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ACCELERATOR RELIABILITY REPORTING AT THE SWISS LIGHT SOURCE

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Abstract

Third generation light sources do aim for a very high reliability of the accelerator. This contribution describes the reliability reporting of the Swiss Light Source at the Paul Scherrer Institut, as it has been performed in the past decade. We will highlight the importance of a formal reporting on the accelerator reliability to support the long term optimization of the reliability of an accelerator facility.

INTRODUCTION

A high reliability is an important goal for all particle accelerators. But in particular third generation light sources aim for very high beam availabilities and very large mean time between failures, in order to facilitate failure-free user operation. The reports about the operation statistics are often published within yearly reports of the institute, they are presented on workshops or contributed to the proceedings of conferences. These reports do aim at the outside: they present the success of the facility to the world.

The operation of an accelerator facility has to be continuously analysed in order to minimize the failure rate of all subsystems. While the work in this area is partially included in the published reports, these reports focus on the successful improvements. They do neither aim for completeness, nor do they provide a comprehensive list of options to improve the accelerator.

The aim of our internal reliability reports are, to provide a basis to make decisions on the improvement of the accelerator and to prioritize resources for the most effective increase of the reliability of the accelerator. These reports are meant to provide a meaningful and honest list of the past problems, an unsparing analysis of past actions, and a catalogue of possible actions to overcome problems, together with a cost estimate for those actions.

We will show how this has been handled at the Swiss Light Source in the past decade: what data was used as a basis of these reports; what metrics was the measure for accelerator reliability; how we discussed the metrics in the process; and how we collected proposed actions.

METHODS

Accelerator Reliability Metrics

A common approach to measure the reliability of an accelerator is to use the beam availability (see Eq. 1) and the Mean Time Between Failures (MTBF) (see Eq. 2).

$$\text{Beam Availability} = \frac{\text{User Beam Time} - \text{Downtime Sum}}{\text{User Beam Time}} \tag{1}$$

$$\text{MTBF} = \frac{\text{User Beam Time}}{\text{Number of Downtimes}} \tag{2}$$

At the Swiss Light Source we calculate two more metrics: the Mean Time To Recover (MTTR) and the Mean Time Between Distortions (MTBD). The MTTR is the average time of a beam outage (see Eq. 3). The MTBD is the average time between any of the following distortions: beam outages, injector failures causing decaying beam or beam orbit feedback failures (see Eq. 4) [1].

$$\text{MTTR} = \frac{\text{Downtime Sum}}{\text{Number of Downtimes}} \tag{3}$$

$$\text{MTBD} = \frac{\text{User Beam Time}}{\text{Number of Distortions}} \tag{4}$$

Failure Data Source

The prerequisite for any thorough failure analysis is high quality data on each failure mode of the facility. Many accelerator focus on the beam outages and analyse only those for the facility. The SLS was the first accelerator that has been designed to run in top-up mode [2]; where the beam current is kept constant by frequent re-injections into the storage ring during user-operation. Therefore it was early on clear, that the failure mode ”injector outage” is equally important to the users. When more failure modes were identified to be important, we decided to set-up an application to automate the recording of these modes and to collect links to the data sources that allow the analysis of these failures [3, 4]. We've identified seven failure modes for the SLS:

- **downtime**: A beam outage, starting below 20% beam-current and ending when beam is restored and given to the users.
- **beamdrop**: An injector failure, starting when the beam drops by 1 mA below the nominal beam current.
- **ofb-fail**: A failure of the orbit feedback system [5].
- **fpf-fail**: A failure of the filling pattern feedback system [6].
- **lifetime**: If the beam lifetime falls below 3 hours.
- **blow-up**: If the horizontal or vertical beam size exceed some limits ($Y_{sig} > 15\,\mu$m or $X_{sig} > 100\,\mu$m at the monitor).
- **misc**: for failures that affect many experiments but do not fall in any of the above categories (network errors, insertion device failures, etc.)

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Table 1: The SLS operation event logging system: recorded failure modes of the past nine years

year	downtime	beamdrop	ofb-fail	blow-up	lifetime	fpf-fail	misc
2005	76	no-data	no-data	no-data	no-data	no-data	no-data
2006	105	52	42	no-data	no-data	no-data	2
2007	110	90	55	no-data	no-data	no-data	4
2008	86	29	75	10	1	12	2
2009	69	21	85	6	14	52	1
2010	77	16	51	2	2	277	2
2011	55	20	55	4	1	73	0
2012	60	34	37	16	5	23	0
2013	72	47	89	7	2	9	0

Table 1 shows the numbers of the different operation events at the SLS for the past years.

Failure Data Selection

The large amount of failure data for the SLS requires some strategy how to analyse it. What data is most important to look at for the reliability report? The obvious approach is to look for the longest beam outages: they have the largest effect on the beam availability. Figure 1 shows the yearly sum of beam outages for the past nine years of operation of the SLS. Less than 10 outages per year are longer than five hours, but they create on average more than half of the downtime.

