UPGRADE OF NSLS-II ACTIVE INTERLOCK SYSTEM

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Abstract

The NSLS-II Storage Ring is protected from possible damage from synchrotron radiation by a dedicated active interlock system (AIS). The AIS monitors electron beam position and angle and triggers beam drop if beam orbit exceeds the boundaries of pre-calculated active interlock envelope. The one year worth of the AIS operation showed that there is a number of erroneous machine trips associated with the AIS. In this paper we describe an upgrade of the AIS that allowed us to get rid of the Storage Ring faults and improved the overall NSLS-II reliability.

INTRODUCTION

The synchrotron radiation from both the bending magnets and the insertion devices (ID) [1, 2] installed in the NSLS-II Storage Ring (SR) [3] can damage the SR in-vacuum components. To avoid such scenario we devised, developed and implemented a dedicated active interlock system [4-6].

The AIS is designed to continuously monitor beam orbit in IDs and to drop the beam in case it exits predefined AI envelope (AIE) [7, 8]. Typical AIE is an xx' or yy' phase space rectangle of +/-0.5 mm and +/-0.25 mrad.

Fig. 1 schematically shows signals that the AIS is monitoring for each ID.

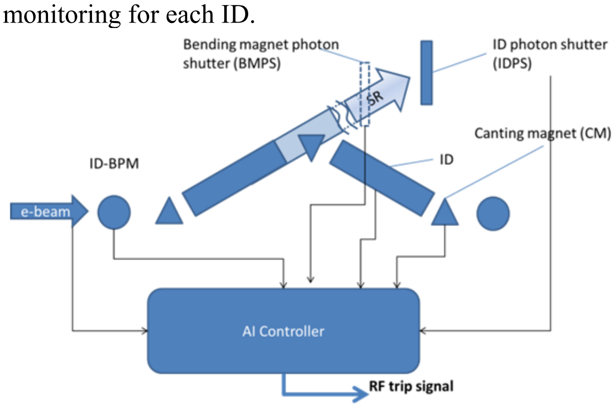

Figure 1: Schematic of signals from various hardware to the AIS. Here we show the canted IDs for the purpose of generality.

The AIS calculates beam angle and deflection at the center of the drift between two neighbouring beam position monitors (BPMs) from respective fast acquisition (FA) BPMs readings (10 kHz data). The beam current readings are obtained from the storage ring DCCT. In case of canted IDs the current of the canting magnets, which create a local bump on the beam orbit, are monitored by the AIS as well.

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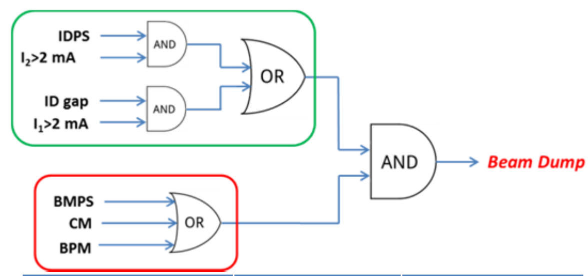
The status of the bending magnet photon shutter (BMPS) and the frontend photon shutter, a.k.a. ID photon shutter (IDPS), are also monitored by the AIS.

The main functional block of the AIS is the AI controller (AIC). It performs the monitoring of various hardware signals and makes a decision on whether the beam shall be dumped. The beam dump is realized by tripping low level RF. The FPGA was chosen for AIC to minimize the response time of the AIS.

The logic of the AIC is shown in Fig. 2.

The logic gates encircled by the green line are responsible for engaging the active interlock. It is getting engaged either when the beam current is above 2 mA and the IDPS is open or when the beam current is more than 2 mA and the ID gap is closed.



	0	1
IDPS	closed	open
I_1	< 2 mA	>= 2 mA
I_2	< 2 mA	>= 2 mA
ID (gap)	gap open	gap closed
BPM (positon/angle)	all within AI limits	some out of AI limits
CM (current)	within range	out of range
BMPS	open	close

Figure 2: Active Interlock Controller logic.

The first set of conditions protects the beamline components from excessive deposit of IDSR power [9].

The second set of conditions for enabling AI ensures that the beam stays within AIE when ID is closed (i.e. not fully open) and when the beam current is above the Safe Current Limit (SCL) of 2 mA. It was calculated that for beam current below the SCL none of the SR or frontend components can be damaged by the IDSR for the beam allowed to be anywhere within the ring acceptance.

The "OR" logical gate in Fig. 2 encircled by the red line defines when the enabled AIS drops the beam.

First possible reason for beam drop is for the beam orbit to exceed the AIE in any of the IDs.

Second possibility is that the BMPS got closed when the AI is enabled. The reason for this option is that the BMPS was designed to accept the synchrotron radiation power from the bending magnets only. The IDSR might damage the BMPS.

