MACHINE TROUBLES DURING USER TIME AT THE SPRING-8

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Abstract

SPring-8 is a third generation Synchrotron Radiation (SR) facility. Since October in 1997 the SR is offered to users. The total operation time of the accelerator complex was, for example, 5456hrs in 2001. The user time was 4033hr (about 74% of the operation time). The time to refill the beam and the down time were 59 hrs and 87 hrs, which correspond about 2% and 3% to the user time, respectively. The sources of the down time were a large reflection from the RF cavity, interlock from rf-bpms of insertion devices, error in power supply of magnet, interlock from flow switch of cooling water, etc. When the beam abort occur, the possible source of the beam abort is shown in a panel by judging the appeared interlock signals.

1. INTRODUCTION

The SPring-8 consists of a 1 GeV linac, an 8 GeV booster synchrotron and an 8GeV storage ring. The circumference of the storage ring is about 1436m. The horizontal and vertical emittances of the beam are about 6nm and 6pmrad, respectively. The maximum stored beam current is 100mA. Ten beam operation periods (we call "cycle") were planned at 2001 [1]. One cycle is about three or four weeks. The beam injection is done once per day and twice per day for multi-bunch and several bunch operation, respectively. Figure 1 shows an example of stored beam current for one cycle. The maximum repetition rates of the linac and the synchrotron are 60Hz and 1Hz, respectively. The injection to the storage ring is done with 1Hz repetition rate. It takes about 20minutes to fill the beam to 100mA

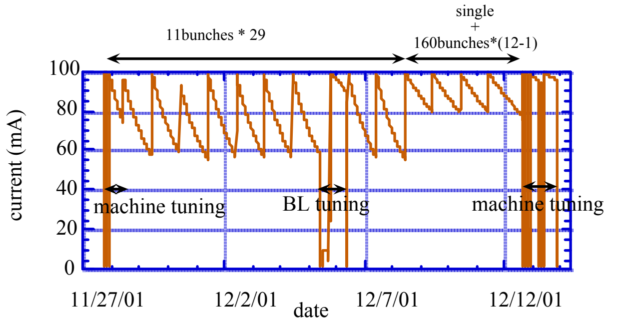

Figure 1. An example of stored current in 10th cycle 2001.

2. OPERATION STATISTICS

The operation statistics of the SPring-8 storage ring is listed in table 1. The values shown in table 1 are in unit of hour. In the table "tuning" is dedicated time for study and tuning of the machine and the beamlines, "user" means dedicated time for Synchrotron Radiation (SR) user not including time for refill the current and "down" means down time due to failure. On March 1997 the commissioning of the storage ring was started. In case of 1997, the user time started on October with the stored current of 20mA. The operation statistics in 1997 is summation from October to December. After 1997 the statistics shown in table 1 is summation from January to December. The maximum beam current in user time was increased to 70mA on September 1998 and was increased to 100mA on June 1999. The optics of the storage ring was changed from Hybrid one to High Horizontal and Low Vertical betatron function on September 1999. Magnet free four long straight sections were installed during summer shutdown in 2000 and the user time restarted on October 2000 [2]. The total operation time and user time is increased year by year.

year	tuning	refill	user	down	total
1997	304	50	906	26	1286
1998	1457.6	110	2512	110	4189.6
1999	1624.2	95.2	3275	57.2	5051.6
2000	1815	70.4	3193.4	88.7	5167.5
2001	1276.5	59.3	4033.2	87.1	5456.1

Table 1. Operation statistics of SPring-8 storage ring. Unit is hour.

3. ABORT SOURCE

Here we present abort sources experianced in 2001. The total number of beam abort was 43 in that year. The source is categorized in table 2. The abort sources were RF, magnet, beamlines etc.

type	failure count	fault time(hr)
RF	14	44.7
magnet	10	16.7
beam line	11	10.7
safety	1	6.5
earthquake	1	2.7
lightening	1	1.2
other	5	3.6

Table 2. Number of faults and down time for each group in 2001.

In table 3 the detail in the main category is shown.

RF		Magnet		Beamline	
arc	4	Flow sw	6	rfbpm at ID	5
reflection	3	PS err	3	Miss operation	1

Kly vac	3	Water leak from tube	1	Vacuum leakage	1
Kly over curr	1			Error inPLC	1
Kly PS err	2			Air pressure down	1
absorber	1			Limit sw of door	1

Table 3. Details of fault for majer group.

