MACHINE PROTECTION DIAGNOSTICS ON A RULE BASED SYSTEM.

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Motivation

For an operator it can be difficult to determine the cause of a beam-loss. One example is pictured in Fig. 1 due to RF thyratron and a BPM failure. Only an expert could determine the actual cause of this beam-loss based on the many error-signals. To automate this determination the expert's knowledge was built into a rule based system. As a result Fig. 2 shows the same beam-loss scenario, but now with the MPS diagnostic application. The beam-loss was on July 2nd 2013.

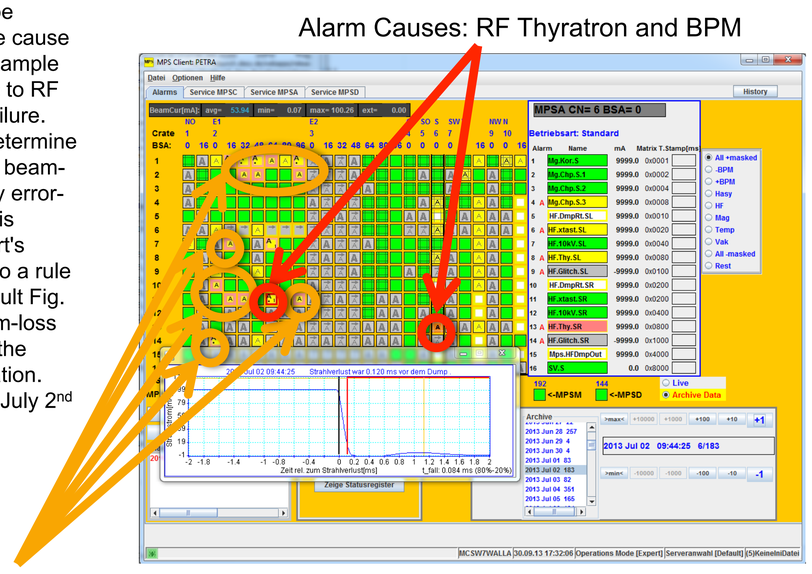

Figure 1: MPS Client application with a beam-loss on the July 2nd 2013

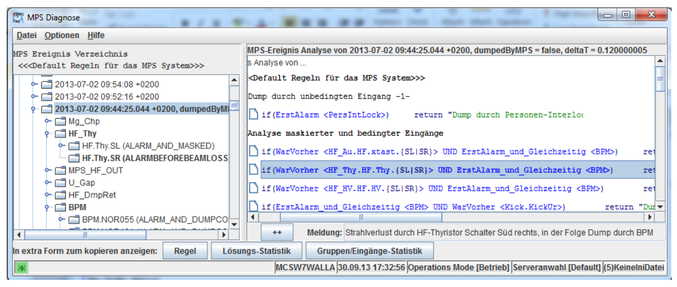

Figure 2: MPS Diagnostic application with a result again on the July 2nd 2013

Introduction

The fast technical interlock hardware of the Machine Protection System (MPS) allows a beam-loss to be detected from multiple devices over the entire PETRA storage ring, see Fig. 3. One such device is a Beam Position Monitor (BPM) which measures the beam orbit. When the orbit drifts out of a defined scope the BPM triggers the MPS hardware which itself generates a dump trigger within a few hundred nanoseconds. This trigger is sent to the Radio Frequency (RF) system which dumps the beam. The timescale between detection of a failure and the beam dump is about 400µs.

