A FAST PROTECTION SYSTEM FOR NARROW-GAP INSERTION DEVICE VESSELS

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Abstract

Presented in this paper are details of an electronic, beam position based interlock system, which has been designed to protect narrow - gap insertion device vessels from the thermal damage that would result from mis steered beam. Details of system design and operational experience are presented, and the paper concludes with an outline proposal for a system enhancement, that would offer diagnostic information immediately prior to an excessive beam displacement trip.

1 INTRODUCTION

In 1998 a major programme of upgrade work was completed on the Synchrotron Radiation Source (SRS), Daresbury Laboratory UK. The upgrade involved the installation of two insertion devices, multipole wigglers, with the intention of enhancing the versatility of the SRS as a synchrotron light source.

When an analysis in to the effect of beam impinging the walls or flanges of either of the associated narrow-gap vessels, as a result of mis-steer, was conducted, a probability of permanent thermal damage, occurring within several seconds of time was indicated. Water-cooling as an engineering solution could be applied to the upstream flanges, but the walls of the vessels would still be extremely vulnerable. Thus the requirement for a protection system to prevent potential thermal destruction of either vessel was founded.

Two systems have been built to the design that subsequently evolved, and have since January of this year provided vessel protection with unfaltering reliability.

2 SYSTEM DESCRIPTION

Protection of a vessel is accomplished by tripping off the Radio Frequency (RF) source when conditions that are potentially thermally damaging to a vessel prevail. The primary interlock signals to achieve this are generated by excessive vertical beam displacement through a vessel, or excessive rise in temperature of the walls of a vessel. Vertical beam displacement signals are provided by Electron Beam Position Monitors (EBPMs) installed within a vessel (two off, upstream and downstream). An array of thermocouples supervised by a Programmable Logic Controller (PLC) provides the excessive temperature signal.

Since all combinations of stored beam and injection energy are deemed to be a safe operating area, an Energy Sensitive Bypass renders beam displacement interlocks inactive during injection. This facilitates steering through the narrow gap of a vessel at injection, by permitting a wider tolerance on beam displacement.

The organisation of primary interlocks is illustrated in Figure 1.

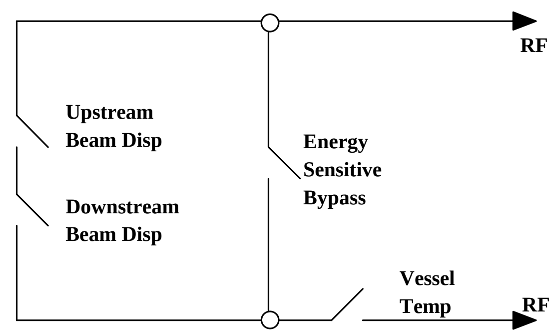

Figure 1: Organisation of primary interlocks

Because confidence in the reliability of primary interlocks is paramount, secondary interlock signals are required to become active, when the integrity of electronic hardware or support signals is suspect. These secondary interlock signals monitor the performance of the electronics for the EBPMs, Total Current Monitor (TCM), power supplies, PLC and also a Direct Current Transformer (DCCT) which provides an energy level proportional signal from the dipole magnet current.

The organisation of all system interlocks both primary and secondary is illustrated in Figure 2, which also includes a keyswitch-controlled bypass of the beam displacement interlocks.

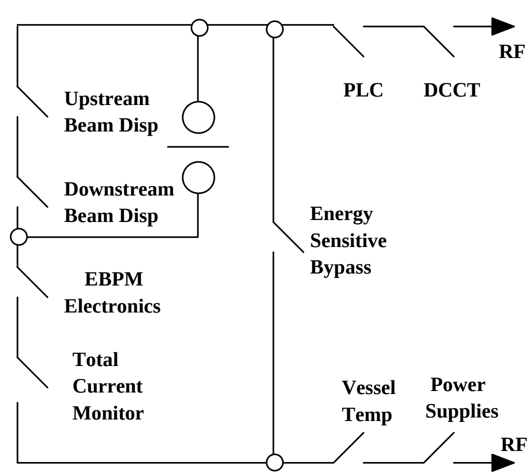

Figure 2: Organisation of primary and secondary interlocks

This bypass permits a wider tolerance on beam displacement at energies greater than injection energy, and is included for possible accelerator physics application.

3 INTERLOCK DESCRIPTIONS

The hardware output of individual interlocks, whether primary or secondary, is a pair of normally open, volt-free relay contacts. These are concatenated in the manner of Figure 2 to provide a galvanic loop output to the RF system. On failure of an interlock, the appropriate pair of contacts will open and trip off the RF source and consequently the beam. Because contact pairs are of 'normally open' configuration the scheme is fail safe. An auxiliary pair of relay contacts is presented to the SRS control and monitoring system for display purposes.

In compliance with the interface standard for the SRS control and monitoring system, a failed interlock is latched, and cannot be reset until the condition that initiated the failure has been remedied.

3.1 Primary Interlocks

Commercial EBPM signal processing electronics (Bergoz), are employed for upstream and downstream beam displacement measurements, to generate corresponding interlocks by comparison with adjustable, pre-set, bipolar thresholds. By comparison with additional thresholds of lesser magnitude (nominally 1.0 mm equivalent), advanced beam displacement warning signals are also generated; these warning signals are OR functioned to drive an audible sounder.

The third primary interlock is generated if any single thermocouple from of an array of 32 devices, that are distributed and mounted about the walls of each vessel, indicates a local temperature in excess of a pre-set threshold. Individual threshold levels are embedded in the software of the supervisory PLC.

3.2 Secondary Interlocks

Failure of a secondary interlock signal occurs if the integrity of electronic hardware or support signals becomes suspect. Hardware performance is monitored by constant detection of the presence of appropriate confidence signals; confidence of support signals is achieved by comparison of signal level relative to a pre-set reference value. Power supply tolerances are set at +/-10% of required value.