3.1 RF

The RF is one of most frequent abort sources. Large reflection from RF cavities and arcing in circulators were observed. The down time was about 30 to 40 munites per fault except one trouble; vacuum leakage from absorber. Last year we experienced a water leakage to vacuum chamber in a photon absorber at the RF station, which protected the cavities from irradiation of SR. The vacuum pressure was increased and the H_2O molecules were dominant at the leakage. The absorber was replaced to a spare. It took 36 hrs to restart the user time. After three days from the leakage, another water leakage from an absorber occurred at other RF station. This made early start of the summer shutdown a few days. We examined the inside of the absorber. Figure 2 shows the cut view of the absorber. The sharp groove can be seen which corresponds to the position of the SR irradiation. We checked other absorbers at the RF stations during the summer shutdown and found that they also had grooves. The mechanism is not clear at present but the cooling water might be activated by the irradiation of the SR and the copper might be had a corrosion. So the new absorbers were made whose cooling channels were apart from the irradiation. All absorbers of the RF stations were replaced by new ones.

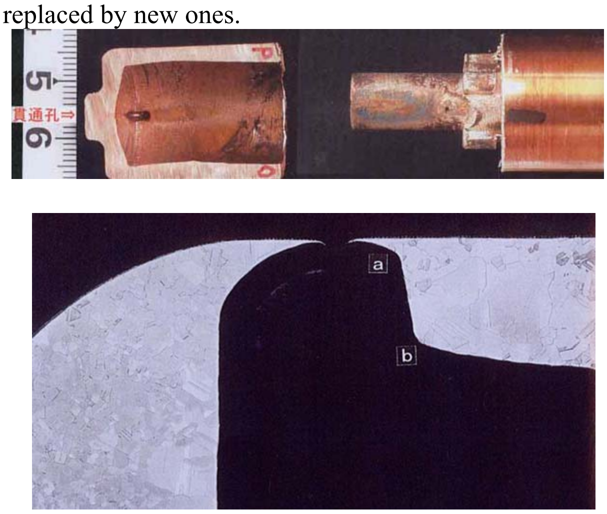

Figure 2. The cut view of the absorber.

3.2 Magnets

Failure in flow switch of the cooling water was most frequent in magnets. We examined one of the switches. There was erosion at the rod of the flow switch and did not work well. The erosion might occur by the fast water flow (~10m/s) and by particles made of copper oxide included in the water. New flow switches were installed during the summer shutdown in 2001. After then such trouble does not happen. In September water leaked from a tube of a quadrupole magnet near an injection point. A large amount of pure water was sprinkled in the accelerator tunnel. It took 5 hrs to remove the spelt water and to restart the beam operation. Figure 3 shows the leakage point of the tube. Usual tubes of magnets are located inner side of the storage ring to avoid SR irradiation. But at the injection point there is no space and the tube is located outer side of the ring where radiation level is high. The radiation dose was measured recently and the dose was estimated to be more than 10^6Gray at some spot. We plan to shield the tubes at the injection point with lead.

Figure 3. The tube which had water leakage.

3.3 Beamlines

The large deviation of the beam orbit results in irradiation to unexpected position of front ends at beam lines by SR and it gives damage to them. The beam should be aborted when the beam orbit has large deviation from the reference one. For this purpose a system of fast beam position monitoring is installed at both ends of all insertion devices. If the deviation of the beam position exceeds the window, the interlock signal is send to Beam Interlock Module (BIM). The full widths of the window are 0.5mm and 0.25mm in horizontal and vertical direction, respectively. It works well at the case such as beam drift by error in a steering magnet power supply, by an earthquake, etc. But the number of rfbpms is rather large (there are 23 insertion devices in operation). And the system must detect the deviation of the beam and send interlock signal within a few milliseconds, so it has a large bandwidth and is sensitive to noise. This leads to frequent beam abort due to malfunctions of the rfbpm. Improvement has been made by beamline group to increase the reliability of the system. One example is that the abort signal is sent only when more than two rfbpms make abnormal signals. This made good reliability of the system instead of a little bit slow response time.

