CAUSE IDENTIFICATION OF BEAM LOSSES IN PETRA III BY TIME CORRELATION OF ALARMS

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Abstract

PETRA III is a high brilliant synchrotron light-source operating at 6 GeV at the DESY site in Hamburg. The Machine Protection System (MPS) of PETRA III is under operation since the beginning of the commissioning of PETRA III in April 2009. Under certain alarm conditions the MPS generates a dump command and protects the machine against damage. As a functional extension the MPS hardware examines the time correlation of alarm sequences after a beam loss. The alarm sequences are evaluated in a software-based system so that the cause of a beam loss can be displayed in the control room immediately. This paper describes the hardware implementation as well as the software rules.

MOTIVATION

Alarms from several external systems i.e. beam position monitors (BPM), temperature system and vacuum system are connected to the MPS. Under certain alarm conditions the MPS creates a dump command, which is used to switch off the RF system. The beam is aborted within 400 µs. [1] [2]

About 250 alarm sources are connected to the MPS. The status of each alarm input is shown on the MPS console software in the control room. To find the cause of a beam loss, operators have to interpret the displayed alarms and the time relation between beam loss and a dump command. Due to the number of alarms this could become a very complex error-prone approach. To support operators a system is implemented which interprets the alarm statuses after a beam loss automatically and gives detailed information what caused this event. In the following the system is discussed in more detail.

PROCESSING INCOMING ALARMS

Special status bits are implemented in the MPS hardware for the needs of cause identification by defined rules. Each alarm input is represented by 7 Bits. Three of these are used for the cause detection. Figure 1 shows the signal flow inside the MPS.

"Just-Before-Loss-Alarm"

The just-before-loss bit is set, if the corresponding alarm input changed to active state within a short time (typically 100 ms) before a beam loss. This status bit is used to detect alarms like magnet power fail or RF system fail which typically cause a beam loss but are not used to generate a dump trigger [1].

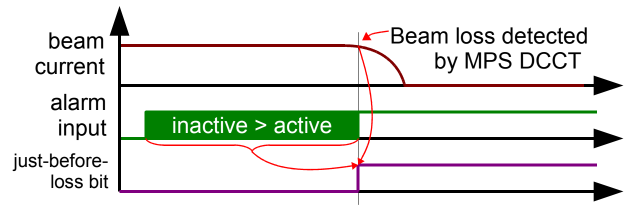

Figure 2: Just-Before-Loss-Alarm bit.

"First-Dumping-Alarm"

The first-dumping-alarm status bit of an alarm input is set, if this input triggered the dump first system wide. If a combination of several inputs had led to a dump trigger, the first-dumping status bit is set for all of these inputs (see Fig. 4).

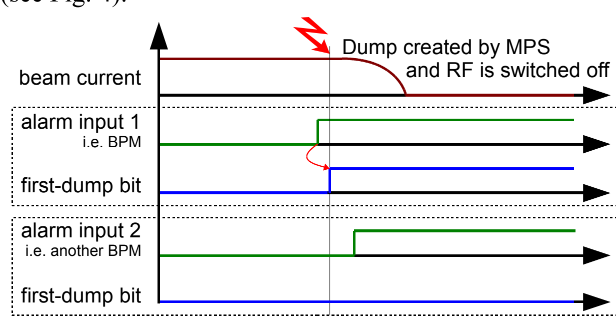

Figure 3: As the First-Dump-Alarm bit is system wide, it is only set for alarm input 1. Alarm input 2 became active after the first-dump-alarm bit had been set for alarm input 1 (see combined dump in Fig. 1).

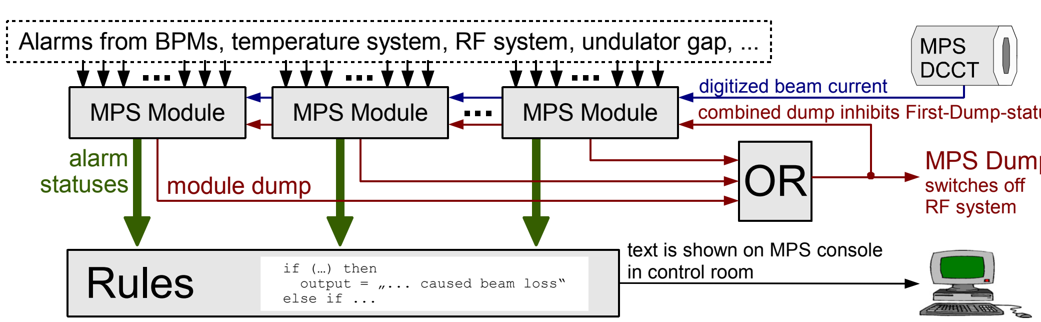

Figure 1: Signal flow inside the MPS.