Finally, for the canted IDs, the canted magnets current out of range will cause the AIS to drop the beam.

AIS UPGRADE

There were two major interconnected upgrades done to the AIS during its first year of operation.

First, we implemented a capability of saving various post-mortem data for AIS beam dumps [10]. These data include FA and turn-by-turn BPM readings prior to and at the moment of the trip, as well as the status of all AIS related subsystems at the moment of the beam dump.

We also developed a set of dedicated software tools for quick and convenient data analysis.

These upgrades allowed us to investigate causes of each AIS trip. Figure 3 shows an example of a typical trip caused by RF malfunction.

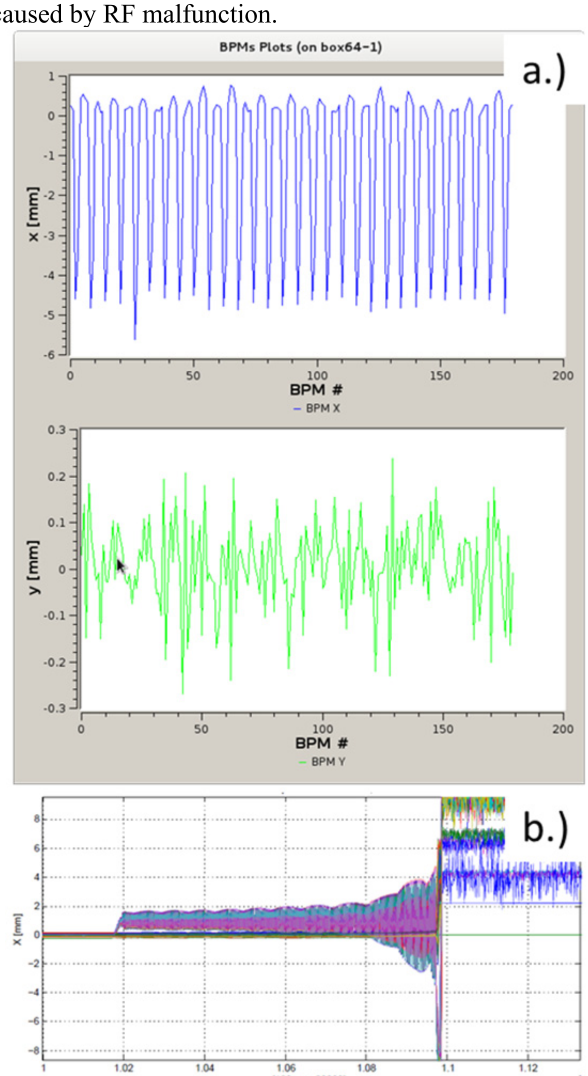


Figure 3: Typical AIS trip caused by RF instability. All BPMs x and y readings at the moment of the trip (a) and horizontal BPMs readings prior to the trip (b).

As one can see, the unstable RF causes beam drift outside of AIE in dispersive BPMs. This, in turn, causes the AIS to trip the beam.

While majority of the AIS trips were justified we noticed that many were caused by BPM glitches rather than actual beam motion. For the reasons still not well understood an arbitrary BPM can show a single unphysical beam position reading outside of the AIE. Such glitch, as demonstrated in Fig. 4, causes unwanted beam trip and machine downtime that shall be avoided.