Each of the two installed systems in the SRS is equipped with a dipole current measuring DCCT to provide signals that are proportional to energy level. Confidence monitoring for these is achieved by additional cross coupling of signals between the systems. For more than two systems this would not be practicable; a self-contained monitoring scheme would have to be sought.

4 PRACTICAL CONSIDERATIONS

4.1 Noise Immunity

By design, the output of a vessel protection system when active, will trip off the RF source and destroy the beam. Consequently, the effect of noise and electrical interference can be catastrophic, as was demonstrated in the early design stages of the system under discussion.

To eliminate noise problems standard techniques have been applied during system construction, but to guarantee noise rejection, a form of filtering has been included across the input of all interlock sources. For valid recognition of an interlock source signal the signal must be present for a specific duration, 100 milliseconds for primary interlocks, 1.0 second for secondary interlocks. These times define the response of the system to an interlock failure.

The excessive vessel wall temperature interlock from the PLC system, and the interlock reset signal from the SRS Control System, both generated externally to the system crate, switch 24 volt lines in an effort to reduce noise.

4.2 Status Display

Full instantaneous display of the status of all interlocks is available via a colour display monitor at a control console in the SRS Main Control Room. Through a control console, interlock resets are also effected.

Early operational experience with this form of interlock status display, demonstrated that consideration needed to be given to the order and manner that failed interlocks are displayed, if a lucid interpretation of events were to be achieved. This is because at beam loss due to a valid interlock failure, a number of other interlocks fail due to their reliance on the presence of beam to maintain safe status. Thus without care, interlock status display would not separate cause from effect.

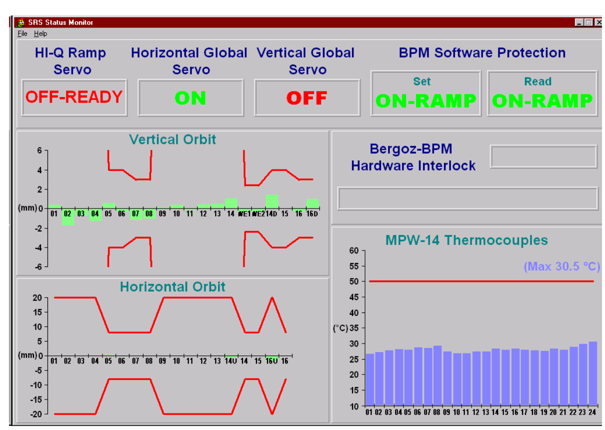

Figure 3: Status display

Trapping' and displaying the first interlock to fail, i.e.

the valid interlock, surmounted the problem.
Consequential failed interlocks whose status is initially suppressed may subsequently be displayed by the application of a system reset. A page of displayed interlock status is shown as Figure 3. Also installed in the SRS Main Control Room is a hardware display panel for each system, on which is mounted digital panel meters, displaying upstream and downstream beam displacement in direct millimetres. The audible alarm sounder detailed in Section 3.1, light emitting diode indications of the status of the Energy Sensitive Bypass and global interlock status are also mounted on the panel.

This auxiliary display panel is shown as Figure 4.

Figure 4: Auxiliary display panel

4.3 General Details

With the exception of the PLC based vessel wall temperature monitoring system, all electronic hardware is housed in a 3U-high eurocrate, which has been kept compact without loss of versatility by judicial allocation of functions between modules.

Figure 5: Hardware arrangement

As shown in Figure 5 signal monitoring and threshold adjustments are accessible on module front panels; all system input and output cables including EBPM button signals, enter through the crate rear panel via appropriate connectors. Spare module slots in the crate are sealed with blank front panels to maintain Electromagnetic Compatibility. The front panel apertures visible in Figure 5 are to permit forced air cooling of the EBPM processing cards, a requirement found to be necessary to achieve the desired performance stability of the said cards.

5 SYSTEM ENHANCEMENT PROPOSAL

Figure 6 shows a schematic illustrating a proposal for an enhancement that offers beam position diagnostic information, immediately prior to tripping the RF.

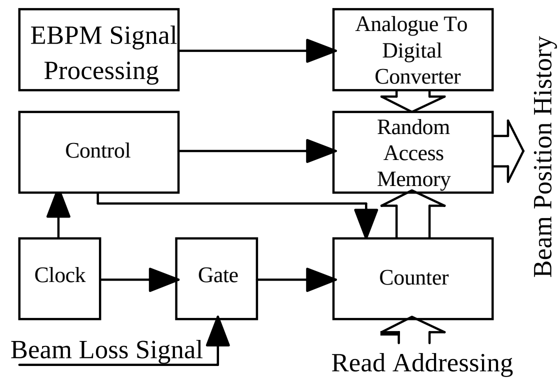

Figure 6: Beam loss data recording system for IDs

Samples of the digitised beam position signal are stored in Random Access Memory (RAM) locations during write mode. A cyclic counter whose serial input is fed from a clock source provides the addressing for the locations. On beam loss the address counter is ‘frozen’ when the clock is inhibited, capturing in digital form the recent history of beam position. Addressing the locations via the parallel input of the counter can access the stored samples when the RAM is set to the read mode. Accessed samples could be read digitally or converted to analogue form.

5 CONCLUSIONS

This paper has detailed a design for a fast, high performance system, for the protection of narrow-gap insertion device vessels. The system is versatile, and suitable for application to most vessels that are equipped with upstream and downstream vertical EBPMs.

REFERENCES

[1] D. M. Dykes et al., "The SRS Multipole Wiggler Vacuum Vessel Protection System", Proceedings, 6th EPAC, Stockholm, (1998).