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"Dump-Simultaneous-Alarm"

The module wide dump-simultaneous-alarm bit is set if changes at the input itself had generated the dump command. With this information it is possible to examine the chronological order in which combined alarms were activated and triggered a dump (i.e. was the undulator gap closed first or became the BPM alarm active or on which BPM the last change to active occurred). Additionally this bit enables recognition if the dump is a consequence of alarm input changes or a consequence of exceeded beam current thresholds (see for example later).

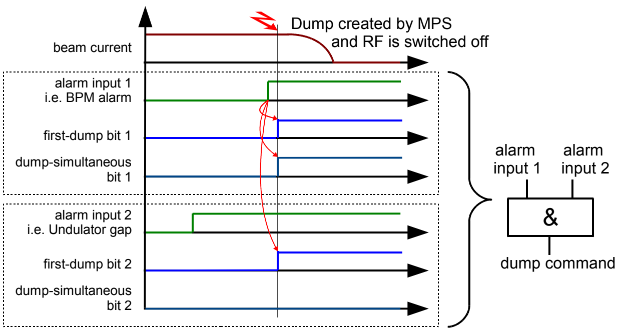

Figure 4: Dump-Simultaneous-Alarm bit: is only set, if the dump was generated simultaneously with changing to active state of this alarm input. First-Dumping-Alarm bit is set for each combined input which had led to the dump.

Other Status Bits

There are four additional status bits that indicate the state of the alarm input. These bits are used for displaying the current status in the MPS console in the control room only and are not required for the cause identification.

MPS Beam Loss Detection

The MPS detects a beam loss with a dedicated DCCT (DC Current Transformer). This makes it possible to detect, what was first: beam loss or dump command. The digitized beam current is transmitted to the MPS modules for comparison with individual beam current thresholds for each alarm input and it is used to detect "just-before-loss"-alarms. A beam loss does not generate a dump trigger.

Use of Timestamps

For the cause detection of beam losses no timestamps are used in this system. Time relationships between alarm inputs and an event (dump or beam loss) are identified inside the hardware. Of course the presented idea could also be implemented using timestamp. In this case the time relations described above have to be extracted from the timestamps.

ALARM DEPENDENCIES

In [3] a concept is described how alarm dependencies can be used to find the cause of a dump or beam loss. Based on this several rules for the cause identification are formulated by knowing the relationship between certain alarms and by using the implemented alarm status bits. A software-like formulation is used to list some important rules:

if (<alarm status> from <alarm input> [AND <alarm status> from <alarm input> AND …])

The notation of the alarm statuses is as follows:

Just-Before-Loss-Alarm:	JBL-alarm
First-Dumping-Alarm:	FD-alarm
Dump-Simultaneous-alarm:	DS-alarm

Rules for Cause Identification

1. **if (JBL-alarm from RF system) then** display = "Beam loss due to RF system fail.";
2. **else if (JBL-alarm from magnet power supply) then** display = "Beam loss due to magnet power supply fail.";
3. **else if (FD-alarm from temperature system) then** display = "Temperature system has created a dump.";
4. **else if (FD-alarm from vacuum shutter) then** display = "A vacuum shutter had created a dump.";
5. **else if (FD-alarm from BPM AND DS-alarm from BPM AND FD-alarm from undulator gap AND NOT DS-alarm from undulator gap) then** display = "BPM system had created a dump.";
6. **else if (FD-alarm from BPM AND NOT DS-alarm from BPM AND FD-alarm from undulator gap AND NOT DS-alarm from undulator gap) then** display = "Dump because the beam current threshold was exceeded at closed undulator gap and BPM alarms.";

EXAMPLES

Here are some examples to improve understanding of some rules. Note: not all alarms generate a beam dump, i.e. RF system and magnet power alarms are used for diagnostic purposes only [1].

Rule 1: "Just-Before-Loss" RF System Fail Alarm

If the RF system fails, this causes directly a beam loss. As a consequence the BPM system detects the inwards drifting beam and generates a dump trigger (which then has no longer effect; see Fig. 5). In this case the MPS had detected an alarm from the RF system before the beam loss, but the dump is triggered after it.

Rule 2: "Just-Before-Loss" Magnet Power Fail Alarm

A magnet power supply fails resulting in a slow beam loss. As a consequence the BPM system detects an orbit deflection and gives an alarm to the MPS which then generates a dump trigger which switches off the RF system and the rest of the beam is lost. The MPS then had detected an alarm from a magnet power supply before the beam loss and an alarm from the BPM system after it (see Fig. 6).

