap. To accommodate this requirement, a long, thin-walled titanium vessel has been designed, prototyped, and installed in advance of the MPW magnets, in order to demonstrate successful operation of the SRS with the 15 mm inertial gap. This small gap has presented problems not previously encountered with the current SRS machine vessels. Small-angle, mis-steered incident photon radiation from the upstream dipole presents a serious danger to this vessel both along its inner flank and along the vessel input flange aperture. Since cooled surfaces were impractical due to space limitations, an active machine protection system was required. This has involved the implementation of several new diagnostic, control, and interlock systems to protect this vessel and machine integrity.

MPW STRAIGHT EBPM DIAGNOSTICS

Some years ago, the SRS EBPM detector system was upgraded from two multiplexed single-plane homodyning detectors to a distributed system utilizing a two-plane detector at each location. These down-converting detectors (1) are connected directly to local 16-bit ADCs, which communicate with the control system via a G64 plant highway. This detector system is now used to routinely servo the orbit position horizontally to maintain beam position to ±10 μm for the duration of the fill.

EBPMs Within Existing Vessels

Due to the age and design of the SRS, the EBPM pickups themselves were installed when beam position servoing was unnecessary. For this reason they are not ideal in that they are located in separate, single plane measuring vessels (i.e. vertical measurement is made in the de-focusing quadrupole vessel and horizontal measurement in the focusing quadrupole vessel). This set-up is unsuitable for use around the new MPW vessel since they do not provide for the critical vertical measurement at each end of the tube, which is necessary to provide angular control across the straight. In order to overcome this problem, a revised pickup arrangement has been installed in the existing vessels. Figure 1 shows a cross section of each revised EBPM within the focusing and de-focusing quadrupole vessels.

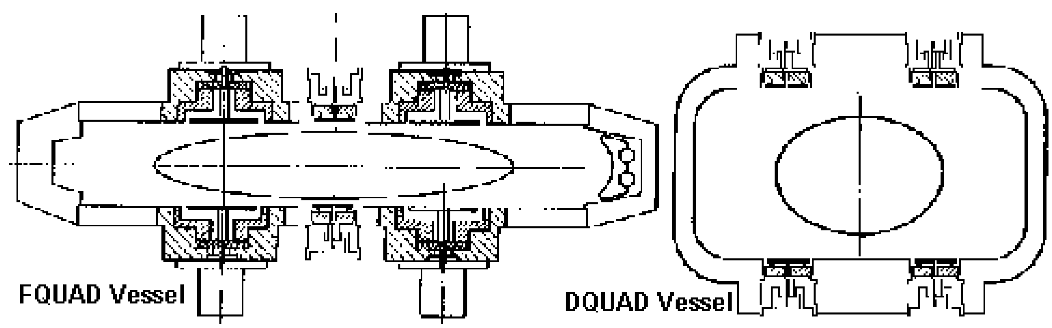

FIGURE 1. Revised two-plane EBPM button scheme, the focusing (FQUAD) and de-focusing quadrupole (DQUAD) vessels.

With this arrangement, the FQUAD vessel still measures the horizontal position using the existing EBPM buttons. Vertical position is now provided using a pair of on-axis, north/south buttons (modified ESRF design). For the DQUAD vessel, the original on-axis, north/south EBPMs were removed and plates carrying four modified ESRF buttons were installed, giving good horizontal and vertical response.

EBPMs Within The MPW Vessel

Since the MPW vessel is to be mounted within the magnet support system, located and isolated by vacuum bellows such that its position is fixed, it is advantageous to measure beam position within the limited aperture of the MPW vessel itself. To perform this function, ESRF-type buttons with titanium bodies were procured and fitted within a pocket at the rear of each flange, such that they and their cabling are prevented from fouling the MPW magnets. This allows the magnet poles to move past the rear of the flange as the gap is closed. Figure 2 shows the location of the buttons within the vessel and also shows an end view taken during electrostatic analysis using the QuickField™ 4 finite-element analysis (FEA) package.

