# Timing and beam dump 29/9/2005

Question to some equipment groups*, **what are the consequences of a failure in the GMT and BST timing systems**, for two types of failure:

- LHC MTG failure, no timing distribution any more
- a failure that leads to the unavailability of the timing in one user crate

Such a failure could be transient (say, for some seconds), or longer.

The consequences of such failure will depend on the operational phase:

- injection
- ramp
- colliding beams

Without timing:

- we can not inject
- we can not start ramping or squeezing
- the post mortem trigger is not distributed

Is there any system that without timing goes into a failure mode that would straightaway cause a beam loss?

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- The BPM system uses the BST to trigger its 10Hz orbit acquisition. Loss of this signal will therefore result in the loss of orbit data from the affected crate(s). The loss of a single crate on the orbit feedback system might still be tolerated, however a total loss of MTG will inevitably break the feedback loop. Faulty correction would result in slow orbit variations since we correct at a rate of ~1Hz.
- The measurement of tune will also rely on the 40MHz clock of the BST to perform its synchronous ADC conversion. If the BST signal is lost then the BST receiver outputs a frequency which is no longer related to the revolution (in fact it jitters all over the place). This means that the tune measurement will either not work at all, or give tune values which are completely wrong. Consequence of this in a tune & chromaticity feedback loop not clear. Fast beam losses could possibly occur if tune goes on a resonance.
- BST receiver - as soon as this loses the 40MHz TTC input we no longer have a valid 40MHz or turn clock. For systems not in the interlock chain, most BDI triggers will come from the BST message. If this is not transmitted or received then no acquisitions will be possible.
- All BDI systems which are supposed to be interfaced to the BIC will not rely on the timing system (BLM / DCCT / BPM for interlock). The exception currently being the FBCT if used.

QPS and EE systems do not depend on LHC timing with respect to safety critical functions, meaning that protection is ensured in case no LHC timing is present.

In the same way QPS and EE supervision will be available but timestamps (e.g. in logging data) may be wrong. LHC timing is however essential for a proper post-mortem analysis (post mortem buffers will be nevertheless created) in order to correlate data within QPS and EE systems and with respect to other accelerator systems.

In case of a timing failure it might be also difficult to determine the first triggering device, i.e. the source of a potential problem. LHC timing is only distributed down to the QPS gateways (managed by AB/CO). A timing reception failure of one gateway will affect up to 120 QPS and EE WorldFip agents.

# Power converters - FGCs Quentin King

Here: FGCs, another matter: gateways (S.Page)

- The timing cards in the gateways have local oscillator that maintains autonomous operation if the GMT signal is interrupted. This means that the WorldFIP field buses should remain synchronised and the FGCs will not be aware of the interruption.
- The consequence will be that timing events will not get to the affected gateways, so FGCs controlled by those gateways will not start a ramp/trim when required and the gateway will not receive post-mortem triggers.
- If for some reason the timing interface in the gateway fails completely, then the WorldFIP segment will stop operating. It is possible to imagine failure modes that could cause the WorldFIP segment to operate in an unsynchronised manner. In principle, the same effect could result if the timing interface emitted timing pulses erratically.
- At the moment the FGC phase-locked loop software is not tolerant to unsynchronised timing pulses and power converter trips were sometimes seen. A new design of PLL algorithm will overcome this vulnerability before commissioning with beam.

# Power converters - FGCs

If traffic ceases on a WorldFIP segment for any reason (e.g. rebooting a gateway), each FGC will continue doing whatever it was doing with its timing assured by its local oscillator. If it was ramping then the ramp will continue. However, there will be a number of consequences at the global level:

- No commands can be sent: it will not be possible to send commands to the FGC so state changes for the converter cannot be requested, nor can reference changes be set up.
- No timing events can be sent: If events can still be received by the gateway (assuming a failure mode that affects the WorldFIP synchronisation but not the reception of timing events), then the events could not be distributed to the FGCs.
- No status data can be published:
  - The gateways will not receive faults and warnings from the FGCs and therefore no alarms, and no continuous logging, no gateway post-mortem log buffers.
- If there is a beam dump, there may be no information about the state of the circuits affected by the loss of communication. PM has different triggering method:
  - The gateway post-mortem logging buffers will be stopped if a post-mortem event is received via the timing system
  - The FGC logging buffers will be stopped when the power converter stops (either voluntarily or involuntarily)
  - PM: YES, if power converter stop. NO, if power converter does not stop.

# Power converters - FGCs

- No real-time control will be possible

- The feedback will be jeopardised. The FGCs will simply hold the last real-time value they received until the next arrives. If the value is a correction on pre-loaded ramp function, then the ramp will continue but with the last correction value. If, however, local function generation is not used and the real-time value is directly used as the current reference, then the current will simply freeze at the last received value. The effect on the controlled beam parameter will clearly depend on how much work the feedback loop had to do, which maybe a great deal during snapback and very little during physics.

- Should an FGC continue running a power converter indefinitely if communications are lost with the gateway? Would it be safer at some point for the FGC to shutdown the power converter or would it be better to keep this decision at the top level and to dump the beam if FGCs have gone offline for longer than a certain time? I (Quentin) would certainly favour a grace period that would be long enough to enable the reboot of a gateway (~ 1 minute). For the moment the FGCs have no time out and will continue to run autonomously indefinitely.

During the ramp and with colliding beams, we do not think that a timing failure will cause the RF systems to fail in such a way as to cause immediate beam loss, since it is only during injection and start of ramp that the timing plays a major part in the control of the RF systems.

Without timing:

- we can not inject
- no injection bucket selection in the RF syncro, no incoming batch selection for the transverse and longitudinal feedbacks. No kicker pre-pulses will be generated. Functions in the RF FGCs driving some parameters of the feedbacks will not be triggered.
- we can not start ramping or squeezing since all ramp functions in the RF system are generated by FGCs. Also some commands to the low-level system are sent via timing events prior to ramping.
- the post mortem trigger is not distributed
- the RF cavity controller low-level system will take its PM trigger from the Beam Permit, so will still function. However, the RF power systems will use the timing event, and so will fail.

# Conclusion

- There are many different failure mechanisms related to the timing system, this is only the first iteration
- In case of an error in the timing system, there is not reason that the beam would be lost within a short time….
- Many operations rely on events and would not be possible:
  - we can not inject
  - we can not start ramping or squeezing
  - the feedback systems would not work
  - the post mortem trigger is not distributed
- Beam monitoring is strongly compromised
- Fast beam losses if tune loop corrects tune based on wrong data: how can this be avoided ?
- Fast Beam Current Transformer: if connected to the BIC, and if timing fails, the system would possibly dump the beam (to be looked at)
- Post mortem trigger: some systems need such trigger, other systems would acquire data without the trigger by the timing system
- Post mortem analysis of the data would be very difficult (correlation between systems difficult to establish)

# Conclusion

Machine protection systems will not fail in case of timing failure.

When the LHC is in physics operation (static machine), a loss of the timing for several seconds (minutes ?) might be tolerable.

During injection, ramp and squeeze, it is hard to believe that operation can continue when the timing is not working correctly: it might be better to dump the beams.

The introduction of the post mortem event into the timing system should be done as safe as possible - this event is required to understand what happened.

I suggest that we should further analyse possible failures in the timing distribution including WorldFIP, and come up with more detailed results and proposal when and how to possibly dump the beam (who can help?)