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FINDING YOUR HAPPY-USER-INDEX

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Abstract

Reliability is defined as the ability of a system or component to perform its required functions under stated conditions for a specified period of time [1]. If we are talking about accelerator reliability then we have to know what the required functions are. Many accelerator facilities restrict their analysis to the beam availability: how reliable is beam provided to the users? We will show that this metrics is often not fully adequate. Specific metrics can be much more useful to allow you to optimize your facility to the needs of your users. The three accelerator user facilities at PSI will serve as examples for these *happy-user-indexes*.

INTRODUCTION

Operation metrics, like beam availability or mean-time-between-failures, are used to quantify the success of the operation of an accelerator facility. In order to be able to compare the success of different facilities, one need to standardize these metrics [2].

These common operation metrics are often not adequate to optimize the operation of a particular accelerator facility: even an accelerator which has a 100% beam availability may has unhappy users, if the beam quality or stability does not meet their expectations.

Additional operation metrics, specific to the particular demands of the users of the specific accelerator can be defined. They help you to quantify your success to optimize the accelerator operation to best fit the requirements of your users. The process of finding these kind of operation metrics will be exemplified by the three user facilities operated at PSI. We will show how these metrics can be used as an index correlated to the happiness of the users.

COMMON OPERATION METRICS FOR ACCELERATOR RELIABILITY

The most common metric used to quantify the reliability of an accelerator is the beam availability. It is most often defined as the ratio between the delivered beam time divided by the promised beam time.

Two other commonly used metrics in these context are the mean time between failures (MTBF) and the mean time to repair (MTTR). The first is defined as the beam time divided by the number of beam outages. The latter is the total duration of all beam outages divided by the number of failures. While these definitions are generally accepted, there are a wide range of definitions in use, what a "beam outage" actually is: when does it start, when does it end?

These operation metrics are of limited use to judge the operation quality of a facility, since they fail to take special user requirements into account. Users may depend on a certain beam quality, like beam orbit stability or beam current permanence. For some facilities the length of a beam outage has a strong impact on how the users are affected.

USER FACILITIES AT PSI

High Intensity Proton Accelerator (HIPA)

A Cockroft-Walton is used to accelerate protons to 870 keV. These protons are further accelerated by two cascaded cyclotrons, first to 72 MeV and then to 590 MeV. Currently up to 2.4 mA can be accelerated, leading to a CW beam power of 1.4 MW, currently the highest CW beam power of any proton accelerator. The diameter of the facility is about 100 metre.

The proton beam is used to drive a spallation neutron source (SINQ) with 14 beamlines. Before the beam hits the spallation target it passes through two rotating carbon targets for muon (5 beamlines) and Pi meson (2 beamlines) production. Every 15 minutes the full beam can be send for up to 7 seconds on a special target for the generation of ultra-cold-neutrons.

Proton Therapy (PROSCAN)

A superconducting cyclotron of just 3.4 m diameter is used to create a 200 MeV proton beam with up to 1 μA.

This beam is used to serve one of several users at a time: GANTRY 1 is a medical facility to irradiate deep-seated tumors, currently more than 100 patients are treated every year. OPTIS 2 is as well a medical facility for eye-tumor therapy, more than 200 patients are treated yearly. The Proton Irradiation Facility (PIF) is used to test the damage on electronics by proton irradiation for space industry, and other accelerator laboratories like CERN, etc. This facility is mainly operated over weekends, when there is no patient treatment scheduled. A second gantry (GANTRY 2) has been commissioned in the past years; the first cancer patients have been treated recently.

Swiss Light Source (SLS)

A linear pre-accelerator is used to create electrons at 100 MeV. A booster synchrotron with 250 m circumference then accelerates the electrons to 2.4 GeV. A storage ring of 288 m circumference accumulates the electrons up to 400 mA. The storage ring is operated in top-up mode, where the electron losses are compensated by frequent re-injection, without interrupting the user experiments.

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The storage ring serves 20 beamlines as 3rd generation light source. The beamline users have highest demands on the beam stability: the beam current is kept stable to better than 1% and the beam orbit is stabilized to better then 1 μm.

Common Operation Metrics of the PSI Accelerator Facilities

There are large differences in the operation of these three facilities.

HIPA is running very few operation modes and can serve all users at the same time. A typical operation week has about 100 to 300 short beam interruptions. Those interruptions are dominated by disruptive discharge of electrostatic injection and extraction elements. In addition some few longer beam outages occur on average in a week.