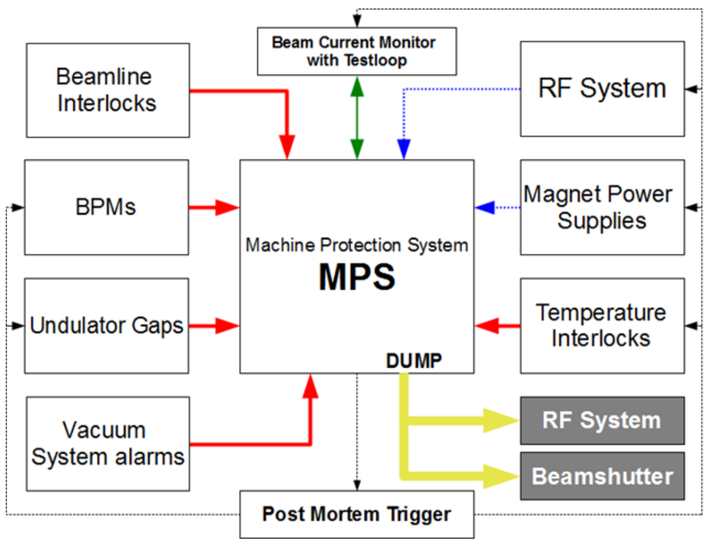

Figure 3: Overview of the MPS system. Red lines indicate alarm signals causing a beam dump. The blue lines are only for analysing the beam losses.

For post-mortem analysis the data is sent to the MPS server. It stores the data in the event archive and provides it for subsequent diagnostics. The MPS diagnostics software loads the data and verifies the beam-loss event. Figure 4 shows the communication overview.

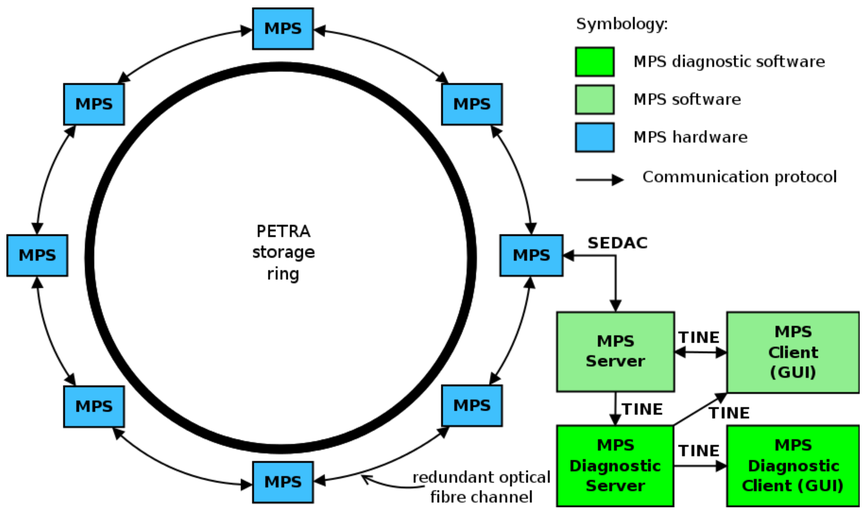

Figure 4: Overview of the communication.

MPS Event

When the MPS hardware detects a beam-loss event the MPS diagnostic application fetches the raw data from the MPS server. The raw data consists of a subset of all connected devices and their alarm state. This structure is abstracted to an hierarchical structure of MPS groups and the alarm state, see Fig 5.

The alarm state is needed for the rule based layer to determine which device causes the alarm.

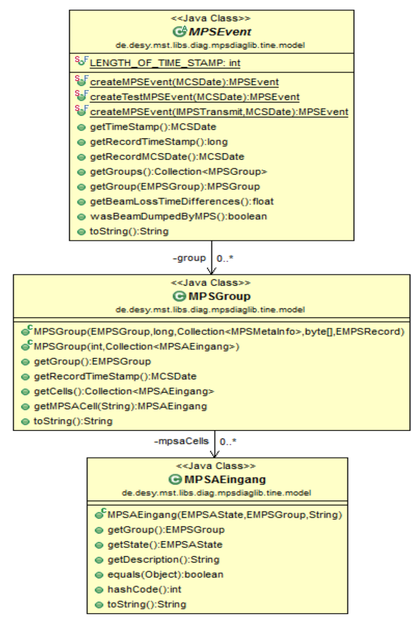

Figure 5: Class diagram of the MPS event

Rule Based Layer

A Domain Specific Language (DSL) architecture is used to automate the experts knowledge. The rule based layer defines with a directed graph which is ordered by the developer. By recursively traversing through the graph the rules are checked. The first rule which matches the pattern is the cause of the alarm. The description of a rule is implemented in a declarative language. It is simple to modify, add, remove or extend the rule system. Furthermore complex rules can also be instantiated. Figure 6 shows a class diagram of the rule based layer. Figure 7 represents an extraction of the implemented rules in the defined order.