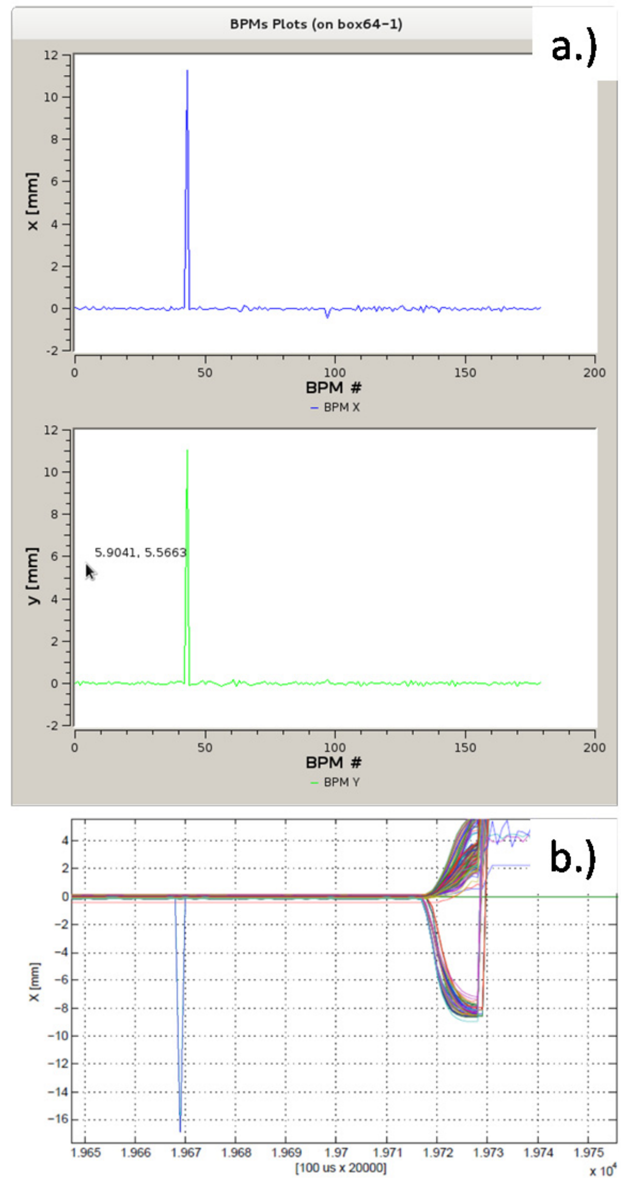


Figure 4: AIS trip caused by BPM glitch. A single BPM shows the beam well outside of the AIE at the moment of the trip. Plots (a) show all BPMs x and y readings at the moment of the trip and plot (b) shows horizontal BPMs readings prior to the trip.

In order to eliminate erroneous machine trips caused by BPM glitches we implemented the AIS glitch filter. At the present time the AIS dumps the beam only if the AIE is violated for at least two consecutive readings.

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Implementation of this filter significantly reduced machine downtime.

FUTURE PLANS

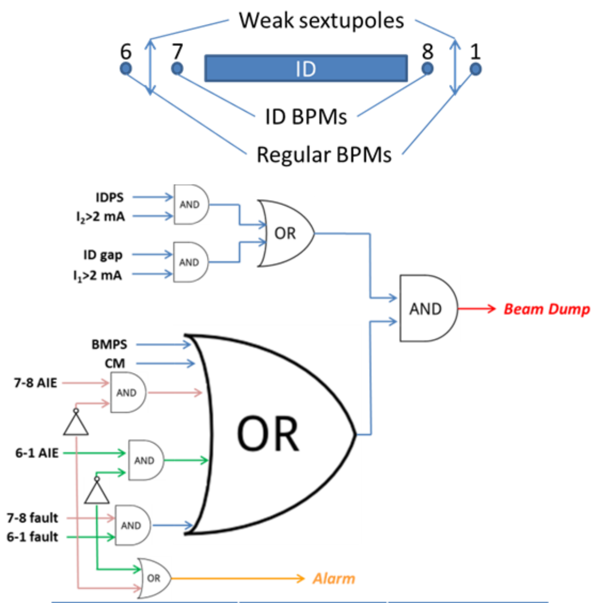
We plan to add redundancy to our system in the near future.

The year worth of the AIS operation showed that BPMs are the weakest part of our system. Several instances of dying and therefore unreliable BPMs caused some downtime for the whole accelerator and significant downtime for respective beamlines. For that reason we are planning to add redundant BPMs to the AIS.

Each ID has a couple of dedicated BPMs. Yet, there are regular BPMs nearby each ID separated from ID drift only by weak sextupoles.

We checked that these sextupoles are weak enough to be ignored when beam deflections from design orbit are small. Thus regular BPMs located nearby each ID can be used to monitor the AIE.

Figure 5 shows the proposed changes to the AIS logic.



	0	1
IDPS	closed	open
I_1	< 2 mA	>= 2 mA
I_2	< 2 mA	>= 2 mA
ID (gap)	gap open	gap closed
7-8,6-1 AIE	within AIE	out of AIE
7-8,6-1 fault	functioning	faulty
CM (current)	within range	out of range
BMPS	open	close

Figure 5: Suggested logic for future AIS upgrade.

We believe that suggested upgrade will allow to eliminate machine downtime when one of ID BPMs fails.

CONCLUSIONS

In this paper we described the most recent status of NSLS-II active interlock system.

We discussed recent upgrades done to the AIS.

We described how implementation of capability of collecting post-mortem data for each beam trip as well as development of respective analysis software allowed us to investigate the trips of the active interlock system.

Since we found that some of these trips were caused by the glitches of beam position monitors, we implemented special glitch filter to the AIS. This filter is preventing erroneous AIS trips and has significantly reduced machine downtime.

Finally we discussed the plans of future upgrades of the active interlock system. We suggest adding some redundancy to our system by including into it the readings of additional beam position monitors. We expect these improvements to increase the overall reliability of NSLS-II operation and increase the availability of the synchrotron to the users.

ACKNOWLEDGEMENTS

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