DIAMOND PERSONNEL SAFETY SYSTEM

M. C. Wilson, K. A. R. Baker, E.V. Buckley, M. T. Heron, Diamond Light Source,
J.R. Alexander, Daresbury Laboratory

Abstract

Diamond is a new synchrotron light source currently being designed and constructed in the UK. The Diamond personnel safety system will protect people from the hazards associated with the accelerators and photon beamlines. The choice of technology and conceptual design of the Diamond Personnel Safety System (PSS) are presented, together with planned analysis methods that will provide a quantitative measure of the overall reliability of the PSS.

INTRODUCTION

Diamond is a new "third generation" synchrotron radiation facility under construction at the Rutherford Appleton Laboratory in Oxfordshire. It is the largest scientific research facility to be built in the UK for 30 years, and will produce ultra-violet and X-ray beams of exceptional brightness, allowing pioneering experiments to be carried out which probe deep into the basic structure of matter and materials. The facility will comprise a 3 GeV electron storage ring, injected from a 100 MeV Linac through a full energy booster synchrotron, and an initial complement of seven beamlines. Inherent in the operation of this equipment are hazards that must be identified, assessed and managed. Radiation hazards carry a particular significance, as a radiation accident carries a stigma from which it can be difficult for a facility to recover.

IDENTIFYING HAZARDS AND MANAGING RISK

Diamond is in the process of setting up a safety framework. Hazard management is a key component within the safety system. The Diamond hazard management system will:

- Identify hazards,
- Assess severity and likelihood,
- Reduce severity (by design),
- Mitigate likelihood,
- Monitor results,
- Assess success.

There will be hazards that cannot be eliminated so a containment system will be required. For Diamond we will "contain" the radiation hazards within shielded enclosures and control light source operation and enclosure access by means of the PSS so that personnel are excluded from the enclosures when the hazard is present.

Mitigation

Unfortunately the desired product of synchrotrons, the synchrotron light, cannot be separated from the hazard, ionizing radiation. As a result, designing out the hazard is not possible and a containment strategy needs to be adopted. Advances in radiation treatment have led to a much improved prognosis for persons exposed to high levels of radiation, but access to any of the vaults with beam in the machine presents a hazard that is as severe as any in the Diamond facility. We can only reduce the likelihood of personnel being exposed to the hazard. The following techniques are used as mitigation to reduce the likelihood of the event:

1. Shielded enclosures with access via locked labyrinths (or shielded doors for hutches),
2. Locked doors requiring the PSS key,
3. A Personnel Safety System.

The PSS will have the following features:

- Captive Permit key allowing either access or beam operation but not both simultaneously,
- Safety switches on doors as interlocks,
- A requirement for search prior to operation,
- Annunciators outside doors, indicating vault status,
- Blue lights in the vault when access is not allowed,
- Signs in the vault indicating danger,
- Beam Off buttons throughout the vault and outside the access doors,
- A time delay between search completion and beam enabling (to allow someone to respond to the blue light warning),
- An audible warning or recorded announcement.

DESIGN

Redundancy and diversity are techniques used throughout the PSS to increase the reliability of the system. Each identified hazard will be controlled by two independent methods, either of which will make the hazard safe. Each method will function by inhibiting the operation of two of the fundamentals of the associated equipment. For example, to prevent stored beam we may inhibit the RF and the dipole magnets. The RF is inhibited by removing the drive signal and by inhibiting the high voltage, whilst the dipole power supply is also inhibited by two techniques. In this way each hazard is made safe by four independent actions.

HARDWARE

When considering the choice of technology, a major decision was whether to base the design on a hard-wired solution, or on a programmable solution with the software defining the safety logic. A programmable solution could be realised using a commercially-available high-integrity PLC, or conventional PLCs of differing types in a redundant and diverse configuration. The development of software for a PSS could be managed by methodologies set out in the standard EN61508. However, many of the advantages of a PLC-based solution, in particular ease of change and configurability, are not applicable to a high-integrity system, as modification of the PSS will require careful consideration and implementation, managed through a control process. Examination of the design of a number of accelerator PSSs based on PLCs, indicates that these do not rely exclusively on the PLC logic but commonly include a hardware check line. In opting for a hardware solution it was decided to base the design of the Diamond PSS on the Daresbury PSS, used at the SRS in Daresbury and at ESRF in Grenoble for the following reasons:

- The Daresbury system is based on multi-pole relays, whose failure modes are simple and well understood;
- The Daresbury system is well established and has user confidence;
- The system will be easier to maintain over a 30 year life than a PLC-based system;
- The ease of change and configurability inherent in a PLC are not advantages for a high integrity system, as modifications will need careful consideration, approval and implementation.

