DESIGN OF MACHINE PROTECTION SYSTEM FOR THE TAIWAN PHOTON SOURCE

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Abstract

The Taiwan Photon Source (TPS) is being constructed at the campus of the NSRRC (National Synchrotron Radiation Research Center). In order to prevent damage to accelerator components induced by various events, design of the global machine protection system (MPS) is on-going. The MPS collect interlock and beam dump request from various system, perform decision, transmit dump beam request to RF system. The PLC based system will be used as a slow MPS which can delivery less than 8 msec reaction time. The fast MPS will dependent on event based timing system to deliver response time less than 5 μsec. Trigger signal for post-mortem will also be distributed by the fast MPS. To ensure alive of the system, several self-diagnostics mechanisms include heartbeat and transient capture will be implemented. The MPS architecture, plans and implementation were presented in this report.

INTRODUCTION

The design and implementation of the global MPS for the TPS is in proceed. There are 24 Control Instruments Area (CIA) provide temperature controlled area around the TPS tunnel for equipments installation. The MPS equipments are distributed on all CIAs include PLC remote I/Os, event receiver, transient capture module responsible for slow-interlock and fast-interlock, sequence events capture. Special input/output patch boards are designed for signal type conversion and easily connectivity and trouble shooting. Roles of the MPS system are collect interlock and beam dump request from various system, performed decision, transmit dump beam request to RF system within minimum delay. Interlock of various subsystems are handled by subsystem level and responsible by various technical groups. Access control and radiation safety have another separated PLC based system to ensure personnel safety. The sole goal of global MPS system is intended to protect the accelerator system from damage due to beam only. Trigger signal for post-mortem will be distributed by the fast MPS also.

MPS REQUIREMENTS

To protect the TPS accelerator equipments, the MPS should collect urgent beam dump requests to beam abort devices (most probably is RF system) within short and deterministic latency time (e.g. less than 10 msec). Input signals consist of cell interlock signals from front-end, vacuum system, beamline, and orbit deviation interlock from BPM system. High heat load due to mis-steering of the beam will damage the vacuum chamber, the MPS should include beam orbit interlock when the stored beam current large than specific value (e.g. 50 mA, to be defined). To provide the flexibility of accelerator commissioning and studying, the beam orbit will not activate at lower current. The MPS need also care some critical devices. Critical element like the beam current measurement DCCT should guarantee its working properly. If these devices failed, the beam is not allowed to store. Configuration of the MPS related components at each cell is shown in Fig. 1.

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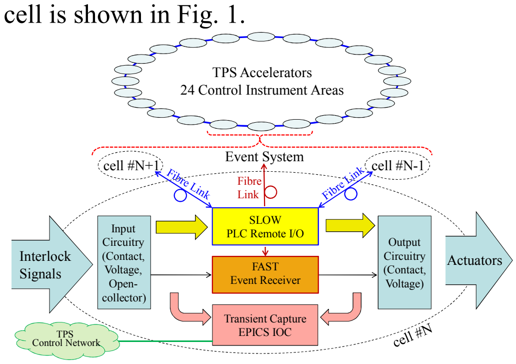

Figure 1: The layout of the cell configuration of the global MPS system.

Subsystem Interlock

Different subsystem interlock sensors check some important device status from temperature, water flow, vacuum, and beam orbit irregularities. A tentative list of the interlock input signals around the TPS is shown in Table 1.

Table 1: Interlock input signals

Device	Quantity	Description
Thermostat Flow meter	2 × 24 2 × 24	Storage ring dipole power supply interlock
Thermostat Flow meter	2 × 24 2 × 1	Booster dipole/quadrupole power supply interlock
Vacuum interlock	2~6 × 24	Storage ring cell vacuum dump beam request
Front-end interlock	2~6 × 24	Storage ring front-end dump beam request
Beamline interlock	2~6 × 24	Storage ring beamline dump beam request
DCCT OK	1	Storage ring DCCT interlock
Orbit interlock active	1	Storage ring orbit interlock active when store beam current more than specific value
BPM interlock	2 × 24	Storage ring orbit interlock input, 48 BPM platforms

BPM Orbital Interlock

The BPM system is used for beam position measurement, which is based on the Libera Brilliance+

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electronics. An orbital interlock signal of the BPM will be generated when the beam position deviates from predefined window. When the orbital interlock of the BPM activated, the global MPS will to do the predefined action immediately (e.g. dump beam).

