THE INTERLOCK SYSTEM FOR U7 UNDULATOR IN PLS

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Abstract

The U7 undulator, the first insertion device in PLS, has been installed at #8 straight section in July 1997. It is expected to produce high intensity photon beam from early1998. Since the high intense photon beam can cause severe thermal damage on vacuum chamber by improperly steered electron beam orbit, the interlock system should be implemented to prevent thermal damage. The U7 interlock system will monitor beam position signals from two undulator BPMs both sides of the undulator to discriminate if the electron beam is in a safe region. When the electron beam is outside a safe region, the interlock system will interrupt the RF power to dump the stored beam. This paper describes the design of the interlock system.

1. INTRODUCTION

The first insertion device U7 in PLS has a device length of 4.3m with a magnet pole period of 7cm, a minimum pole gap of 16mm, and a peak field strength of 1.01Tesla. It is designed to operate in the photon energy range of 23 eV to 2.1 KeV using the 1st, the 3rd, and the 5th harmonic undulator radiation at 2.0 GeV electron energy. The control of pole gap distance had been successfully tested and finally we observed photon beam radiated from the undulator at the front end of the U7 beamline with 2mA stored beam current.

During the operation, improperly steered electron beam in the undulator straight section will radiate high power photon beam which can damage the aluminum vacuum chamber. When the stored beam current is 250mA and the beam energy is 2.5 Gev, the aluminum chamber starts to melt only after 15 ms if the photon beam hits the chamber perpendicularly at the distance of 10m from the center of the undulator. Therefore, we need a fast interlock system to dump the stored beam within the response time of 10ms to protect the vacuum chamber from thermal damage or even melting down. Since the minimum response time about 150 ms of the Machine Interlock System (MIS) working in PLS is too long to protect the chamber securely, we need another fast interlock system for the beam orbit in the U7 undulator straight section.

The undulator interlock system (UIS) monitors continuously electron beam orbit from two beam position monitors at each side of the undulator to discriminate if the beam is in a safe region. It generates interrupt signal to block the RF drive when the beam deviates from the safe orbit.

Parameters	Values
Energy	2.5 GeV
Max. Beam Current	400mA
Peak Photon Power Density	10.1 kW/mrad^2
Al Chamber Melting Temp.	660°C
Interlock System Response Time	10 ms

Table 1: Design Parameters

The undulator photon beam port is located at the distance of 8.87m from the center of the undulator and its diameter is 185mm. However, since the vertical size of the neck of the transition chamber between the sector chamber and the front-end chamber is only 10mm, we should make much effort in the design of the system for beam not to hit the chamber.

2. DESCRIPTION OF THE SYSTEM

The UIS is composed of three parts: Beam Position Monitor (IDBPM), Main Processor Module (INTMPM) and RF Interface Module (INTRIM**).** The beam position monitor and the main processor module are housed in a same 3U-size Euro subrack which is installed in the control shed #7, and the RF interface module in the RF Station. The signal link between the control shed and the RF station is made by an optical fiber to interrupt the RF system reliably. A coaxial line is used to receive a RF status as well as a redundant path of the interrupt line between the control shed and the RF station.

The UIS reports the system status to the upper-layered control system so the operators in the main control room can monitor its operation status via graphic displays at the console computer. The UIS sends interrupt request to PLC-based Machine Interlock System (MIS) as well, which is used as a redundant system to interrupt the RF power when U7 interlock system reports 'Fault' status. An alternative path of the interlock line is to cutoff the high-voltage drive system of four RF cavities.

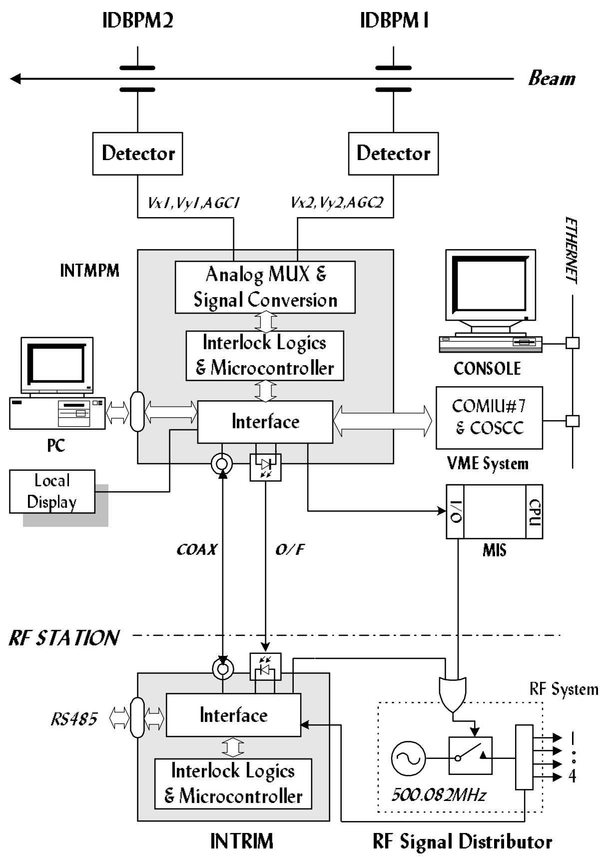

Figure 1: Schematics of the Interlock System

2.1 Detector

In the design of the system, we have considered several detectors, like as SR BPM, SR Vacuum Gauge, Photon BPM, for the UIS. SR BPM is finally selected as the proper sensor to meet the requirements of the response time and system accuracy. The 4-button type pickup units are installed at the upstream and downstream of the #8 straight section. The detected beam signals are fed to the processing electronics which are installed in #7 control shed via 20m, 1/4" heliax coaxial cables. In the processing electronics board, the beam positions and beam current are detected for use as the interlock signal.