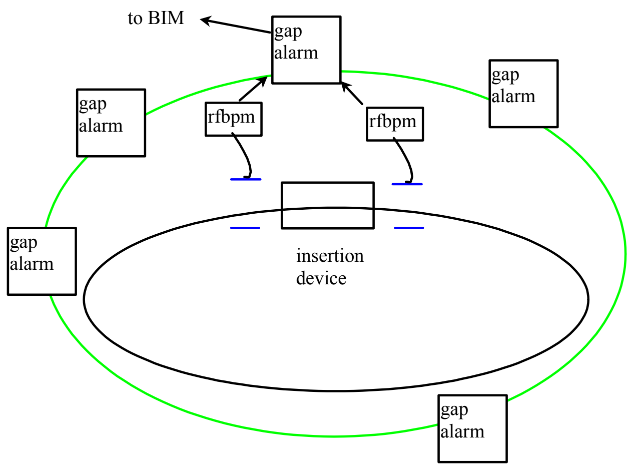

Figure 4. Schematic drawing of rfbpm at insertion devices.

3.4 Voltage drop in power lines

The lightning is frequent on July and August in Japan. The machine is in summer shut down in that season. The beam down due to voltage drop of power line was 5 times during user time from 1997 to 2001. The source of the voltage drop is usually lightning to a cable of an electric power company. The voltage drops greater than 15% in power line causes troubles in magnet power supplies. Figure 5 shows the number of voltage drops over 15% to the nominal value for two years. We are investigating the possibility of user operation in summer. If the summer operation will be in practise, the power company will arrange to equip arresters at some towers of a power cable of 77kV lines where frequent lightning are observed.

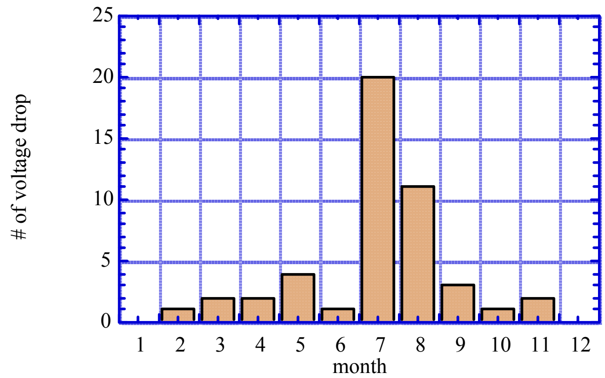

Figure 5. Number of voltage drop greater than 15% from Jun 1999 to May 2001.

3.5 Earthquake

The beam is lost 3 times by large horizontal orbit deviation caused by earthquake until now. Movement of ground may cause change of circumference or misalignment of magnets which kick the beam. If the deviation of the beam exceeds the threshold of the rfbpm system of the insertion devices, the beam is aborted. Figure 5 shows an example detected on 24 March 2001. The center of the shock was AKINADA, about 170km apart from the SPring-8 and the magnitude was 6.4. The beam was lost by the interlock signal from the rfbpm in horizontal direction. The vibration was so large that we stopped all machine operation and we checked the inside of the tunnels, radiation shields and experimental hutches of beamlines. After the confirmation we restarted the beam operation. The down time was 2.7hrs. Another pattern of earthquake is that the center of the shock is far from the site. Such earthquakes do not lead to a beam loss.

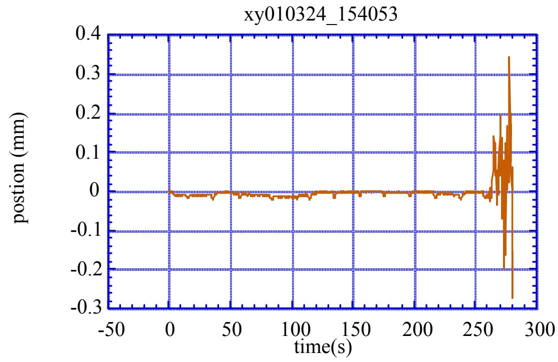

Figure 6. The horizontal orbit drift due to an earthquake on 24 Mar. 2001.

4. INTERLOCK SYSTEM

The stored beam is aborted when abnormal state in radiation safety or some faults in machine and beamline. Figure 7 shows the schematic view of an interlock system concerning to the accelerator. When some troubles occur, the signal is sent to the Beam Interlock Module (BIM) which is linked to other BIMs with optical fiber. The BIM sends interlock signal to the RF station and the RF power fed to the RF cavities is cut off.

