PROTECTION AND DIAGNOSTIC SYSTEMS FOR HIGH INTENSITY BEAMS

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Abstract

This paper presents a summary of the facilities for beam interlocks and diagnostics to protect the CERN SPS machine. An overview of the existing systems is given, which are based on beam loss and beam current monitors and large beam position excursion in the horizontal plane. The later system mainly protects the system against a failure of the transverse damping system. The design for a new large excursion interlock for both transverse planes is also presented in some detail. For this system a digital approach is being taken to allow post-mortem analysis of the behaviour of the beam prior to the activation of the interlock.

1 DIFFERENT BEAM INCIDENTS

The following table 1, which is reproduced from the 1998 BI day [1], shows the different systems for which the interlock systems have to protect against their failures.

Equipment	Delay	Built-in	BI prot.
RF Cavity Failure	50 [ms]	Supra only	BLRING
Main Power Supplies Trip	15 [ms]	6 [ms]	BLD
Magnet Failure	50 [ms]	NO	SBCT
Transverse Damper	100 turns	NO	Large Oscillation Interlock

Table 1: Time scales of beam incidents after equipment failures and protection systems

Delay: time between equipment failure and beam hitting vacuum chamber
Built-in: delay between failure and beam dump for equipment built-in protection system.
BI prot: the system that the SL/BI group suggests as indirect protection system.

In the following text, each of the 4 BI protection systems mentioned in table 1, will be described in more detail.

2 BEAM-LOSS RING (BLRING)

The SPS BLRING system is based on ionization chambers. These chambers, with a multi-electrode layout and a volume of 1 [dm3], are filled with air at atmospheric pressure. A bias of 800 [V] gives a pulse rise time of approximately 1 µs, and the sensitivity is about 5*10-6 [C/Gy]. More information on the ionization chambers can be found in [2]. The software for the system was completely redone during the year 1999 The system involves several installations: 1) around the SPS ring with real-time interlock, 2) North and West extraction channels, and 3) on the splitters in the TT20 transfer line towards the North area. For the beam loss interlock, a cable was pulled all around the SPS ring, which is connected to the SPS emergency beam dump. For each of the 6 BA's, the users can specify a number of monitors. If at any point in the current elementary cycle, the number of monitors which shows losses above their threshold is higher than the just mentioned figure, the beam dump is triggered. The main difference with respect to the BLD system is that the interlock is handled in software, which gives a latency that is (at maximum) the time between acquisitions from the beam loss starts until it is detected by the system. Presently, all BLRING systems are working with a time between acquisitions, which is 20 [msec], but this could be lowered to a minimum of 10 [msec]. A Labview application allows the users to set the necessary parameters (gains and thresholds). A suite of fixed displays allows the surveillance of beam losses for each of the monitors around the SPS ring. A new logging system was put into operation during 1999. The integrated losses during one hour with and without beam are read from the equipment and stored in a measurement database.

3 BEAM-LOSS DUMP (BLD)

The BLD system is installed to protect against large losses in 3 regions around the SPS ring, namely:

1) Injection losses into the SPS machine
2) Extraction losses towards north area
3) Extraction losses towards West area.

It should be mentioned that since the BLD monitors are in the SPS ring, any losses that occur in the regions covered by the BLD monitors, which are above the set limits, would trigger the beam dump. The users can change the gain, which is applied to the signals coming from the SPS tunnel, as well as the thresholds at which the system will react. The interlock is done in hardware to minimise the latency, and is working such that if any of the (maximum) 16 channels show beam losses above their set threshold, the beam dump is triggered. The BLD system is based on the CERN G64 standard, which is no longer supported. The BLD protection system will therefore be replaced by new hardware developed at CERN, and the software will be the

BLRING system based on VME. The analogue signals from 16 BLRING detectors will be used to detect loss levels and if any of the detectors show losses above their corresponding threshold, the beam will be dumped with a delay less than 10 [usec]. The BLD hardware diagram can be seen in figure 1. The installation of the modified BLD system will happen during the year 2000.

