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

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Introduction

The synchrotron lightsource PETRA III

- circumference 2.3 km
- operates at 6 GeV
- 100 mA beam current (200 mA planned)
- experiments at 14 undulator beamlines

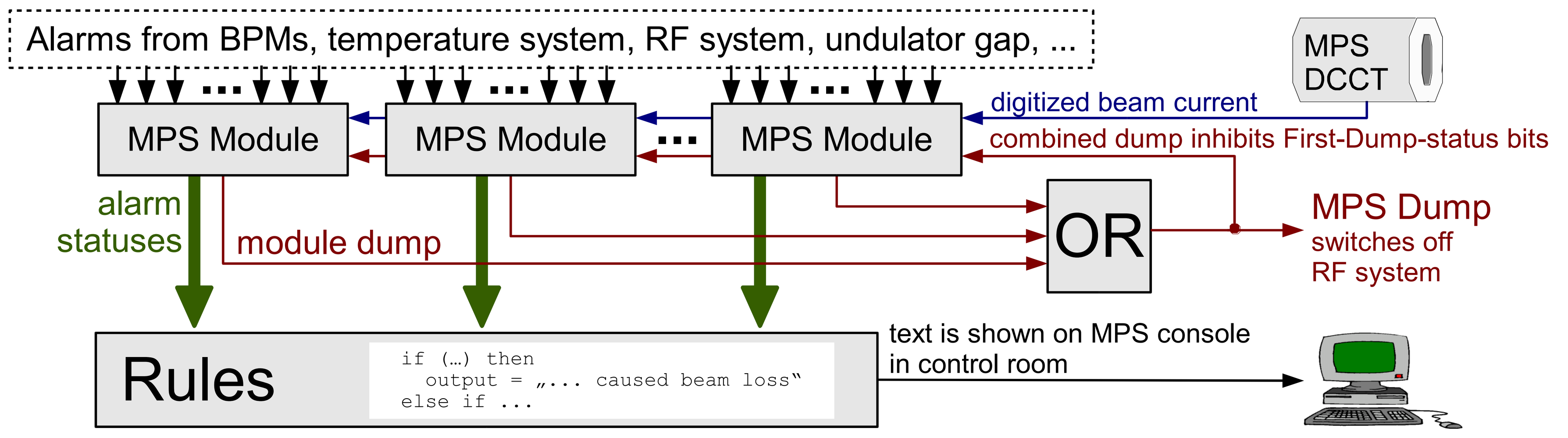
Machine Protection System (MPS) for PETRA III

- generates beam dump under certain alarm conditions to protect machine against damage
- about 250 alarms are connected to the MPS: BPM (beam postion monitor), temperature system, vacuum system, undulator gaps, magnet power supplies, RF system, …
- some alarms are used for cause detection only (i.e. RF system and magnet power fail)
- examines time correlation of alarm sequences which are evaluated in a software based system

Motivation

- Implement a system which supports the operator by interpretation of alarm statuses after a beam loss automatically by displaying a detailed cause information on MPS console in control room