PROSCAN can only serve one user at a time. Each user has specific requirements for the operation mode. Very different modes are regularly requested several times a day. It is actually difficult to distinguish beam interruptions from intentional mode changes in the weekly beam plot.

The SLS again has very few different operation modes and serves all users simultaneously. There are very few beam interruptions, on average less than two per week in user operation.

Figure 1 shows the beam current for a typical operation week for each of the three facilities. Table 1 shows the common operation metrics figures for the three facilities.

Table 1: PSI User Facility Statistics of 2012

Metrics	**HIPA**	**Proscan**	**SLS**
Scheduled beam-time	4936 h	3023 h	4968 h
Number of downtimes	6610	-	59
Total downtime	321 h	78.6 h	63 h
Availability	93.5%	-	98.7%
MTBF	45 min	-	83 h
MTTR	2.9 min	-	1.1 h

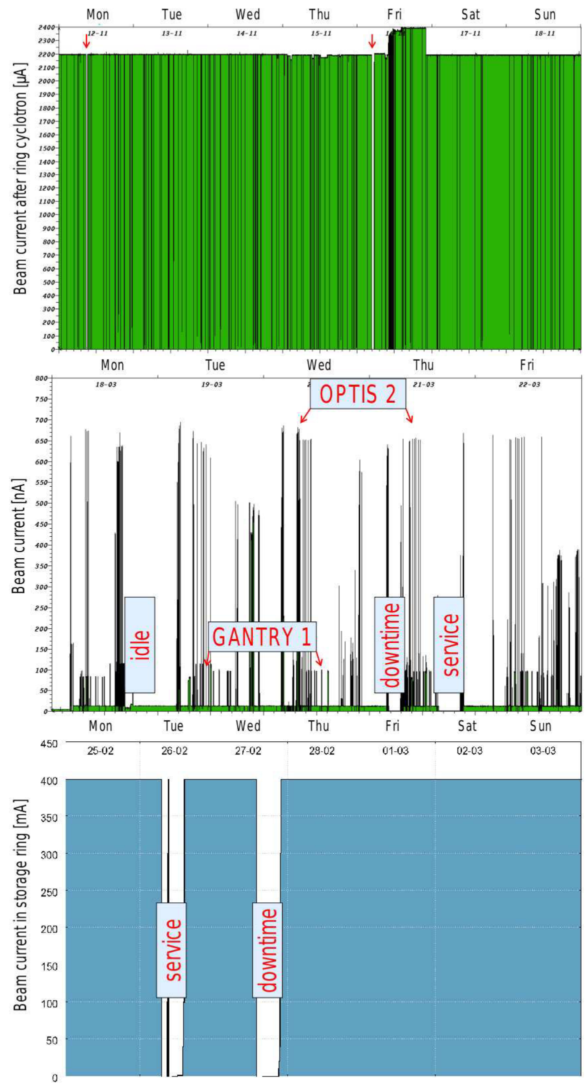

Figure 1: Comparing a typical operation week for all three PSI user facilities. The upper plot shows the beam current for HIPA for seven days; the middle plot for PROSCAN; and the lower plot for the SLS.

HAPPY-USER-INDEX

The accelerator facilities at PSI vary in the demands of their users. This can of course not be taken into account for the common operation metrics. Therefore each facility has additional, specific metric, that is closely related to the user demands.

High Intensity Proton Accelerator

The users at HIPA depend on the event rate at the experiment. Higher event rates shorten the measurement duration and improve the signal-to-noise ratio. The experiment event rates are mainly driven by the beam-on-target. Users therefore pushed over the past decades to increase the beam-on-target of the facility, even if this reduced the beam availability. Figure 2 shows how the beam integral increased over the past decade and that the beam availability was second priority.

PROSCAN Proton Therapy

In tumor therapy the treatment can often accommodate to short beam outages. These interruptions do cause delays in the routine and are in substance an inconvenience to the patience and the staff. On the other hand can a long beam outage result in the cancellation of a treatment. For the individual patient this has the potential to be life-threatening.

