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IMPLEMENTATION 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) and commissioning expected in 2014. In order to prevent damage to accelerator components induced by various events, a global machine protection system (MPS) was installed and implemented. The MPS collect interlocks and beam dump requests from various system (thermo/flow of magnets, front-end, vacuum system, and orbit excursion interlock), perform decision, transmit dump beam request to E-Gun or RF system. The PLC based system with embedded EPICS IOC was used as a slow MPS which can delivery less than 8 msec reaction time. The fast MPS was 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 were implemented and tested. The MPS architecture, installation, and validation test results were presented in this report.

INTRODUCTION

The Taiwan Photon Source (TPS) is being constructed at the campus of the NSRRC (National Synchrotron Radiation Research Center) and commissioning expected in 2014. In order to prevent damage to accelerator components induced by various events, a global machine protection system (MPS) was installed and implemented. 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, heartbeat-controlled output channels, 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 E-Gun or RF system within minimum delay. Interlocks 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.

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SYSTEM STRUCTURE AND REQUIRED FUNCTIONALITY

The MPS should collect urgent beam dump requests to beam abort devices (most probably is E-Gun or RF system) within short and deterministic latency time (e.g. less than 10 msec) to protect the accelerator equipments. Input signals consist of cell interlock signals from magnet thermo/flow, front-end, vacuum system, beamline, and BPM orbit deviation interlock. 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.

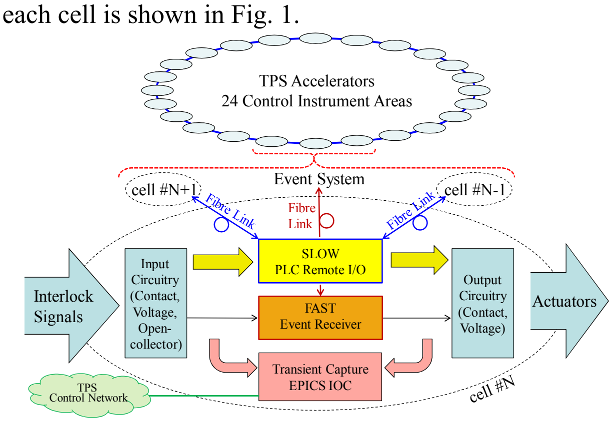

Figure 1: The layout of the cell configuration of the global MPS system.

STATUS OF IMPLEMENTATION

System Configuration

The PLC based slow MPS should provide following functionality that 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. 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 as shown in Fig. 2. Each loop contains 12 remote

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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. The layout of the cell configuration of the global MPS system is shown in Fig. 2 and the configuration of master cell at CIA#22 is shown in Fig. 3.

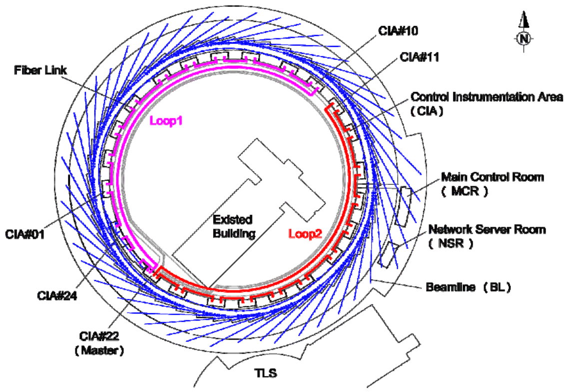

Figure 2: The layout of the cell configuration of the global MPS system.

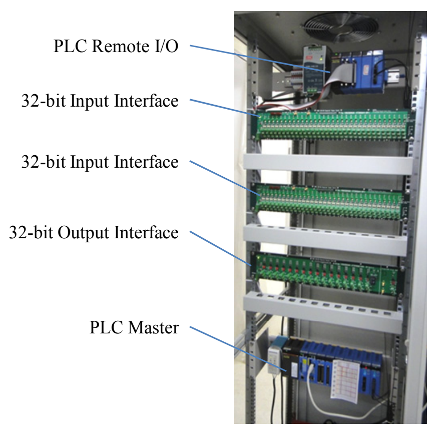

Figure 3: The layout of the master cell configuration.

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 [1], [2]. 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.

Input and Output Patch Board

The input and output patch boards consists standard opto-isolated input and open-collector output circuits as shown in Fig. 4. Patch Boards were designed accompany with the PLC I/O module to support contact, open-collector, and voltage input/output to meet various input/output requirements. It also supports 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. In the output patch board, the ch32 is used to output the PLC heartbeat (program design, 1Hz) and connect to input patch board ch64 for monitoring, when the heartbeat is fault (no flash), the output patch board will be disable all outputs function by disconnect the +24V Power Supple. This function can be Enable or Disable.