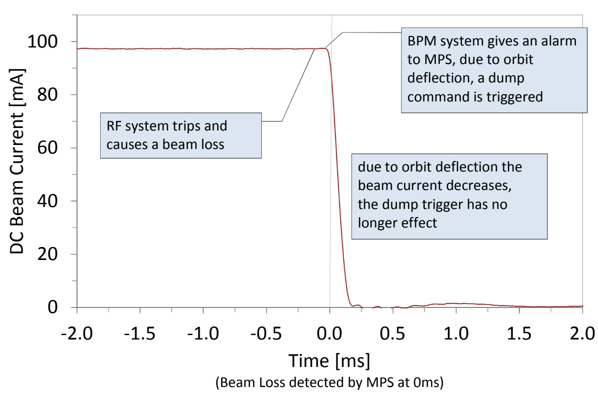

Figure 5: RF failure before the beam loss (rule 1).

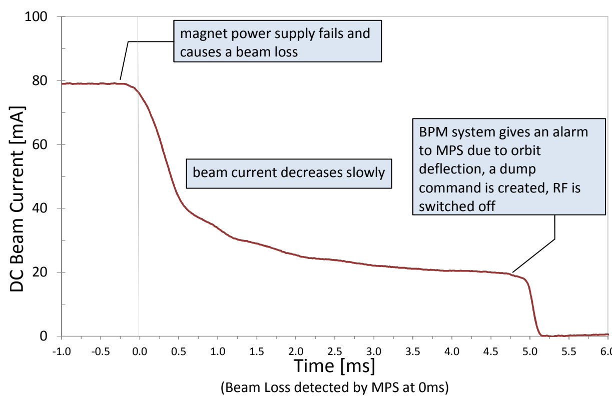

Figure 6: Magnet power failure causes the beam loss (rule 2), BPM alarm and dump afterwards.

Rule 4: Temperature System Alarm

If the temperature at a certain position is too high, the MPS receives an alarm from the temperature system and a dump is triggered directly. As a consequence of this, alarms from the BPM system can occur but the order of the rules ensures that the correct cause is detected (rule 4).

Rule 5: Closed Undulator Gap, BPM Alarm

Each BPM alarm is masked in the MPS by the corresponding undulator gap and by an individual beam current threshold [1]. Typically the undulator is closed during a user run and the present beam current exceeds the beam current threshold for this input (BPM). As long as there are no orbit deflections at the corresponding BPM a dump is not triggered. If the relevant BPM detects a bad orbit a dump trigger is generated and rule number 5 matches.

Rule 6: Closed Undulator Gap, BPM Alarm, Beam Current Exceeds Threshold

Due to simultaneous and first alarm bits it is also possible to detect, that no alarm input had changed its state when the dump had been triggered. Thus the reason for the dump was exceeding the beam current threshold of an input. This specific case of an event is included in this rule (see Fig. 7).

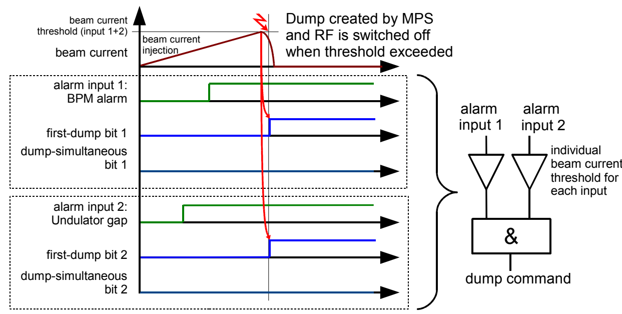

Figure 7: Dump by exceeding the beam current threshold of a BPM alarm input when orbit alarm already active and undulator gap is closed while increasing beam current during injection (rule 6).

FIRST RESULTS

With the first set of rules applied to the datasets in the archive 94% of the events could be identified (510 events, beam losses and dumps). Many of the remaining 6% are caused by beam losses, which were caused by the feedback system during machine studies. Regrettably no feedback alarms are connected to the MPS yet so that no rules could be set up to identify the cause of these beam losses.

CONCLUSION

The idea of a system, which processes upcoming events and creates a human understandable output, could be realized. Further tests of the output are necessary but first results show, that it could get a very helpful tool to complete the MPS diagnostic capability. The current implementation is very flexible and simple and it is possible at any time to define new rules or modify existing ones. With a view to the PETRA III extension this is an important point.

ACKNOWLEDGEMENTS

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