The major metric of interest for the operation of Proscan is the yearly number of outages longer than 2.5 hours. We have seen that the operation mode of the Proscan facility changes frequently during the course of the day, which complicates the analysis of the beam current plot in order to detect beam interruptions. Outages longer than 2.5 hours

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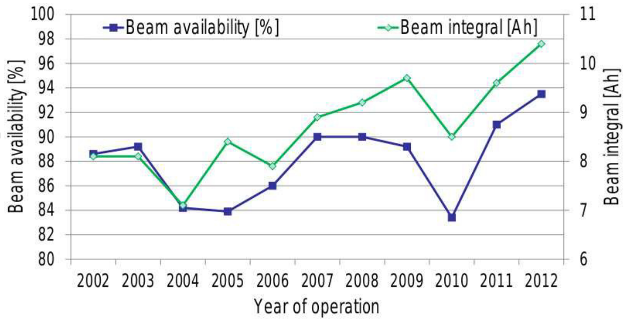

Figure 2: The beam integral has been progressively increased over the past decade at the High Intensity Proton Accelerator. The beam availability went up and down over the same interval, since it was second priority: the users were happy to sacrifice beam availability for a higher beam integral.

are easy to detect and have the largest impact on the therapy program.

Swiss Light Source

The users of the Swiss Light Source demand stability. Beam stability to them means stability of the beam orbit within better than a micrometer. In order to reach this kind of stability, we need to have a thermal equilibrium of the machine. That requires a high availability of the beam and the operation in top-up, at constant beam current, and it requires the proper functioning of the fast orbit feedback.

We count the number of all pertinent beam distortions to calculate a mean-time-between-distortions (MTBD). We take into account all beam outages, beam current drops from injector outages and orbit feedback failures. Figure 3

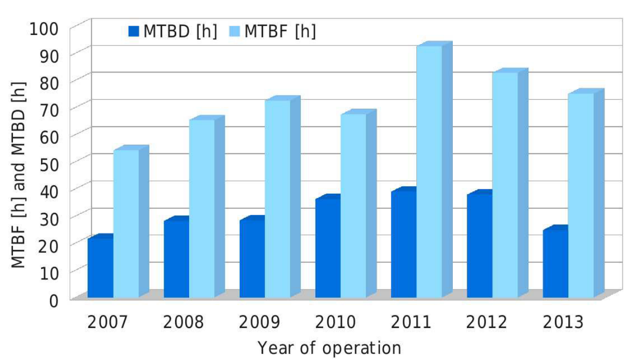

Figure 3: The mean-time-between-distortions (MTBD) at the SLS is calculated taking all pertinent beam distortions into account. Since beam stability is the primary demand of the users, this metric correlates strongly with the user satisfaction and quantifies therefore the reliability of the machine. The mean-time-between-failure (MTBF) is the time between two beam outages. In 2013 problems with the magnet power supplies increased the number of orbit feedback failures: this is visible in a reduced MTBD while the MTBF is not affected.

shows for the SLS the MTBD over the past years in comparison with the mean-time-between-failures (MTBF), that only takes beam outages into account. In 2013 the MTBD drops considerably while the MTBF stays at a good value with respect to the years before. This drop was dominantly driven by an increased number of orbit feedback failures: aging in magnet power supply ADC cards caused transient failures and outages of corrector magnet power supplies, which in turn led to outages of the fast orbit feedback. At the end of 2013 all ADC cards have been refurbished.

DISCUSSION

Particle accelerators are today used in a large variety of applications. The user demands can differ significantly. The reliability of an accelerator is often measured in beam availability and mean time between failures. But reliability is the ability of a system to perform its function under stated conditions for a specified period of time [1]. The function of an accelerator is rarely ever limited to just provide beam; in nearly all cases the beam is required to fulfill specific requirements, given by the application. Therefore the metric in which we measure the reliability of an accelerator needs to take the specific application of the beam into account.

For high energy physics machines the integrated luminosity has always been the major operation metric to judge the success of an accelerator. This metric is directly correlated with the user satisfaction: a high luminosity means, that the users can take a large number of high quality data from their experiments.

The demands of today's users of other types of accelerators are often much less uniform. It is therefore often not simple to find an operation metric that can be measured and that strongly correlates with the user satisfaction.

The example of the MTBD at the SLS shows, that it is possible to find simple statistics that are much closer correlated to the user demands than the commonly used beam availability and MTBF.

CONCLUSION

A metric to quantify the reliability of an accelerator must take the specific application of the facility into account. The author is convinced that an operation metric should strongly correlate with the demands of the users. These demands depend on the particular purpose of the facility, therefore every type of accelerator facility needs to find its own metric: the specific *happy-user-index* of that type of facility.

REFERENCES

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[2] A. Luedeke, M. Bieler, M. Pont, J.F. Lamarre, "The Common Operation Metrics Initiative for 3rd Generation Light Sources", IPAC'14, MOOCB02, in this proceedings