OVERALL DESIGN CONCEPTS FOR THE APS STORAGE RING MACHINE PROTECTION SYSTEM*

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Abstract

The basic design and status of the machine protection system for the Advanced Photon Source (APS) storage ring are discussed. The machine is passively safe to the bending magnet sources, but the high power of the insertion devices requires missteering conditions to be identified and the beam aborted in less than one millisecond. The basic aspects of waterflow, temperature, beam position, etc. monitoring are addressed. Initial commissioning of subsystems and sensors is statused.

I. INTRODUCTION

The Advanced Photon Source (APS) storage ring (SR) will be a third-generation synchrotron radiation user facility and is expected to become operational in late 1996. At 100 mA stored beam current and 7-GeV beam energy, the ring is designed to be passively safe to the 80 bending magnet (BM) radiation sources under normal cooling water flow conditions even to beam missteering [1-3]. Under the same beam conditions, however, the 10-kW x-ray beams from any installed "closed gap" insertion devices, if missteered, pose an immediate threat (in the few-ms timescale) to the extruded aluminum vacuum chamber. The machine protection system (MPS) is based on an array of different types of sensors that will be used to determine if conditions are unacceptable. It would then initiate a fast beam abort by interrupting the low-level rf for the power to the accelerator cavities. The stored beam would then coast inward radially to a scraper and be lost in 300 µsec. Water flow, vacuum gate valve status, and beam current levels will be initially involved. This will be augmented by beam missteering sensors using selected rf BPM monitors, resistive wire monitors (WMs), and resistive temperature devices (RTDs). A commissioned beam-limit chassis covering the region of the insertion device (ID) chamber is a prerequisite for installation of the first 2.5-m-long undulator.

II. EXPERIMENTAL BACKGROUND AND SENSOR STRATEGIES

The APS presents a challenge both in terms of size, with its 1104-m circumference ring, 80 bending magnet sources, more than 600 controllers of water/temperature, etc., and in the required ms abort time scale if the 10-kW ID beam becomes missteered beyond the accepted limits. It has been calculated that certain areas of the extruded aluminum vacuum chamber could reach unacceptable temperatures if the 10-kW beam dwelled on it longer than a few ms. Since space limitations preclude a full description of the system, only its key features will be addressed.

The APS MPS system can be divided into roughly three functionally different subsystems: (1) the low-level fault condition sensors, (2) the local MPS logic summation boxes, and (3) the central MPS summation chassis with interface to the fast beam abort system (FBAS) itself. The FBAS method is via a momentary interruption of the storage ring rf system. At this time to address the 1-ms abort response time requirement, the abort command results in the momentary interruption (~100 msec) of the low-level rf which is amplified by the high-power rf klystron system. Redundant paths are used, and the beam intensity is monitored by an integrated current transformer (ICT) to verify the beam is below 0.5 mA within the 100-ms time window. Eventually, it is anticipated that a second way to abort the high-power rf will be used should the system sense that the beam current has not reached the low limit in 100 ms.

A. The Low-Level Fault Condition Sensors

A variety of sensors are involved to verify the machine systems are within their prescribed limits. The cooled water flow to all absorbers and temperature (copper metal system), the cooled water flow to the extruded aluminum vacuum chambers (Al water system), and the status of all vacuum gate valves are monitored through a series of 80 VME-based latch cards. Figure 1 shows a schematic of a single sector overview (there are 40 sectors) with a monitoring of flow transducers and thermocouples. The 1-MHz heartbeat is generated in each board and is only interrupted if one of the limits is reached.

An independent water flow and valve status comes from each front end (the UHV section from the accelerator gate valve to the ratchet wall) which includes photon shutters and other apertures.

The threat of the missteered ID beam and even the BM beams for stored currents greater than 100 mA has resulted in a series of devices. The principal protection is by monitoring the beam positions from about 240 of the 360 rf BPMs in the SR. Each dedicated beam limits chassis will cover six BPMs from two adjacent sectors. Although the BPM electronics have single turn capability, the raw output will undergo a 32-turn (~100 µs) average, and this position will be compared to a "warning limit" and an "abort limit." In the latter case, (and if the local ID has a closed gap) the heartbeat from this chassis to the local MPS summation box would be interrupted, resulting in the local MPS heartbeat being interrupted to the main MPS summation box. The FBAS would be activated then, and the beam would coast into the scraper in less than 300 µs.

*Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

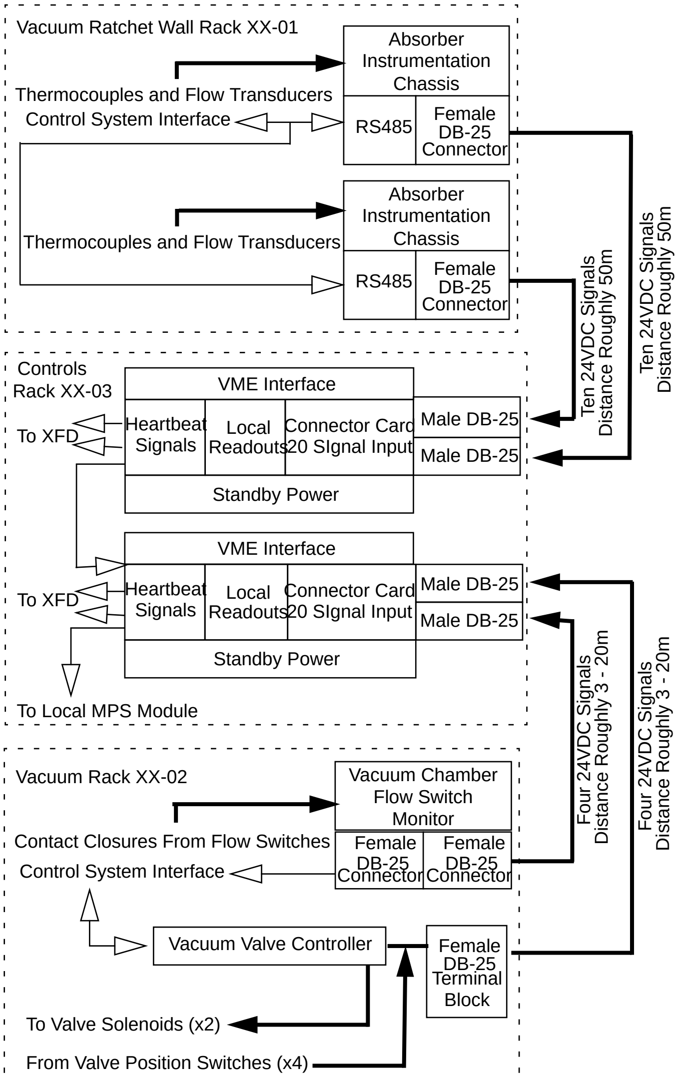

Figure 1: Single sector overview of the water system and vacuum isolation valves to the local VME latch card.

Additional protection from global orbit missteering situations is provided by a small number of resistive wire monitors located above and below the x-ray beam centerline [2]. These are located on the ID front ends which also transport part of one of the two dipole sources in each of the first five sectors of the SR. The temperature change of this wire under x-ray irradiation causes a resistance change which the wire monitor electronics chassis compares to a preset limit. It also has a heartbeat that feeds a local MPS module. This response timescale is more like tens of ms while a threat from a BM source only is many seconds [3]. Also a series of resistive temperature devices (RTD) will be mounted on the upper and lower wall of each dipole vacuum chamber. A bending magnet beam that is missteered will provide sufficient thermal load so processing electronics can detect the temperature change. The prototype electronics chassis has been built, and the RTD subsystem will be tested in the summer of 1995. This particular protection is planned to be installed prior to test operations above the baseline 100-mA stored beam current.

An additional redundancy is planned by using the beam position information in the orbit feedback systems reflective memory. An independent microprocessor would evaluate positions and even angles to assess beam orbit correctness. This system would be linked to the main MPS module due to the global nature of its data pool.

The local MPS inputs and outputs are summarized in Table 1. There are a few sectors where the eight-channel allotment is exceeded; in those either the sensor heartbeat will be shipped to the next available module or a daughterboard will be developed.

Table 1: Summary of Inputs and Outputs for the Local MPS Module.

8 Inputs Per Local MPS and 1 Output		
Inputs	Total aborts	# Inputs Per Local MPS
Wire Monitors	2	1 in 2
Surface Temp	20	1
Vacuum	20*	1
Water Flow	20*	1
BPMs	20 BM	1
	20 ID	1
XFD	40*	2
Output	1	1

*sum 2 sectors

B. *The Local MPS Module*

The local MPS module relies on eight fiber receivers for the input 1-MHz heartbeats and uses Altera-based chips to evaluate the incoming channels. Since both Alteras detect the same inputs, a redundancy factor is developed. The module has a VME architecture and is monitored also by EPICS via an I/O connector. The boards are powered by a supply separate from the VME chassis. Since unused inputs are masked in Altera programming, no jumpers are used. One heartbeat is sent on fiber to the main MPS modules. Figure 2 shows a schematic of the module.

C. *The Main MPS Module and FBAS Interface*

The main MPS module in this phase is comprised of three local modules to cover the heartbeats from the 20 local MPS modules and a decision making card that has an input to the rf pin diode switches. An ICT used as an average current monitor provides input on the low (0.5 mA) or high limit (100 mA) in the ring. Abort requests are ignored if the current level is less than 0.5 mA (as in the early commissioning). Two beam monitor level signals are used.