DCCT Reliability Issues

The DCCT is used for beam current measurement. To insure the DCCT without problem during beam storage is essential from safety view points. A self-diagnostic system will help to ensure DCCT is working properly. A tone loop is used to inject a small AC current with frequency high enough (5 kHz in this test), and not affect the beam current acquisition and lifetime calculation. The AC current tone is detected by a lock-in amplifier as shown in Fig. 2. A small 1~2 μA AC current can be excited by a current loop to justify the working status of DCCT. The sum signals from BPM electronics are also used as a tool to evaluate the correctness of DCCT by the software routinely.

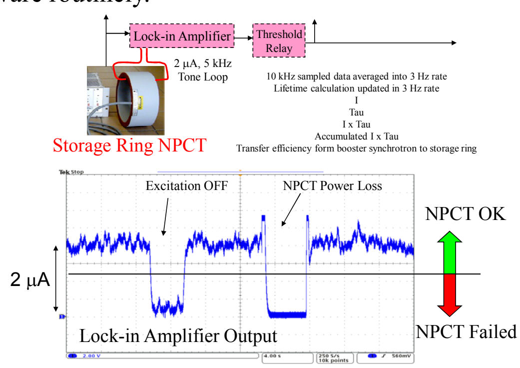

Figure 2: DCCT self-diagnostic system.

PLC BASED SLOW MPS

The PLC based slow MPS should provide following functionalities: delivery a dump beam request from source subsystem in the 24 cells within 10 msec after alarms are received. The PLC modules configuration and distribution are shown below.

PLC Configuration

The slow MPS consists of one main unit with 24 sets of remote I/O modules which distributed at 24 CIAs. The main unit includes sequencer CPU and EPICS IOC CPU. The remote I/O modules located in each CIA is communicated with sequencer CPU via FA-bus. The distribution is configured with two loops. Each loop contains 12 remote I/O modules. There are 64 bits DI and 32 bits DO reserved in each CIA for sensors interlock input and actuator output, respectively. All units are linked together by fibre-optic cables. The system can work normally when single fibre is broken.

Input/Output Adapter

The PLC I/O module consists standard opto-isolated input and open-collector output circuits. To meet various input/output requirements, adapters were designed accompany with the PLC I/O module to support contact, open-collector, and voltage input/output. The adapters also support the input/output for the fast MPS signals. The extra outputs to connect to the post-mortem data capture system which can provide better time resolution to distinguish the sequence of the events happened were also implemented.

Embedded EPICS IOC

The Yokogawa FA-M3 PLC with embedded Linux CPU option has been available for controlling pulse magnet power supply for TPS project [1]. The Linux CPU running the EPICS, it is compatible with the TPS control system. A host PC running Red Hat Enterprise Linux is used to develop the embedded EPICS IOC. KEK [2] has implemented driver/device support for the EPICS records. The EPICS IOC handles around 2300 PVs with 0.1 second scanning rate (in this test), which takes < 20% CPU utilization. The CPU utilization rise to 50% when 50 simulated clients accesses PVs one by one with 20 Hz scanning rate. However, the system time response included delay and jitter will increase with the present of the EPICS CPU may be due to the bus sharing between two CPUs.

Interlock Logics

The interlock logics are handled by sequencer CPU, and the EPICS IOC CPU can through the shared memory to get the whole system status, as well as, to control the output module indirectly. The interlock input becomes active (close for contact, short for open-collector, and +24V for voltage type) when alarm occurs, this ensures continuous protection even during loss of electrical power or wire disconnection.

Reliability of the System

There are several measures to guarantee the reliability of the MPS system. Two independent systems (PLC and event system) were able to deliver dump beam request to ensure reliable operation. The PLC sequencer introduces heartbeat to each subunit and read back for check. The heartbeat is also used to control the power of subunits. The power of the wiring patch panel will shut down without heartbeat which guarantees the machine is safe. Critical output will combine outputs of two subunits located at nearby CIA to avoid single point failure.

