NEW ELECTRON BEAM POSITION MONITORING AND FEEDBACK SYSTEM UPGRADES FOR THE SYNCHROTRON RADIATION SOURCE AT DARESBURY LABORATORY

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Abstract

The installation of a new APPLE/II undulator with user controlled polarisation has necessitated the upgrade of the Electron Beam Position Monitoring (EBPM) detector electronics and position feedback systems. The upgraded installation will utilise commercially available multiplexed detection electronics, coupled with a two phase control system interface replacement. Phase one involves the replacement of the existing G64 based read-back system with direct analogue connections to the VME beam steering and Feedback system. This allows existing monitoring and feedback software to work with improved update rates (~1Hz → ~8Hz). Phase two will see the installation of new high-performance control system front ends and will allow real-time monitoring at up to 100 Hz and provide snapshots with resolution of 1-10 KHz.

INTRODUCTION

The SRS at Daresbury Laboratory is a second generation light source based on a 2 GeV electron storage ring. It routinely operates with circulating currents of 150-250 mA and beam lifetimes of >24 hours. In 2004/2005 it provided synchrotron radiation to approximately 36 experimental stations on 15 beamlines. Operations began in 1980 and in 1987 it was upgraded by re-designing the lattice to provide a higher brightness source. During its 25 years of operation there has been a continual programme of improvement through the addition of insertion devices into the storage ring, new beamlines and experimental stations and through the development and upgrade of many of the accelerator technical systems. At present, the SRS routinely operates with six insertion devices – two high-field superconducting wigglers, three fixed polarisation multipole wigglers and a new APPLE/II variable polarisation undulator (VPU).

This VPU has user controllable polarisation which means that careful control of the electron beam orbit is required to ensure that no unwanted perturbations are introduced as the gap and phase of the undulator are altered. This is largely achieved through the use of trim coils on the undulator that automatically cancel out electron beam disturbances via a feed-forward control system. However, there was also a need to improve the performance and reliability of the EBPM system in order to provide better diagnostics and the ability to operate feedback systems at faster update rates than previously possible.

EXISTING SYSTEM

The SRS has a series of 16 horizontal and 16 vertical BPM pickup vessels installed, one of each type in each machine straight, separated by ~1.5 m. Button type pickups are used, and the signals from these, cabled to adjacent combining 180º passive hybrids, to provide Σ and Δ output signals at 500 MHz .The existing EBPM electronics and feedback system was installed in 1993 and was designed with the intention of monitoring and stabilising the circulating electron beam to better than 10 μm over a single fill of the storage ring [1]. Most of the orbit movements seen on the SRS are due to thermal drift of components as consequence of the need to perform an energy ramp from 600 MeV to 2 GeV after every refill. This means that update rates of 0.5 – 1 Hz for the BPMs and 0.05 – 0.1 Hz for the feedback systems were adequate to meet the performance targets. The rest of this section describes the components of the system.

EBPM Processing Electronics

The in-house designed processing electronics [2], located locally in the tunnel, shown in Figure 1 below, used a down conversion technique followed by a half wave rectification at 500 kHz to convert the RF signals into DC values corresponding to the amplitudes of the Σ and Δ RF signals. These were then digitised via local 16 bit ADCs.

Typical performance figures of the system are:

Vessel Cal. Factor	14 (H. and V. plane)
Typical Beam Dimension	0.1mm V x 1.0mm H.
Dynamic Range	10-400mA (low gain)
	1-40mA (high gain)
Position Sensitivity	~ 0.05mA.mm
Resolution	≤ 10μm
Stability (over fill period)	≤ 20μm
Stability (over 1 hour)	≤3μm rms (H plane)

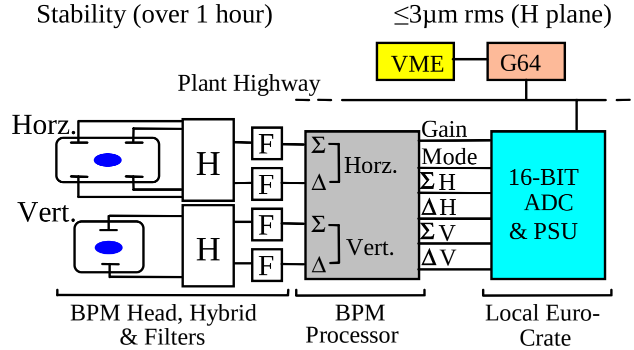

Figure 1: Basic SRS EBPM single straight system.