The latch mechanize was implement via the PLC program to hold the status of the input and output channels. This function is useful to clarify issues and provide additional information for the system maintenance and diagnostics. Input and output latch reset functions were also implemented as PVs.

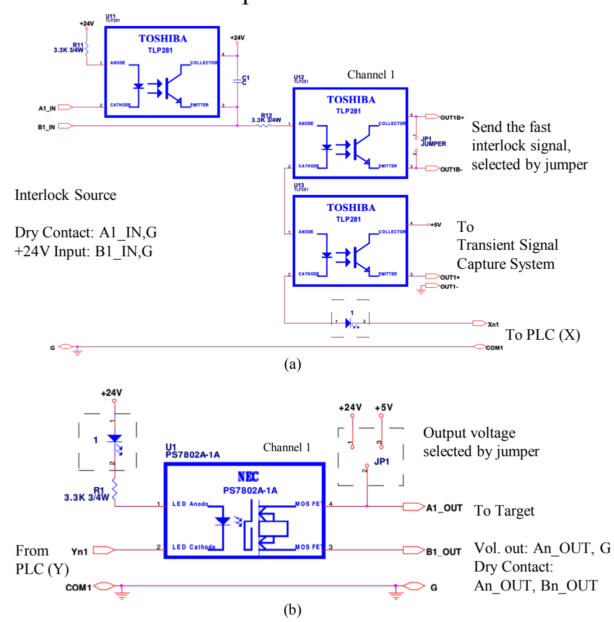

Figure 4: The (a) input and (b) output circuits for MPS I/O patch board.

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 [3]. 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 [4] implemented driver/device support for the EPICS records including ai/ao, bi/bo, longin/longout, stringin/stringout and mbbi. The EPICS sequencer can perform any kinds of logic operations as well as the ladder program runs in PLC sequence-CPU. Both can perform data read-write I/O and registers. The EPICS sequence program with comments is more understandable compared with ladder program. And the work of implementing ladder program may be omitted. EPICS sequencer helps to develop the applications more efficiently.

In this MPS application, the EPICS IOC handles around 2300 PVs with 0.1 second scanning rate, which takes < 20% CPU utilization. The CPU utilization rise to

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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.

Subsystem Interlock and Interlock Logics

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

Table 1: Subsystem Interlock Input Signals

Device	Quantity	Description
Thermostat Flow meter	2 × 24 2 × 24	Storage ring dipole power supply interlock
Thermostat Flow meter	138 138	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

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, such as power supply interlocks, will combine two modules of outputs channel to avoid single point failure. All the interlock functions are handled by PLC 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 latch function was implemented, which can memorised the input/output status and shown on user interface. It is useful for diagnostic the interlock system.

Control System User Interface

Reading and writing the sequence CPU parameters by EPICS IOC CPU through the shared memory was implemented. The preliminary EDM for maintenance is shown in Fig. 5, 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 input/output latch status and reset mechanism are also included.

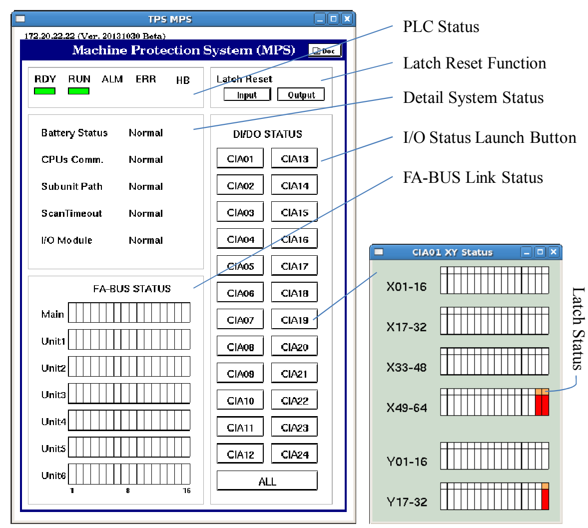

Figure 5: The client user interface of the MPS.

CONCLUSIONS

The Taiwan Photon Source (TPS) is being constructed at the campus of the NSRRC. A machine protection system (MPS) architecture, plans and implementation were presented, which is used to prevent damage to accelerator components caused by mis-steering beam or various component failures. The system consists of slow and fast part. The full configuration of the PLC based slow MPS can delivery less than 8 msec response time. The fast MPS will dependent on event based timing system to deliver response time less than 5 μsec. To ensure alive of the system, several mechanisms (self-diagnostics, heartbeat) will be implemented.

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