Machine Protection Working Group

Minutes of the 59th meeting, held 13th October 2006

Present: A. Gomez-Alonso, R. Schmidt, B. Puccio, V. Montabonnet, R. Steinhagen, E. Carlier, R. Denz, F. Schmidt, A. Koschik, B. Todd, L. Scibile

Meeting Agenda:

- LHC Magnets and Time Constants of their Effects on the Beam [AG]

LHC Magnets and Time Constants of their Effects on the Beam [AG]

A. Gomez Alonso made a presentation introducing work which has been carried out in simulating failures of LHC magnets and the effects this has on the beam.

A. Gomez Alonso began by explaining that the principle motivation was to study the timing of the beam losses induced by magnet failures to determine the magnets failures which lead to the fastest beam losses. Beam Loss Monitors will detect losses, but in certain cases this mechanism is so fast that it is wise to rely on another system to trigger a beam dump. The magnets that are shown to have a large influence on the beam in the case of failure need to be interlocked using Fast-Magnet Current Change Monitors (FMCMs).

Three different types of failures in the magnet have been studied:

1. Power Converter failure leading to constant voltage output (i.e. short circuit, or maximum voltage).
2. Power Converter failure leading to constant current change (i.e. the converter begins a voltage ramp by mistake).
3. Magnet Quench, where the current decay has been modelled by a Gaussian curve. At injection energy this is with $\sigma = 2000$ms, and at collision $\sigma = 200$ms.

R. Denz asked whether the failure of the magnet energy extraction systems had been considered, and pointed out that extraction systems for some superconducting corrector magnets could lead to a fast current change. **R. Schmidt** explained that **V. Kain** carried out studies of this in both dipole and quadrupole magnets, but not in higher order magnets such as the correctors.

A. Gomez Alonso continued by explaining the criteria for a 'beam loss' to be recorded, in the case of bending magnets:

1. The time for the beam to move to 6σ, or
2. The time for 1.15×10^{11} particles to be lost.

In the case of the focussing magnets:

1. The time for the tune shift to reach 1%, or
2. The time for 1.15×10^{11} particles to be lost.

The criteria #2 in both cases allow comparisons between failures in different types of magnets.

Worst case assumptions have been made, giving pessimistic results. The power converters have been assumed to give 10% over-voltage, the beam has been considered to have the worst possible phase difference and beta values, and it has been assumed that a missteered beam hits a primary collimator first.

Several tables of results were shown in the presentation, each showing the failure modes and times before beam losses for each magnet at both injection and collision energy. Numerous results were labelled as 'not reached'. **R. Steinhagen** questioned whether this was really true for the orbit corrector magnets (CODs), as studies have shown that the CODs are capable of diverting the beam into the aperture. **A. Gomez Alonso** agreed, and reminded that the current study is very simplified, more complex situations could be addressed by a future study.

A. Gomez Alonso continued by presenting the conclusions of the studies. At injection: Power Converter failures lead to the fastest beam losses, and only five magnet-failures led to losses within 10ms. At collision energy: both Power Converter failures and Quenches are responsible for fast beam losses, only three magnets can suffer failures leading to relevant losses within 10ms. (see Table 1 and Table 2).

Another method to assess the time constant for beam losses is particle tracking. The simulations were done with MADX, but limited to a sub-set of the final machine, in a very simple state. For example, only the phase-I collimators were implemented, and no alignment or field errors were included.

A. Gomez Alonso then compared the results of the simulation to the results presented in the tables. The simulation of a failure of the MBXW at 7TeV closely matched the value derived in the study. However, the MQWA at 450GeV had been predicted to lead to losses after more than 10ms, the simulations showed that the actual time was around 5ms. **A. Gomez Alonso** showed that this was due to several simplifications in the study:

1. Losses had assumed to occur in a single location, this is unrealistic for quadrupoles.
2. Losses were assumed to mainly occur in the primary collimator, this is also unrealistic.
3. A tune shift was not considered in the study.

A. Gomez Alonso concluded that these studies present a valid starting point, but now need to be focussed on more realistic machine situations. **F. Schmidt** agreed, adding that the injection parameters should be modelled more realistically, including things like beam-beam effects, the multipole field errors that lead to a reduction of the machine dynamic aperture and beam crossing angles. **R. Schmidt** suggested an experiment on the D1 magnet in the machine in order to measure the real current / field decay, giving physical results to match to the simulations, as the D1 magnet failure leads to some of the fastest beam losses. **R. Steinhagen** commented that eddy current induced in the vacuum chamber could reduce the change of magnetic field. **R. Denz** added that it may be useful to include more advanced failures in quench situations, where only part of the magnet becomes normal conducting, leading to a heterogeneous field having a higher-order effect on the beam. **R. Steinhagen** also suggested that common-mode failures of the orbit correctors are a possibility, due to the location of the Power Converter electronics, this is to be confirmed.

AOB

None.

Next Meeting
November 3rd 2006 at 10:00 in room 864-1-C02
BT

Magnet		T_{loss}[ms]	Failure
MBW	D3,D4 in IR3, IR7	1.1	Max ΔV
MBXW	D1 in IR1, IR5	1.4	Max ΔV
MCBWV	Warm dipole correctors	3.3	Max ΔV
MCBWH	Warm dipole correctors	3.4	Max ΔV
MBXWT	ALICE orbit comp.	7.9	Max ΔV
MQWA	Q4, Q5 in IR3, IR7	11	Max ΔV
MBXWS	LHCb orbit comp.	13	Max ΔV
MBX	D1 in IR2, IR8	18	Max ΔV
MBXWH	LHCb orbit comp.	21	Max ΔV
MBRB	D4	26	Max ΔV

Table 1 : Ten Worst Magnet Failures at Injection Energy (450GeV)

Magnet		T_{loss}[ms]	Failure
MBXW	D1 in IR1, IR5	1.7	Max ΔV
MBW	D3,D4 in IR3, IR7	6.5	Max ΔV
MCBWH/V	Warm correctors	9.0	Max ΔV
MBXWT	ALICE orbit comp.	10	Max ΔV
MQXA/B	Inner triplets	12	Quench (4mm)
MBXWS	LHCb orbit comp.	15	Max ΔV
MBX	D1 in IR2, IR8	34	Quench
MBRC	D2	41	Quench
MB	Main dipole	42	Quench
MBXWH	LHCb orbit comp.	58	Max ΔV

Table 2 : Ten Worst Magnets Failures at Collision Energy (7TeV)