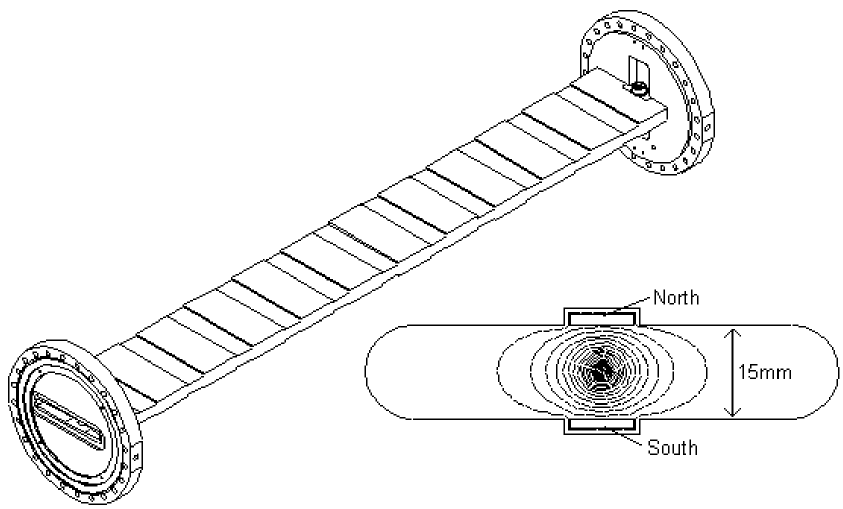

FIGURE 2. MPW vessel showing vertical EBPM layout and the equipotential distortion during simulations.

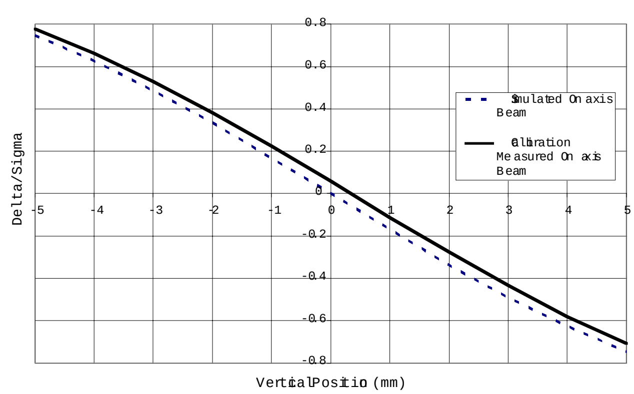

FIGURE 3. Comparison of simulated and measured MPW EBPM response.

The FEA simulation showed excellent correlation with measured calibration results using a swept wire technique on the prototype (Figure 3). The combination of such a small aperture with a relatively large button area (pickup plate diameter = 10 mm), gives a highly linear response with a low electrical calibration factor. Table 1, which compares EBPM calibration factors, shows the MPW EBPM to be less than half the value of other vessels. This means the control of beam position through the MPW device will be significantly improved, giving a higher stability source for users. The EPBMs will be incorporated in a local vertical position control system after the magnet's installation.

TABLE 1. Summary Showing MPW Straight EBPM Electrical Calibration Values

Vessel	Vertical Cal. Factor	Horizontal Cal. Factor
DQUAD EBPM	14	14
FQUAD EBPM	12	13
MPW EBPM	6	

Beam Position Processing and Machine Protection

Processing for the modified two-plane EBPMs is done with the existing Daresbury down-converting detector. For the new EBPMs within the MPW vessel, a commercial system manufactured by Bergoz Instrumentation using the switched-button amplitude measurement technique has been installed. This system offers advantages over the Daresbury design in that it is designed onto a single Eurocard, has a fast position update rate (1 kHz as standard), produces smoothed DC level outputs representing beam position, and has sufficient side-band rejection to allow single-bunch beam mode operation. Furthermore, this system lends itself to the simple introduction of a position-based hardware beam trip in the event of a mis-steering of the photon beam from the upstream dipole.

Facilities on the card allow the output response to be directly related to the beam position. Since the EBPM response is very linear, the system has been set up to provide a DC output representing 1 V/mm. A pair of simple windowing comparator systems is used on both the upstream and downstream MPW EBPMs to provide active interlocks along with a lower-level audible alarm in the event of a slow position drift towards the trip level. Furthermore, the cards produce three other signals which are used to guarantee their operation. Figure 4 shows a schematic block diagram of the MPW beam position hardware interlock.

The active interlock interrupts the low level rf drive to the klystron amplifier. A trip initiated by the beam position or by one of the other interlocked card test signals aborts the beam in 20 mS, thus protecting the MPW vessel. To allow filling of the storage ring, a simple override relay, actuated from the storage ring dipole DC current, bypasses the interlock chain, becoming automatically active at beam energies above 0.65 GeV (450 A).