Since the 108 BPM processing electronics installed around SR can be handled only through the VME-bus control system, we use the commercial BPM processor made by Bergoz which has analog position outputs. With the gain of the processor set to 3V/mm in x- and y-direction, we achieved the resolution of 10μm at the test bench when the 500 MHz input signal power is –60dBm. The dynamic range of 70dB was confirmed through the performance test. All outputs such as x-, y- position and AGC value of the processor are updated at 25KHz and transferred to the UIS. They are also transferred to the VME control system to use as the orbit data

2.2 Interlock Logics and Microprocessor Interface

The 6 input signals from IDBPM1 and 2 are switched to 12-bit A/D converter AD7893 by an analog-multiplexer ADG428 and the conversion data is shifted to a dual port memory serially. Two microprocessors are used: one for the control of input/output of the data and the other for the calculations and discrimination if the beam is inside the safe region. The result interlock signal is sent to INTRIM as an optical signal at the rate of 500kbps and to MIS through relay contacts. The status signal is sent to the main control system via VMEbus and Ethernet. The single-mode optical fiber at 1310nm is used for the transmission of the interlock signal. On the other hand, the status signal is transmitted via RG58 coaxial cable.

All of the signals are isolated with transformers or photocouplers, and much care has been exercised in the design of the matching circuits between input and output because the RG58 must give the path in both directions. The circuits are assembled in three 3U-size eurocards which are equipped with a local display and a keypad for manual setting.

2.3 Interrupt of the RF System

The RF interface board INTRIM has a dedicated micro-controller and interface circuits, and is installed close to the RF signal distributor in the RF station. The INTRIM produces one TTL output to turn the RF switch off and 4 relay-contact outputs to interrupt the high voltage drive of the RF cavities. When the RF status signal turns to off-state, it sends the RF status to the INTRIM to close the whole interlock process through the coaxial cable. Since the switching time is only 15ms, the coax RF switch being used in the path of RF drive signal does not meet the system requirements of the response time. It has to be replaced with a faster switch. All the processing electronics are assembled in one 3U-size eurocard.

2.4 System Redundancy

The redundancy can be explained in two classes: a hardware redundancy and a system redundancy. In the hardware redundancy, this system has the back-up interlock boards running in cold standby but they are not switched to other boards automatically. The coaxial path used to receive the RF status performs the transmission of the interlock signal instead of the optical fiber when the optical path has a fault. This system has two interrupt points: one is to block the low level RF signal drive and the other is to cutoff the high level cavity high voltage drive. The PLC-based machine interlock system can work as a redundant system against the fault of UIS to interrupt the RF and dump the electron beam in 150ms

3. SOFTWARE FEATURES

The software jobs are performed by the 8-bit microprocessors at the maximum rate of 16MHz and it is programmed in C and Assembler. The control parameters, such as the calibration factor and turn-on beam current, can be also set locally from the front panel keypad.

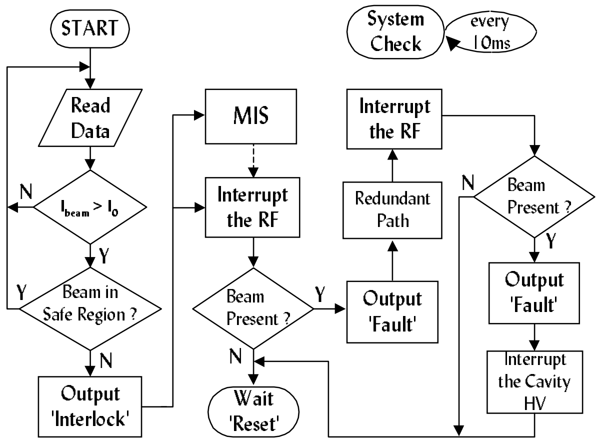

Figure 2: Flowchart of the main operation

3.1 Main Processor Software (MPS)

First of all, the MPS calculates the X and Y positions and the beam current by using the analog position signals and the AGC signals from IDBPM1 and IDBPM2. At that time the position calibration factor must be required. The main purpose of MPS is to generate the interlock signal to dump the beam when the beam current is higher than the turn-on current and the beam orbit is outside the safe region. Under the normal condition, it produces a specific check-pattern to examine INTMPM and INTRIM electronics, and signal transmission paths at the rate of 10ms.

The specific codes used in communication between two modules (INTMPM and INTRIM) have properties to be immune to the external and internal system noises as well as to the misinterpretation of messages and bit processing errors. It reports the system status to host computer regularly.

*3.2 RF Processor Software (RPS***)**

The RPS continuously checks the RF status bit and replies to the MPS demands for checking the system. It generates the RF interrupt when it receives the interrupt signal from INTMPM. In the worst case when the beam is still stored after the interlock signal is released, it generates another interrupt signal to disconnect the high-voltage to the RF cavities.

4.CONCLUSIONS

More insertion devices like Elliptically Polarized Undulator will be developed and installed in the PLS storage ring in the near future. Since they will require their own interlock system as well, we will standardize each module as much as possible. We will also develop redundant system backups including a position detector, processors, various signal paths, and INTRIM with multi-channel inputs.

REFERENCES

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