4 SPS BCT SYSTEM

The BCT systems are used to measure the intensity of beams in the ring and transfer lines. Several installations exist to measure with high precision, all the different types of beams. The operational range is from low intensity lead ions up to the very high intensity beams for fixed-target physics. In the future, LHC injection and beams for the CNGS extraction will be supported as well. After a problem, which caused a hole in the vacuum chamber, a new beam current interlock was put into operation in 1998. The principle is, that if more than a selectable intensity is lost during the energy ramp, the beam is considered unstable and is subsequently dumped. The BCT interlock system checks the loss in beam current every 5 [msec].

5 LARGE OSCILLATION INTERLOCK

This system, which is also known as the 30 [mm] interlock, is presently a fully analogue system, acting only in the horizontal plane. It is meant to protect the machine elements from large excursions for high intensity beams. It has the fastest response time among all interlock systems described here, as it allows dumping the beam within one SPS turn. If the beam intensity exceeds 10^{12} charges, position measurements above ±30 [mm] are integrated. If during one revolution period, this integrated value is above a threshold (hardware setting), the beam dump is triggered. As the system is fully analogue, the post-mortem analysis is very difficult. Presently, this is obtained by reading the memory contents of a digital scope, recording the beam position and intensity. An example of a beam dump triggered by this system can be seen in figure 2. The present hardware is not flexible, cannot be reconfigured for various beams circulating in the machine, and is difficult to maintain. We therefore propose to replace it by a system working in both transverse planes, using fast ADCs to sample the beam position and DSP techniques. The goal is to be able to dump the beam within 2 revolutions after an instability is detected. The front-end will make use of logarithmic amplifiers to absorb the full dynamic range in position and intensity without any gain switching. At low beam intensities, the logarithmic amplifiers are not completely saturated and might represent a problem. The two BPM signals (LogA, LogB) will therefore be digitized, and the DSP algorithm will compute the intensity = (A+B) and the position = (LogB – LogA). The system diagram can be seen in figure 3. The operators will be given the possibility to set many of the operational parameters to adapt the interlock system to particular beam conditions. The first tests with beam will take place during the second half of 2000, and the system will be put into operation during 2001.

REFERENCES

[1] Summary of the 9th BI day 1998, edited by J.J.Gras, SL-Note-98-078 (BI)

[2] J. Bosser, G. Ferioli, “Comparative test results of various beam loss monitors in preparation for LHC“, DIPAC99

[3] R.E. Shafer, "Log-ratio signal processing technique for beam position monitors", BIW92

[4] G. Vismara, "Signals processing for Beam Position Monitors" Tutorial at BIW2000