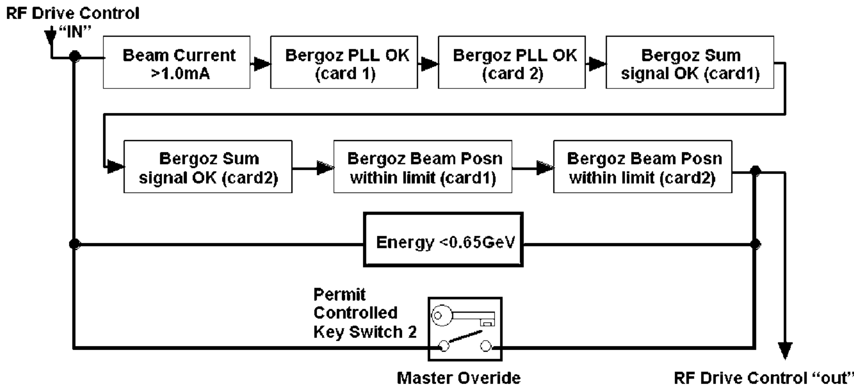

FIGURE 4. Block diagram of MPW beam position trip system.

SECONDARY INTERLOCK PROTECTION SYSTEM

Temperature Interlock

A temperature interlock system has been installed in addition to the BPM fast interlock in an attempt to give protection against slower temperature rises due to the photon beam striking the MPW vessel surface at a glancing angle in the horizontal plane. Thermocouples have been installed on the prototype ID vessel and surrounding equipment along the top and bottom of the vessel.

The system is comprised of 24 K-type thermocouples feeding into individual linearizing amplifiers that provide a 0–10V output signal proportional to temperatures from 0 °C to 1000 °C. A DL3000 ΔT Data Logger is used to compare the temperatures against the trip temperature level, which has been set at 50 °C. If any part of the vessel reaches the trip limit, the rf will immediately be tripped off.

Figure 5 shows how the thermocouples and data logger are integrated into the control system. Aside from the independent hardware temperature trip system, diagnostics and monitoring is provided through a 3U VME system, accessed over 10 Mbit Ethernet.

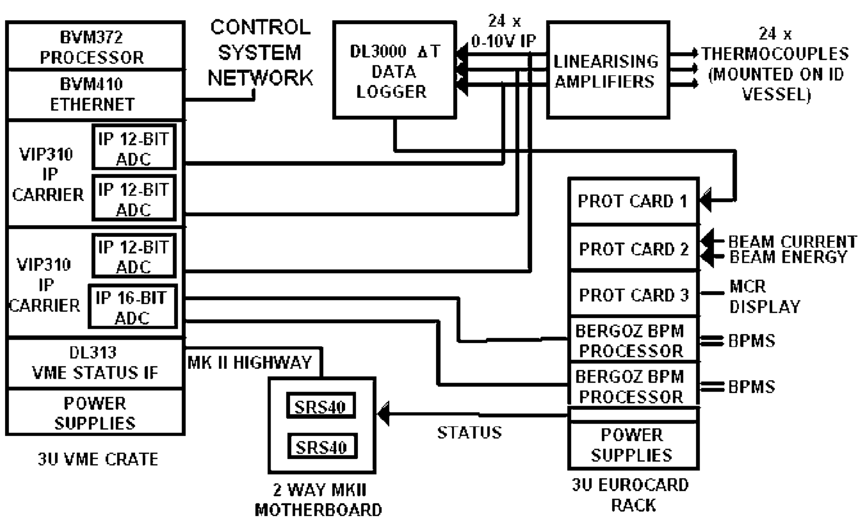

FIGURE 5. Schematic of control system interface to MPW protection systems.

The VME system is treated as a standard SRS control system Front End Computer (FEC) (2) with Industry Pack (IP) modules, using a Daresbury Status Interface module to access the analog signals and system status. Standard applications on the operator consoles can be used to monitor and log the additional BPM position and temperature information.

Software Protection Systems

A number of software-oriented steps have been taken at the SRS to further assist protection of the hardware systems. These include developing a software interlock system and making modifications to the existing software to enforce tighter orbit control and prevent dangerous electron beam mis-steering.

The software interlock and diagnostics provide a secondary safety system for the prevention of damage to the MPW vessel. The interlock continuously monitors orbit position from the existing 16 horizontal and vertical electron BPMs and, in the case of an excessive drift in position, will trip off the rf system.

The electron and photon beam position monitors, along with the storage ring power supplies, are interfaced to the control system via a network of VME systems via an Ethernet LAN as shown in Figure 6. The BPM software resides on the Gateway Processor (GP) along with the steering system front end computer (FEC) interface.