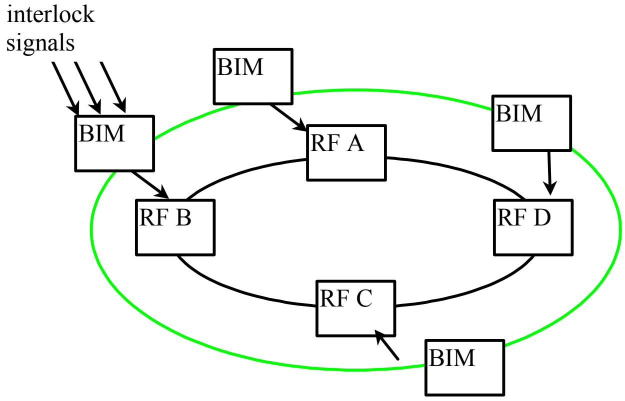

Figure 7. The schematic view of interlock system.

To judge what is first source, the BIM has two optical fibers propagating opposite directions. Using this information and checking other interlock status the probable abort source is displayed in a graphical user interface shown in figure 8. Using this tool the identification of the abort source is easy and the down time is shortened.

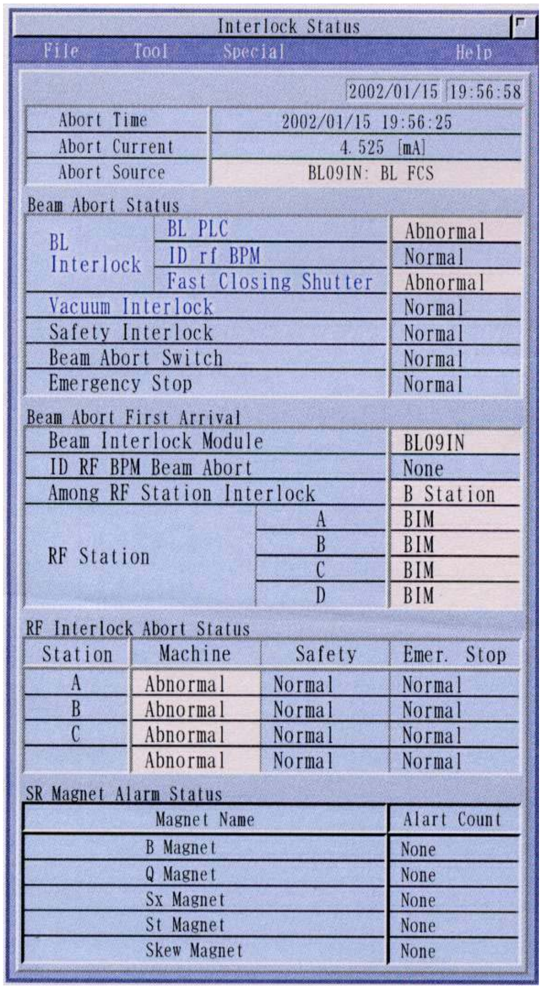

Figure 8. A GUI for judging abort source.

5. DELAY IN REFFILL

At the refill of the beam to the storage ring, it usually takes about 19 minutes to inject the beam and check the status (such as COD, betatron tunes). The injectors are prepared in 30 minuets before an injection. When some troubles occur in injectors the beam injection is delayed. Total delay time was about 8 hrs in 2001, for example. As for linac, faults in modulator, vacuum pressure increase in accelerator cavity or waveguide is observed. As for booster synchrotron, RF down due to large reflection from cavity was observed. About 10 minutes is needed to recovery.

6. CONCLUSION

The SPring-8 is operated 5456 hrs in 2001. The user time was 4033 hrs and the down time was 87 hrs. The probable source of the beam abort is shown in a panel of GUI. It is effective to identify the source and to shorten the down time. Vacuum leakage from absorber in RF station was observed. The leakage was caused by SR irradiation. The absorbers in RF sections were replaced by newly designed ones. Water leak from a cooling tube of a magnet near injection point was observed. The tube was located in high radiation level. The tube was replaced to spare. Other tubes will be shielded by lead.

Reliable for user means not only to shorten the down time, but also means to maintain the beam quality such as beam orbit stabilisation [4]. Further efforts are made to increase the machine reliability in SPring-8.

7. ACKNOWLEDEMENT

The author wishes to thank staffs of accelerator division.

8. REFERENCES

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