Machine Protection System for HEPS

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On behalf of Machine Protection System
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1. Brief introduction of HEPS & MPS
2. Requirements & Design
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Brief introduction of HEPS & MPS
### High Energy Photon Source

<table>
<thead>
<tr>
<th>Main parameters</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy</td>
<td>GeV</td>
<td>6</td>
</tr>
<tr>
<td>Circumference</td>
<td>m</td>
<td>1360.4</td>
</tr>
<tr>
<td>Emittance</td>
<td>pm·rad</td>
<td>34.2</td>
</tr>
</tbody>
</table>
| Brightness @20 keV    | ph/s/mm²/mrad²/0.1%BW | $3.2 \times 10^{22}$ @low-$\beta$  
                          |                     | $0.77 \times 10^{22}$ @high-$\beta$ |
| Beam current          | mA         | 200                            |
| Injection             |            | Top-up                         |
Machine Protection System

- The HEPS (High Energy Photon Source) operate with large amount of power and energy stored in beams and superconducting magnets.

- In order to prevent damage to accelerator components in case of failure, highly reliable Machine Protection System (MPS) is indispensable.

- MPS equipments are distributed in all the accelerator area. It collect urgent beam dump requests to beam abort devices within Very short time. Input signals from PS, ID, RF, vacuum, beamline, BPMs, BLMs and so on.

- SPS signals: ~ 3200
- FPS signals: ~ 2000
Requirments & Design
## Requirements

### Interlock protection requirements based on radiation

<table>
<thead>
<tr>
<th>Trigger conditions</th>
<th>22kHz data from bpm on both sides of the ID,</th>
<th>Horizontal closed orbit</th>
<th>&gt;2.8mm or</th>
<th>vertical closed orbit</th>
<th>&gt;1.5mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interlock protection response time</td>
<td>&lt;0.1ms , the faster the better</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam dump method</td>
<td>RF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam dump time</td>
<td>&lt;1ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data preservation time length</td>
<td>Turn by turn BPM data</td>
<td>10 thousand turns pre and post trigger time(~0.9s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>0.5s data pre and post trigger time</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Note:

1. This table is to protect Vacuum components from synchrotron radiation damage, and the integrated interlock protection scheme need Control, Physics and other systems design together.
2. when receiving trigger signal, lock the cache data, and can transmit these data at a slower speed.
3. Personnel safety and machine protection should be considered.
- The MPS consist of Slow Protection System (SPS), Fast Protection System (FPS) and Run Management System (RMS).
  - The SPS is Programmable Logic Controller (PLC) based system which can deliver less than 20 msec reaction time.
  - The FPS is Field Programmable Gate Array (FPGA) based system which can deliver less than 20 μsec reaction time.
  - The RMS guarantee HEPS running safely and easy to operate, together with Personnel Protection System (PPS), it can set the accelerator modes by mechanical key switch.
Design Principles

- **Independence**: MPS responsible for the accelerator operation safety, it’s just provide interlock signals between related systems, data transfer over a independent network.

- **Redundancy**: critical equipments or signals should be redundant configuration.

- **Fail-safe**: failure in MPS should lead to a safe state automatically according to preset interlock program.

- **Safety, availability and reliability**: self-diagnostic, heartbeat...
MPS Architecture

IoC  OPI  SERVER  RMS

Ethernet/EPICS

LA-MPS  BS-MPS  SR-MPS

Beamline interlock
pps
Fire monitoring
Oxygen monitoring

Interlock signal

Hardware Interlock signal

LA  BS  SR
System & equipment

Event record/analyse

Overall interlock

System/equipment interlock
MPS Layout

- Central Station
- Master Station
- Substation

Storage ring C=1360.40m

Booster 0.5-6GeV C=454.07m

BTS

LTB

dump

Linac
SPS Layout

- IOC
- OPI
- SERVER
- RMS

PPS
Beamline ID
Vacuum PS ...

SPS Master station

PLC FL-NET

- LINAC substation
- Booster substation
- SR substation1
- SR substation8

YOKOGAWA
FA-M3 Dual-system Redundancy
Widefield3
F3SP71/76-
• Work when Device/System fault will cause beam loss
• Response time: less than 20 µsec
• Inputs
  ■ Beam diagnosis: BPMs, FCs, BLMs...
  ■ Power supplies
  ■ RF faults
  ■ Insertion devices
  ■ etc
• Behavior: Injection forbidden, electron gun shutdown, RF power off
FPS Architecture

- MPS Main Station
- Machine Mode
- Trigger
- RF LLRF
- Electron GUN
- Linac FPS Chassis
- Booster FPS Chassis
- Ring FPS Chassis
- FPS Master Controller
- FPS I/O Interface
- Signal conditioning board
- BPM
- PS
- RF fault
- BCM
- BLM
- ID
MTCA/ATCA Workshop for Research and Industry

FPS Layout

- LA-FPS SubStation
- BS-FPS SubStation
- SR-FPS-1 SubStation
- SR-FPS-2 SubStation
- SR-FPS-3 SubStation
- SR-FPS-4 SubStation

Connections:
- Fibre net
- Ethernet

- SPS
- PPS
- RF
- Electron GUN

At least 200 I/O

At least 200 I/O

At least 200 I/O

At least 200 I/O
• 9U, 21 slots
  ■ Slot1-2, Controller
  ■ Slot3-4, Output
  ■ Slot5-6, free for Input
  ■ Slot7-21, Input
FPS Master Controller

- Xilinx SoC + FPGA
- 6U, Refer to CPCI specification
- J1 to J5 connector used

At least 200 Inputs
**FPS I/O Interface**

- 14 channel inputs
- 6U, Refer to CPCI specification
- J1 to J2 connector used

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**I/O Interface Diagram**

- FPGA
- J1 25 pin
- J2 22 pin
- I/O Conditioning (if necessary)
FPS-optical receiver circuit schematic
• RMS guarantee the accelerator running safely and easy to operate. Together with PPS, RMS can set and validate machine modes and machine state.

• Global level defined.

• Interface to MPS and PPS through cables, interface to the other system through cables or EPICS CA.

• PLC and industrial computer based.

• Whole system UPS (Uninterruptable Power Supply) powered.
RMS Relationship

Relationship with related systems and equipments
Function can be completed through software applications.

Machine modes selected by key switch and machine state set by touch panel in central control room.
Only in “Running” state, beam can be extracted.
Summary
Machine protection is not an objective in itself, it’s to maximise operational availability by minimising down-time, and avoid irreparable equipment damage.

The preliminary design has been done, detailed design (fault classification, operation modes) is on-going.

R&D platform for MPS will be set up, Prototype will be developed.
Thanks for your attention!