The hardware will be organised as a dual guard line interlock system based on relays.

The electronics will be contained in a double-height 19” Eurocard rack and will be interfaced to EPICS for monitoring purposes via an interface card and a VME processor. Each rack will incorporate an EPICS Input Output Controller (IOC), which will have the capability to monitor the operation of the PSS but will not be involved in any safety function.

STANDARDS

Operation of any accelerator in the UK is subject to Ionising Radiation Regulations 1999[2] (IRR99) and the associated Approved Code of Practice and Guidance (ACOP), which include requirements for the design of the PSS.

The Design of the Diamond PSS conforms to the requirements of the “Prior Authorisation for Operation of Accelerators”, as permitted by regulation 5 of the IRR99, which will allow Diamond to operate. These require a system of enclosures, interlocks and trapped keys to keep the exposure to ionising radiation as low as reasonably possible.

ANALYSIS

Analysis will be undertaken to predict the likely incident rate. This will take into consideration the effects of failure of hardware, the frequency of operation and the likelihood of a particular event resulting in an accident. The aim is to reconcile the safety of the system with the incident rate identified as acceptable within Diamond. Analysis is likely to include fault tree analysis as undertaken on the SRS at Daresbury[1] and other techniques.

Once the PSS is operational, data will be collected to test assumptions made in the analysis.

TESTING AND SERVICING

Testing will be an important part of ensuring the continued safe operation of the PSS. A dual guard rail system will require two faults on the same system before a fault becomes a safety failure. The testing regime must be frequent enough to detect a single fault before a second fault is likely to occur. This implies the need for thorough and routine testing. A testing program is envisaged that will test modules, crates and the system routinely. In addition possible failures will be monitored during routine operation by the EPICS control system.

Diamond will expect to replace safety-related components on a statistical basis to prevent age-related failures.

A service schedule will be created that reflects the use of the components and their expected useful life time.

SEARCH PATTERNS

The procedure for ensuring personnel safety at Diamond is as follows:

- Search the hazardous area and ensure no-one is within the shielded area,
- Lock the hazardous area and place the key in the PSS key-park,
- When all keys are present in the key-park, the PSS will permit operation of the equipment.

Diamond is a large machine; a search of the whole machine as a single area would be complex and time consuming. The machine is therefore split into zones, each of which can be searched and locked independently of the others. The search of a zone will not need to be repeated unless access is made to that particular zone. The Linac vault will be one zone, whilst the Booster and Storage Ring will be split into three and ten zones respectively, separated radially by gates. Each beamline hutch will be an independent zone. Only designated personnel will be permitted to search the machine.

A typical search will require the searcher to

- Swipe his or her access card in the card reader by the access door,.
- Make entry to the area by the access door,
- Walk to the furthest point and press the search button,

- Sweep back towards the access door pressing search buttons at points which encourage the searcher to examine obscured areas,
- Close and lock the door,
- Take the door key and place it in the PSS key-park.

SUMMARY

The Diamond PSS design will be based on the hazard analysis of the system, a probabilistic analysis of the components and an estimate of the frequency of operations. It will exhibit redundancy and diversity for reliability and avoidance of common-mode failures. It will be based on a conservative choice of hardware with demonstrated functionality and reliability.

The accelerators will be split into zones, each of which may be searched and locked quickly and independently of the others. The operation of the accelerators is controlled by captive key lock and switches which allow either access or operation but not both simultaneously.

Statistics on reliability and frequency of operation will be gathered and used to test the assumptions in the safety model.

REFERENCES

[1] "A Report on the Review and Formal Analysis of the SRS Personnel Safety System," J R Alexander, M T Heron, P Quinn PAC2001

[2] "The [UK] Ionising Radiation Regulations 1999," Statutory Instrument 1999/3232