Aborts are initiated when a heartbeat signal is lost, either of the two beam monitoring analog signals are removed, or the maximum beam current is detected by the analog circuits. The line that requested the abort is latched, the start/stop injection signal is latched low, the rf gates open for 100 ms, and the beam current level logic circuits are activated. If the beam current in the ring has not fallen below 0.5 mA in 100 ms, the rf

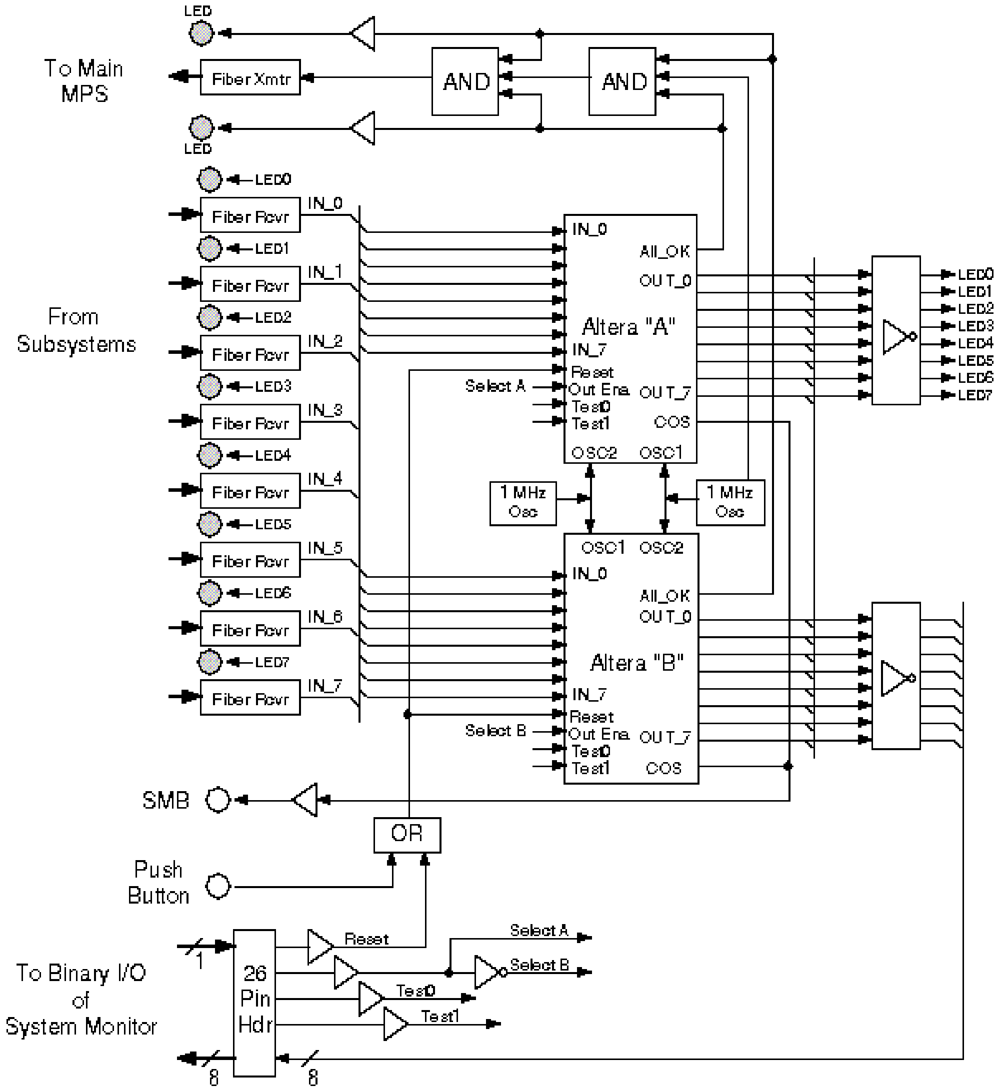

Figure 2: Schematic of the local MPS system module. Each module handles eight inputs and covers two sectors.

gate sensors open until it does. The second rf abort technique would also be activated in the final system implementation.

III. STATUS AND EARLY COMMISSIONING

All local MPS modules, the main MPS module, and rf interface card, the current monitor, and the fiber optic links are installed. The current monitor low limit at 0.5 mA has successfully tripped the rf when the beam exceeded this limit. Single sector water/vacuum valve status has been tested and the front-end monitor system has been linked. The wire monitor test and RTD test are expected this summer. The beam limits chassis is in the final design and test phase and is expected to be tested in May or June 1995. Production of multiple units will follow this summer.

Additional issues of rapid beam vertical instabilities whose average position is within limits, but exceeds the limits for short times, and beam transverse size blowup are being evaluated. The time before damage occurs is much longer, and this relaxation of the response time helps.

IV. SUMMARY

In summary, the APS MPS for the storage ring is being commissioned and validated as the ring is brought into operation. A multilayered defense with redundant channels is used to address the challenge of dealing with missteered beams in third-generation x-ray sources.

V. REFERENCES

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