EVENT SYSTEM BASED FAST MPS

The fast MPS is intended to send beam abort signal within a few machine turns (1 turn = 1.729 μsec) around the TPS facility. The system will implemented by the backward link functionality of TPS event system [3, 4]. The beam abort signal issues form specific system will use a local event receiver to send event back to the timing master. The timing master will broadcast this urgent event to all event receivers which are distributed around the TPS equipment areas and beamlines. The beam dump request might be sent out from vacuum system, front-end or photon beamline. The system will used to distribute the post-mortem trigger around the TPS facility also.

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CONTROL SYSTEM INTERFACE

Reading and writing the sequence CPU parameters by EPICS IOC CPU through the shared memory was implemented. The preliminary EDM user interface is shown in Fig. 3, which can use to monitor the status of the sequence CPU, FA-Bus, and remote I/O modules. Status and error messages will be easily retrievable in this GUI page. The MPS reset mechanism is also included.

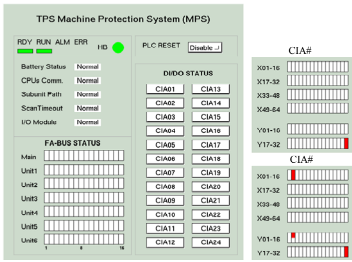

Figure 3: The client user interface of the MPS.

CURRENT STATUS AND RESPONSE TIME MEASUREMENT

PLC Based Slow MPS

The slow MPS consists two fibre loops with 24 remote I/O modules were used for the preliminary functionality test and response time measurement. The photograph of the slow MPS test bed is shown in Fig. 4. The 24 remote I/O modules were configured as it located at CIA around the ring. Fig. 5 indicates that the worst-case response time is less than 8 msec from interlock input and process by the interlock logic and output. The jitter is due to the PLC communication with EPICS IOC which takes around few microseconds to exchange the date.

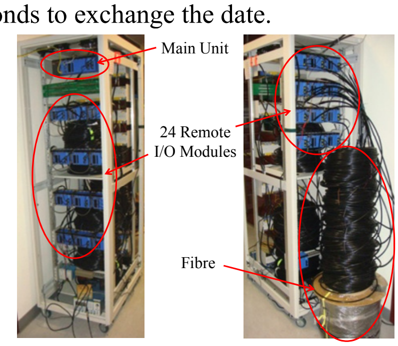

Figure 4: Full scale test bed for PLC based slow MPS.

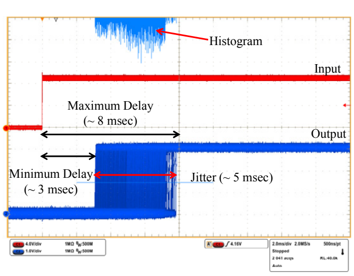

Figure 5: Slow MPS response time measurement.

Event System Based Fast MPS

The fast MPS is based on the backward link of the event system. Interlock signal is send back to the timing master by the mechanism of backward link. When the event is decoded, it can broadcast this event to all event receivers around the ring. Response times of uplink and downlink for the event system were measured at test bed. From the interlock signal active to the signal output at all EVRs, round-trip response time was measured. The signal flow, as shown in Fig. 6, consists of EVR2 => fanout => 310 m fibre => 2 stages fanout => EVR1 => EVG, => 2 stages fanout => 310 m fibre => fanout => EVR2, three fanout concentrators processing times and propagation delay time along event system fibre network. The fast MPS can deliver urgent request from one place to another place within 5 μsec.

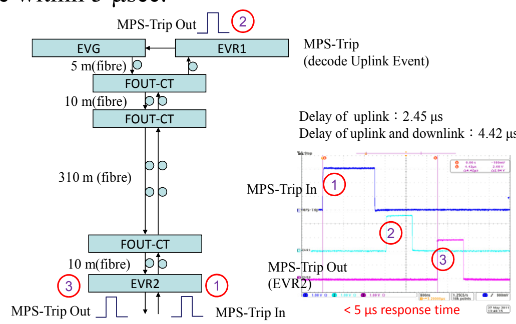

Figure 6: Fast MPS response time measurement.

SUMMARY

In order to prevent damage to TPS accelerator components from mis-steering beam or various subsystem failures, a global machine protection system (MPS) architecture, plans and implementation was presented in this report. The system consists of slow and fast part. The full configuration of the PLC based slow MPS can delivery less than 8 msec guarantee reaction time. The fast MPS will dependent on event based timing system to achieve short reaction time less than 5 μsec. To ensure reliability of the system several self-diagnostic functionalities were implemented also.

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