G64 Digitizing System

The sum (Σ) and difference (Δ) analogue signals from each set of processing electronics fed directly into distributed 16-bit analogue-to-digital converters (ADCs) positioned close to the EBPMs in order to reduce noise pick-up and signal loss. These ADCs were custom-designed and communicated with a G-64 bus based digital processing system over a parallel highway. This highway was the same as that used in the SRS status control and interlock system [3] thus allowing re-use of existing designs and expertise as well as commonality of components and support. Four separate highways were used to cover the entire storage ring and these fed in pairs into two G64 processing systems each handling 8 vertical and 8 horizontal EBPMs.

The G64 system performed the calculations needed to translate Σ and Δ signals into beam position readings as well as allowing simple time averaging and automatic system calibration.

VME Beam Steering System

The calibrated and time-averaged readings produced by the G64 systems were transmitted over an RS485 serial link to the main SRS Beam Steering System [4]. This system was designed and installed in the early 1990s and consists of one master VME crate and four slave crates. The slave crates are responsible for reading the data from the EBPMS (via the RS485 link), monitoring and controlling all steering magnets through banks of 16-bit ADCs, analogue multiplexors and digital-to-analogue converters (DACs) as well as reading photon beam position from a number of Tungsten Vane Monitors (TVMs).

Data from these slave crates is transmitted to/from the master crate using a dedicated Ethernet network with the TCP/IP protocol. The master crate is responsible for combining data from all parts of the storage ring and distributing it to the rest of the SRS control system for display, archiving etc. It also runs global horizontal feedback software for the electron beam position and provides data for a global vertical feedback system of photon beam position.

SYSTEM UPGRADES

In order to improve the performance and reliability of orbit monitoring and feedback control it was decided in November 2003 to put in place a project to upgrade both the EBPM system and its associated monitoring and control systems. The project was split into two consecutive phases to minimize disruption to operation of the SRS.

In phase one it was planned to install new low-loss coaxial cables from the BPM pick-up buttons, to replace all the existing EBPM processing electronics with commercial modules, and to remove the G64 digitizing system and feed the analogue signals from the new EBPM processing electronics directly into the existing VME beam steering system.

In phase two new control system front end computers (FECs) will be added in parallel to the existing VME beam steering system. These FECs will provide much faster access to EBPM data than is possible at present. This will allow much better orbit position diagnostics and data visualisation.

PHASE ONE UPGRADE

EBPM Processing Electronics

The choice of available EBPM electronics designs now includes the option of commercial systems. Two such systems were considered for the upgrade.

Digital

The digitally based Instrumentation Technology (ITECH) Libera system has a fully embedded EPICS control system, produces fully digitised data at turn by turn rates and slower integrated rates directly over Ethernet. High data rates are achieved via separate internal detection channels. Slower, high precision beam position for orbit control utilises a novel internal switching arrangement to process each button signal down all detection channels to remove any errors caused by channel difference. The system utilises one whole unit per EBPM, the units being available in a 19" rack mounting module.

Analogue

The analogue based Bergoz system is fully standalone, and produces an analogue voltage, representing position as an X and Y output value. Typical data rates are 2.5 kHz for closed orbit readings. It is left to the control system to digitise these values and produce actual beam position data. The production of position signals by the electronics is achieved by multiplexing the EBPM button signals through the same detector, in order to minimise errors. This system does not at present produce turn by turn data, but a complementary card can be substituted to provide this function. The form factor for this system is Eurocard based, with one crate able to support 10 EBPM cards.