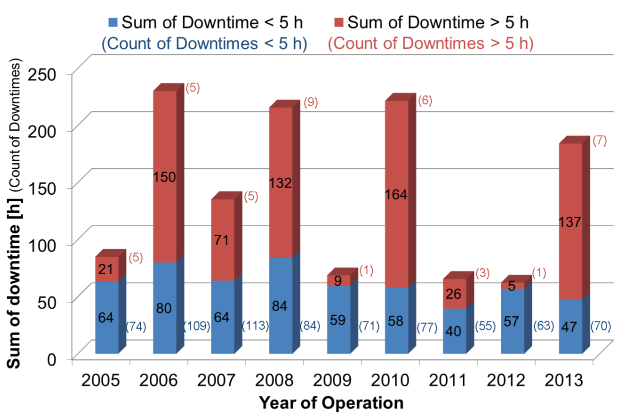

Figure 1: The yearly sum of beam outages for the SLS, split into outages longer and shorter than five hours. While the total duration of outages shorter than five hours stays rather constant, the long outages vary a lot from year to year. The small number of these outages dominates the beam availability: they are the first to be analysed.

The mean time between failures is dominated by frequent outages: not the length of the outage is important for this number, but the number of outages per year. Figure 1 shows the yearly count of outages for the different subsystems. This graph visualises the success of the RF group in the reduction of the number of faults. They improved the filters in their interlock system and changed to coincidence arc detectors, both helped to reduce the number of

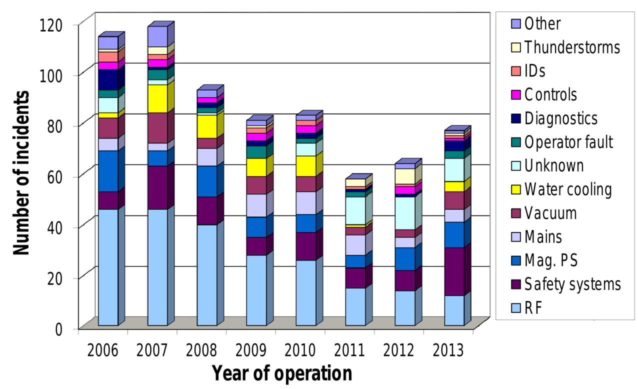

Figure 2: The figure shows the total number of beam outages per year, split into the failure causes. A large number of beam outages means that this subsystem has a strong impact on the Mean Time Between Failures (MTBF).

false-positive interlocks of the RF.

The graph shows as well that the failure rate of magnet power supplies increased slightly for 2012 and 2013. Aging of components of the ADC cards was eventually identified to be the cause of this problem and all ADC cards have been refurbished at the end of 2013.

Proposed Measures

The analysis of the operation events helps to create a list of the operational problems of the accelerator. Many of these problems have already been addressed by the subsystem groups. These actions should be listed in the report and their effect should be evaluated. Additional measures have often been suggested, but were not implemented due to a lack of resources. Those proposed measures should be listed in the reliability report. Their potential impact on the improvement of the accelerator reliability should be put into relation to their costs and the required resources.

The proposed measures can address any of the failure modes. They either address the frequency of the failure, in order to increase the mean time between failures (MTBF) of this type. Or they are meant to shorten the average recovery time (MTTR) for a particular mode of failure.

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RESULTS

Two reliability reports have been written for the SLS, one in 2009 an the second in 2013. Before 2009 we did report our operation statistics mainly in the yearly PSI reports and partly in conference proceeding. The reports were in contrast to the yearly reports a topic of discussion in the regular meetings of the higher management of the facility. The proposed measures often became follow-up topics in those meetings and in some cases resulted in strategic long term decisions, like upgrade plans or the replacement of large and expensive components. Some of the proposed measures were even funded ad-hoc after the publication of the report: like the implementation of coincidence arc detection units at the RF stations, that eventually prevented about a dozen false positive arc interlocks - and therefore unnecessary beam losses - every year after they had been implemented.

The reports are as well important to evaluate the significance of the operation metrics to the requirements of the users. We introduced the mean time between distortions in 2013, in order include injector failures and orbit feedback outages in a meaningful way in the operation metric. Because a good beam availability alone is not sufficient to satisfy the SLS users: their dominant demand is for beam stability, and stability requires undisturbed top-up injections and a working orbit feedback.

DISCUSSION AND CONCLUSION

We believe that the accelerator reliability reports have proved to be an excellent tool to efficiently and effectively direct the available resources to improve the reliability of our particle accelerator. The reports can in addition justify the costs of past measures by documenting the impact of these actions on the operation of the accelerator. They allow as well to discuss the reliability metric of the accelerator and to define additional operation statistics to quantify the accelerator reliability. In particular for the long term planning of the resources, like for system upgrades and replacement a tool is required that provides solid data for strategic decision making.

While yearly status reports are often aimed at the outside world, the accelerator reliability reports are aimed to the inside. Therefore it is easier to be frank about the unsolved problems. It allows you to keep a clear focus on the data and to discuss what actions are best suited to improve the accelerator reliability. The reports are not limited in length like for most publications; but a concise style takes care that the reports are known by the management: the management is as well directly addressed by the distribution list of the internal report.

Of course the quality of a reliability report depends clearly on the quality of the failure data. An automated recording of the operation events helps to provide complete and precise data; a database of the events eases the analysis of this data. Very important is the participation of the system experts to contribute their ideas of possible improvements to the report and to judge the costs and required resources of the proposed measures.

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