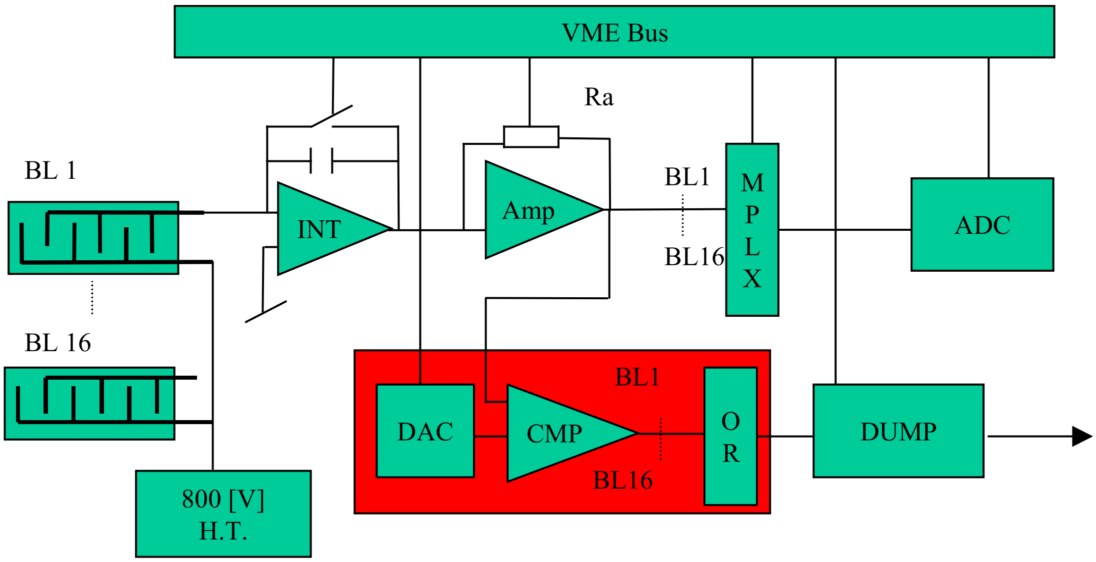

Figure 1: The BLD hardware

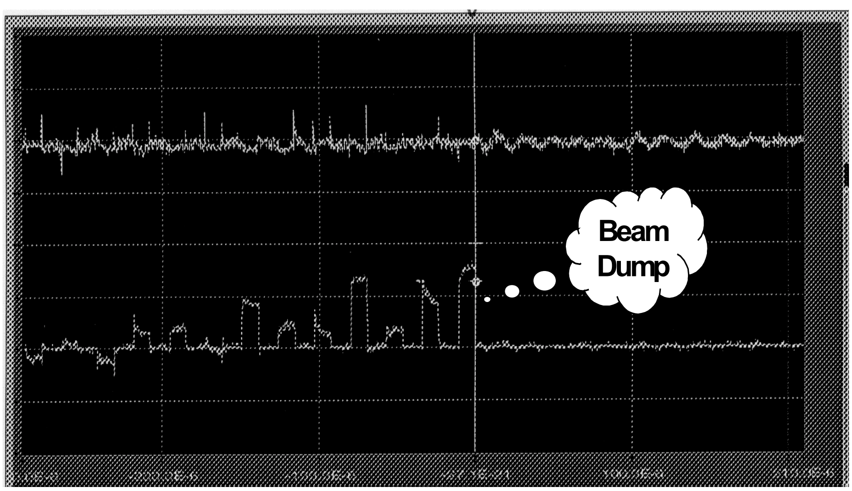

Figure 2:An actual beam-dump from the present large-position interlock system as seen using a digital storage oscilloscope.

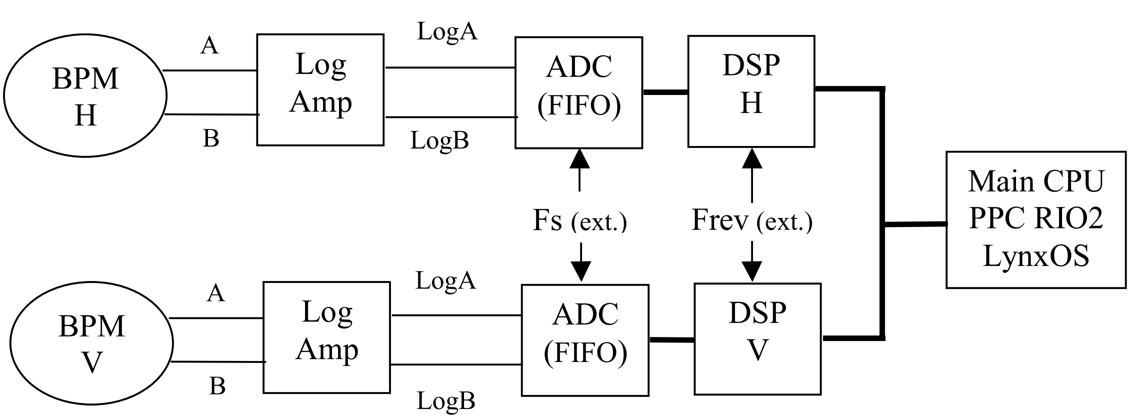

Figure 3: The hardware proposed for the large oscillation interlock