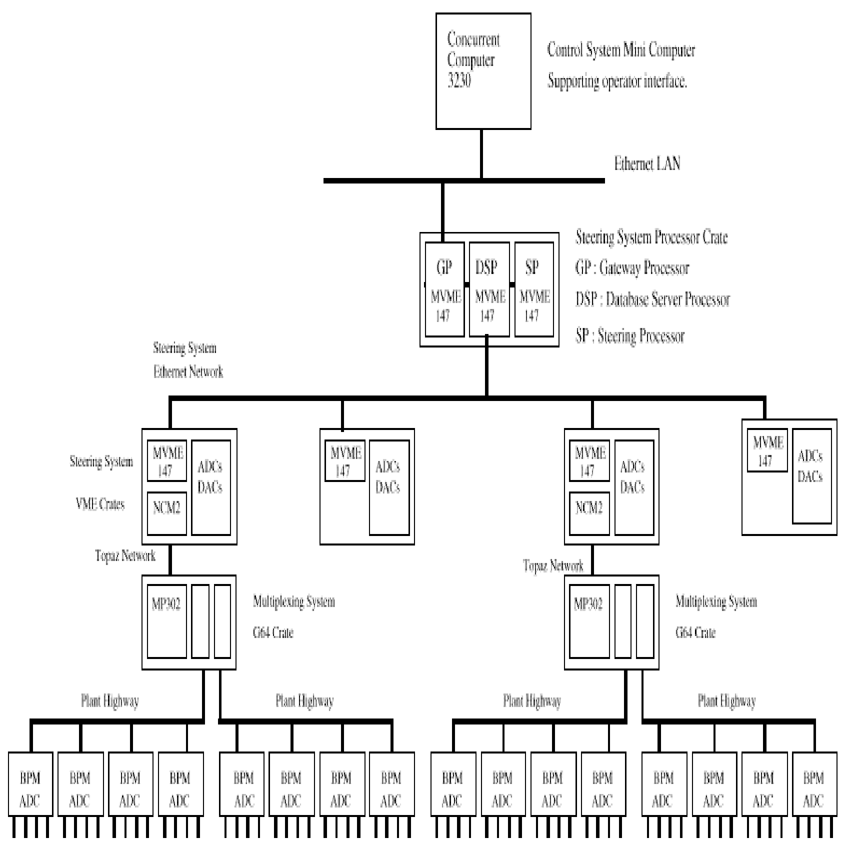

FIGURE 6. Schematic showing beam position monitoring data paths and hardware.

The system can be operated in two modes:

1. Ramp mode: all BPMs are monitored every 2 seconds during energy ramping and, if any one BPM is outside its own predefined limit, the interlock trips off the rf.
2. User beam mode: similar to ramp mode except that the orbit is captured on entering this mode and limits are taken relative to the start orbit.

Warning and trip limits are flexible and can be set at any time for each individual BPM. Warning limits are set just inside the trip limits and, when reached, will light an LED on the diagnostic control panel. Update rates faster than 2 seconds can cause deleterious competition for processor time with the ramp servo process.

The software trip diagnostics, written to log files on the VME steering system, include details of orbits when the trip occurred, along with times and mode of operation. Software has been written for the Windows NT to access this data and integrate it with the rest of the PC control system.

Both the ramping and user beam modes have been commissioned. The software interlock system is routinely used in Ramp Mode for both ramping and user beam conditions, although the user mode is expected to be used in the future. The system has also proven to be useful when a beam is dumped due to the hardware interlock tripping; the software system is then triggered, recording additional orbit diagnostic information.

ADDITIONAL SOFTWARE PROTECTION

Controlled Application of Bumps

The existing bump application software has been modified to prevent applying bumps that could produce harmful effects. All bumps applied now are absolute and have pre-defined limits in both the horizontal and vertical planes. A bump reset is performed only by cycling the magnets or by applying fixed steering file settings.

Ramp Servo Control

Improvement of the energy ramp software has been necessary to provide servo control of the orbit from EBPM readings whilst ramping the stored beam.

Jaw Settings

Ramping of the stored beam is permitted only when the horizontal and vertical jaw positions are within defined limits. This restriction gives limited protection, but does trap some orbits which would irradiate the MPW vessel if the jaws were left fully open.

Refill Sequence Manager

A change in the philosophy of SRS operation has required introducing sequencing software to control the precise order of events during refills. It utilizes the universal scripting language Tcl/Tk 8.0™ with a custom in-house library to interface the software to the control system. Each step of the refill process is defined by a Tcl scriptlet, written in consultation with accelerator physicists. This software has allowed an efficient refill procedure to be established and provides additional safety by ensuring that correct settings are applied in each operating mode.

REFERENCES

[1] Smith, R. J., P. A. McIntosh, T. Ring, "The Implementation of a Down Convertion Orbit Measurement Technique on The Daresbury SRS," presented at the 1994 European Particle Accelerator Conference, London, UK, June 1994.

[2] Martlew, B. G., M. J. Pugh, and W. R. Rawlinson, "Present Status of the SRS Control System Upgrade Project," presented at the 1996 European Particle Accelerator Conference, Sitges, Spain, June 1996.