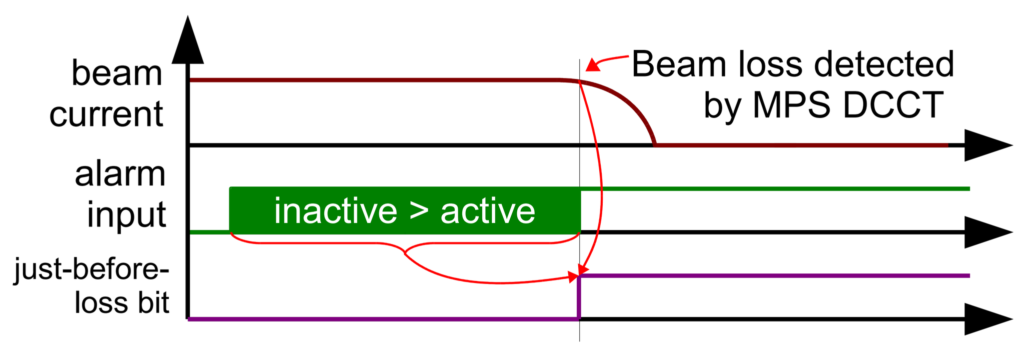
Processing incoming alarms



- alarm inputs can mask other inputs (i.e. BPM alarm masked when undulator gap is open)
- each alarm input is masked by an individual beam current threshold
- dedicated DC Current Transformer (DCCT) digitizes present beam current and distributes it to all MPS modules (for comparison with thresholds); additionally used to detect beam losses
- each MPS module generates a dump if alarm condition is fulfilled, the combined dump switches off the RF system (beam dump) and inhibits First-Dump-Alarm status bits in MPS modules
- each alarm input represented by 7 status bits
- three of these status bits are used for cause detection of beam losses by software defined rules

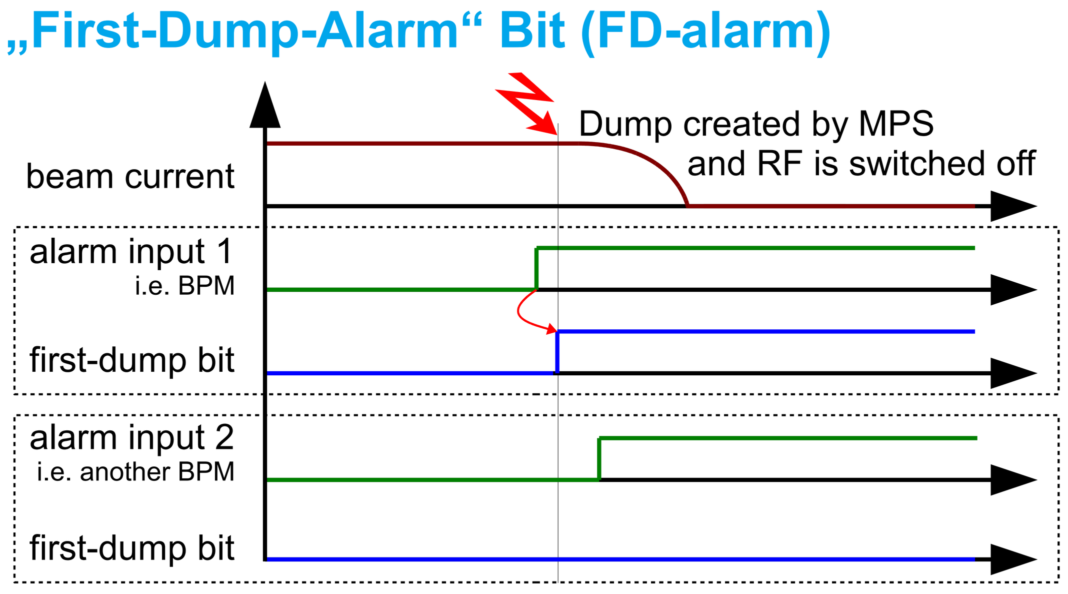
Alarm Status Bits Generated in the Hardware for Cause Detection

„Just-Before-Loss-Alarm" Bit (JBL-alarm)