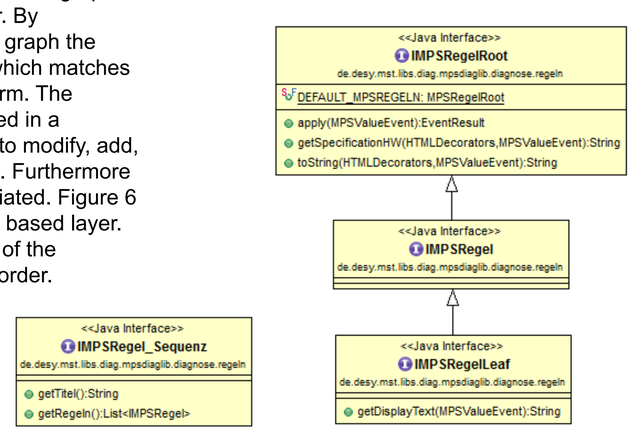

Figure 6: Class diagram of the rule layer

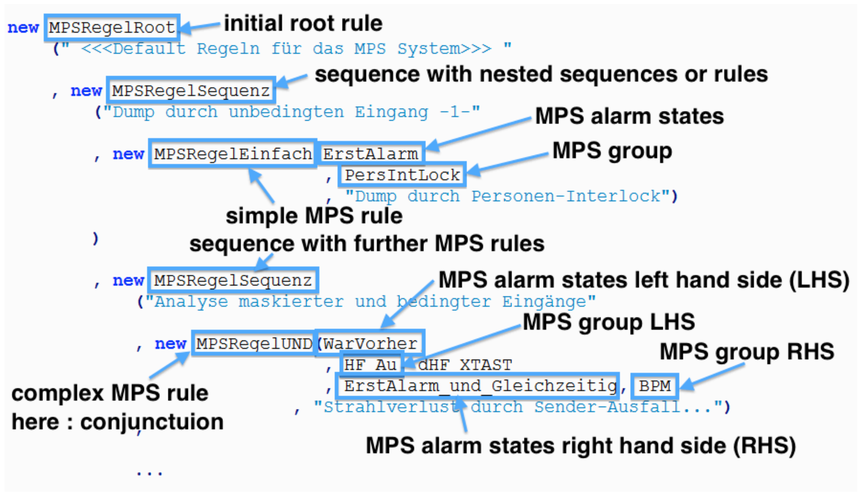

Figure 7: Extraction of the implemented rules

Displaying the Resulting Message

Creating the message for the operator is now trivial. Figure 8 shows a message determined on August 28th 2013.

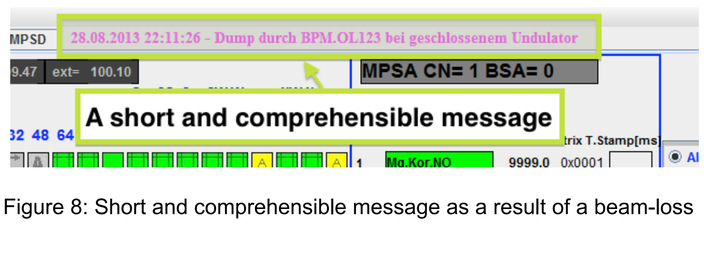

Figure 8: Short and comprehensible message as a result of a beam-loss

Statistics

The MPS diagnostic server determines the correct cause of the beam-loss with a success rate of 97 %.

Conclusion

- Operators see a short comprehensive message of the last beam-loss in the MPS client application.
- The success rate of 97 % is a very good result for a first iteration.
- The efficiency and error-handling of the operations group is strongly improved..
- The work of the operator is strongly improved.

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