Detection System Choice

The nature of the SRS EBPM system and its separated function single plane horizontal and vertical measurements, means that despite the storage ring having only 16 EBPMs, 32 modules are required to implement a new system. Consideration of the cost of upgrading the controls steering system to interface with EPICS units, the quantities of units required, and the phased approach to the steering system upgrade in the timescales allowed, directed the choice of system to be the analogue option. This has been realised by the purchase of 32 Bergoz cards (plus spares), installed into 4 Bergoz crates distributed on the SRS controls gantry above the storage ring. New coaxial cabling has been installed using Habia Flexiform, to bring the EBPM button signals directly out of the ring tunnel to the four station crate containing the detector

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cards. Figure 2 shows one EBPM station. An additional 4 ‘single turn’ cards were purchased to provide single turn positional information at discrete locations should the need arise to observe injection conditions during a fault situation.

Figure 2: Picture of Bergoz BPM crate.

Modifications to VME System

The four VME slave crates each consist of a MVME147 processor, an RS485 serial interface, a single 16-bit ADC module with a number of additional electronic analogue multiplexors and 64 channels of 16-bit DAC. They use Microwares OS-9 operating system which, together with the application software, is contained in EPROMs on the processor board.

To support the phase one upgrade a number of modifications were needed to the hardware and software:

- Addition of one new analogue multiplexor in each slave crate. This provides 16 further channels of analogue input for monitoring of both X and Y outputs of eight EBPM processing modules.
- New cabling from the EBPM processing modules to the analogue multiplexor.
- Removal of the RS485 serial interface.
- Removal of the G64 digitizing system.
- Modification of the embedded software to account for the hardware changes.
- Modification of the database in the master crate to reflect changes to the slave crates.

PHASE TWO UPGRADE

Phase two of the upgrade is will see the introduction of new control system front end computers operating in parallel to the existing beam steering system. These new FECs will use Intel x86 processors running the Linux operating system. They will be linked by a high speed reflective memory system that will allow synchronisation of orbit monitoring and capture around the entire storage ring.

It is intended to use 16-bit ADCs with integral transient capture buffers. This configuration should provide real-time orbit monitoring at approximately 100 Hz while the transient capture will allow post-mortem analysis of captured events with a resolution in the range 1 – 10 kHz.

In order to make full use of these enhancements in performance it is necessary to develop new display and diagnostic software for use in the control room.

CONCLUSIONS

Phase one of the upgrade was successfully completed in March 2005 and the SRS is now routinely operating with the new EBPM system. Initial commissioning went very smoothly with only a small number of cabling and termination problems requiring attention and normal operation of the SRS was re-established within 24 hours of the switch over. Work is currently progressing on phase two and it is anticipated that this will be completed in autumn 2005.

The new system has a number of performance and usability improvements:

- Less complex system design leading to easier maintenance and better reliability.
- Use of standard commercial modules that are widely used on other accelerators as well as elsewhere on the SRS.
- Elimination of the slow, poorly documentated G64 digitizing system.
- The processing electronics has been moved from inside the ring tunnel to the controls gantry. This allows much easier access for measurement and fault-finding.
- The VME embedded software has been simplified hopefully leading to better reliability.
- The ability to provide ‘first turn’ monitoring at a limited number of locations around the storage ring has been added.

REFERENCES

[1] B.G.Martlew, R.J.Smith, S.L.Smith, “Development of Global Feedback for Beam Position Control in the Daresbury SRS Storage Ring”, EPAC’94, London, July 1994, p.1574

[2] R.J.Smith, P.A.McIntosh, T.Ring, “The Implementation of a Down Conversion Orbit Measurement Technique on the Daresbury SRS”, EPAC’94, London, July 1994, p.1542

[3] B.G.Martlew, D.G.Peters, D.E.Poole, “A Microprocessor based Status Control and Interlock Protection System for the SRS”, PAC’87, Washington DC, March 1987

[4] W.R.Rawlinson, B.G.Martlew, M.J.Pugh, M.McCarthy, “Development of a VME-based Control System for the SRS Orbit Feedback Project”, EPAC’94, London, July 1994, p.1785