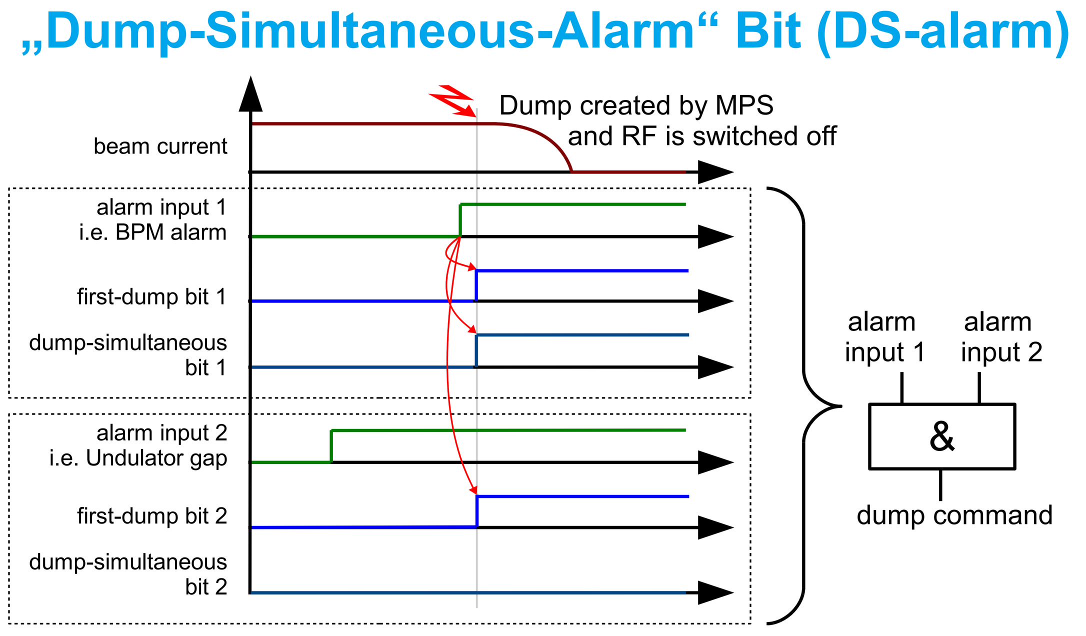
- input status bit is set, if input had changed to high within in short time (typically 100 ms) **before the beam loss**
- status bit is used to detect alarms which typically cause a beam loss, i.e. magnet power fail or RF system fail
- these inputs does not generate a dump trigger

„First-Dump-Alarm" Bit (FD-alarm)



- if the alarm input triggered a **dump first**, this status bit is set
- first-dump-alarm bit is system wide, combined dump inhibits status bit in all modules
- if a combination of several inputs had led to the dump the first-dump-alarm bit is set for all of these inputs

„Dump-Simultaneous-Alarm" Bit (DS-alarm)



- if the input **change to active** triggered the dump, this bit is set (change to active of input simultaneously with dump)
- this status bit is module wide
- allows detection of chronological order of alarms (was the undulator gap closed and the BPM triggered the dump or vice versa?)

Rules for Cause Identification

Evolving Rules

Rules are based on …

- … the time correlation of alarms and events (beam loss, dump; given by status bits explained on the left)
- … their order, which arises from the relationship of alarms to each other (i.e. BPM alarm could be consequence of magnet power fail but not vice versa, but BPM alarm could be consequence of or reason for RF system fail)

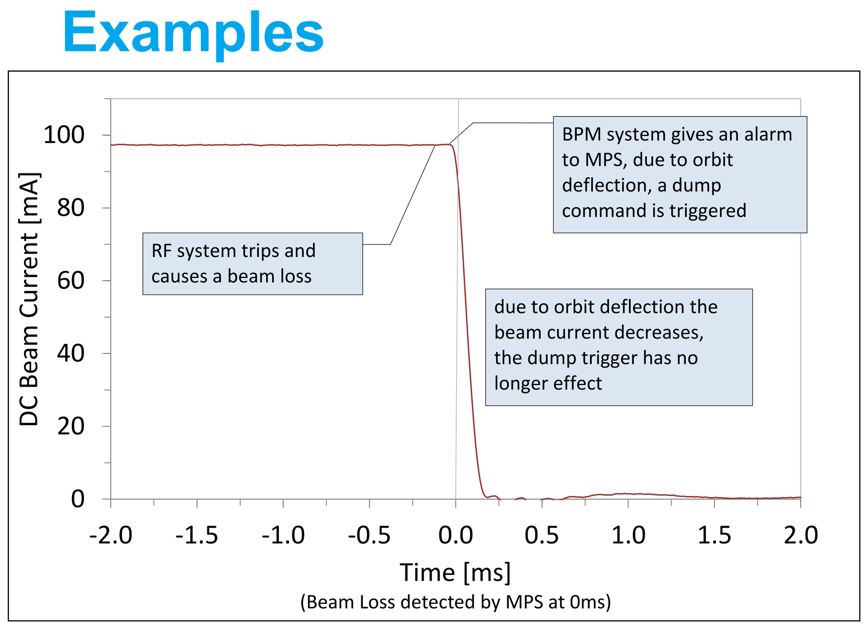
Subset Rules

```
if ( JBL-alarm from RF system ) then
      display = "Beam loss due to RF system fail.";
else if ( JBL-alarm from magnet power supply ) then
      display = "Beam loss due to magnet power supply
      fail.";
else if ( FD-alarm from temperature system ) then
      display = "Temperature system has created a dump.";
else if ( FD-alarm from vacuum shutter ) then
      display = "A vacuum shutter had created a dump.";
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.";
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.";
```

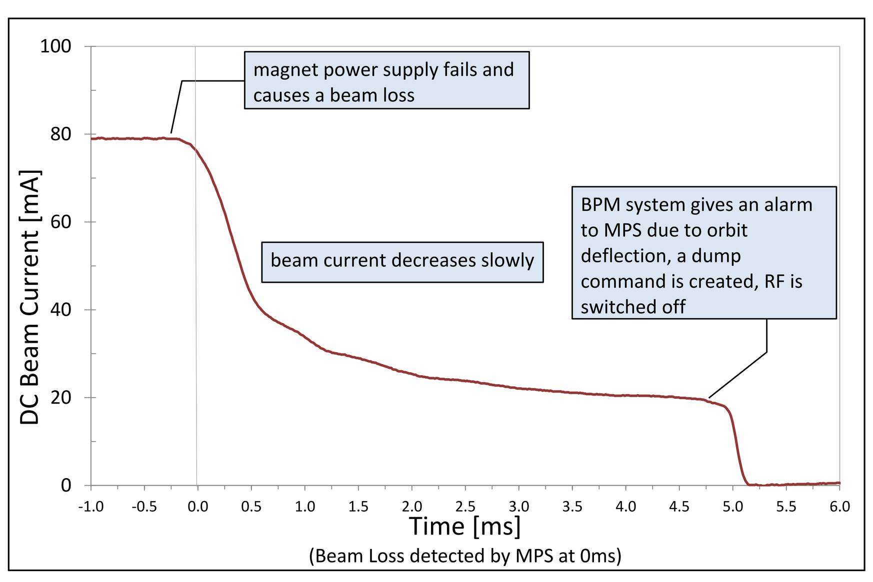
Use of Timestamps

- no timestamps are used in this implementation
- relationships between alarm inputs and events (beam loss, dump) are identified inside the MPS hardware
- the presented idea could also be realized using timestamps
- the mentioned relationships on the left have to be extracted from timestamps

Examples

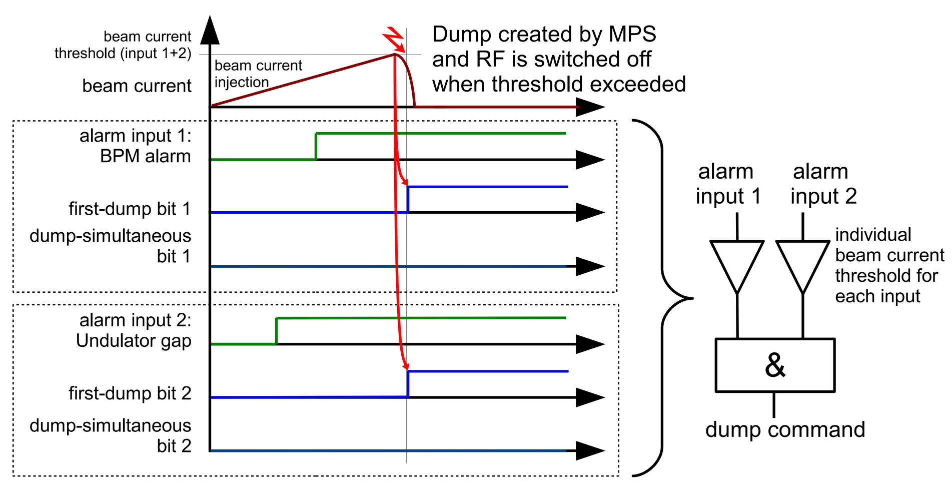


„Just-Before-Loss"-alarm from RF system (rule 1); BPM alarm afterwards



"Just-Before-Loss"-alarm from magnet power supply (rule 2); BPM alarm afterwards

Special case



Due to dump-simultaneous and first-dump alarm bits it is also possible to detect, that no alarm input had changed its state when the dump was triggered. Thus the reason for the dump was exceeding the beam current threshold of an input.

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)

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