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Commissioning of the Beam Interlock System for the TT40 and TT41 Transfer Lines of the SPS

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Abstract

The extraction area of LSS4 in the SPS and the TT40 and TT41 transfer lines have been equipped with a new interlock system to protect the machine elements against beam induced failure during operation with the high intensity CNGS beams. The system commissioning that was performed during the 2006 SPS run followed pre-defined commissioning procedures. An extensive WEB based documentation of the tests has been established to track the state of the interlock system, in particular of interlock references. This document presents a short summary of the commissioning as well as the complete documentation of the interlock tests.

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1. Introduction

The new TI2, TT40 and TI8 transfer lines to the LHC and the new TT41 transfer line to the CNGS target will be equipped with a new beam interlock system to be ready for LHC and CNGS operation [1,2]. The interlock system also covers the existing TT60 transfer line (between the SPS ring and TI2) and the SPS extraction regions in LSS4 (LHC ring 2/TI8) and LSS6 (LHC ring 1/TI2). The interlock system is based on the same hardware components that will also be used for the LHC ring [3]. For the machine start-up in 2006 the interlock system for CNGS which includes the LSS4 extraction and the TT40 and TT41 transfer lines was installed and commissioned for high intensity beam operation.

This note documents the commissioning of the CNGS beam interlock system. The individual documents describing the tests have been assembled in the large appendix of the note. A short introduction describes the interlock system, provides some estimates for the manpower effort invested into the commissioning and presents the conclusions of the first large scale test of the new beam interlock systems.

2. Interlock System Layout

The interlock system for CNGS as operated in 2006 included four Beam Interlock Controller (BIC) modules [3] and 31 User Boxes (CIBU) that provide a standardized interface to the interlock system clients [4,5]. The four BIC crates were installed in two standard AB-CO VME crates. The system layout including the BIC inputs is shown in Figure 1. The BIC modules were connected to an EXTRACTION_PERMIT loop that provided the signal to enable the extraction kicker MKE in LSS4. Further details on the interlocked equipment may be found in Ref. [2,6].

CIBC.TT40A	CIBC.TT40B	CIBC.TT41A	CIBC.TT41A
Vacuum TT40	OP Inhibit (CCC button)	Vacuum TT41	TBSE TT41
WIC TT40	TED TT40	WIC TT41	CNGS Shutter
MKE status	BTV TT40	TT41 PC	T40 Target
MSE magnet + girder	BLM TT40	Main Bend PC	BTV TT41
TT40 PC	BPM LSS4	Main Bend DCCT	BLM TT41
MSE PC	Beam Intensity	FMCM MBSG	BPM TT40+TT41
Bumper PC	**SIS TT40 + LSS4**	FMCM Main Bend	T40 Target
FMCM MSE		**SIS TT41 + CNGS**	Horn/Reflector Status
			Hadron Stop Cooling
			Fire Alarm

Red = un-maskable, Green = maskable, Magenta = Soft. Interlock

Figure 1 : Layout of the BIC modules for the CNGS run in 2006 with the associated User Inputs. Software interlock signals were supplied to CBIC.TT40B (LSS4 and TT40 surveillance) and CIBC.TT41A (TT41 and CNGS target surveillance).

3. Interlock System Tests

The hardware connections from the client systems to the BIC modules were tested individually during the SPS shutdown in the period March-April 2006. At the beginning of the SPS run all connections had been tested and validated and the system was ready for detailed commissioning tests of the interlock logic.

The interlock logic for all the client signals was tested between May and August 2006. The tests followed the procedures described in Ref. [4,7]. The documents describing the test conditions and results as well as the status of the interlock system commissioning were kept up to date on a dedicated WEB site:

https://cern.ch/sps-mp-operation/

This WEB site also holds all information relevant for the operation of the interlock system like timing references, settings, configuration etc. It provides extensive documentation both for the expert and for the machine operators. The complete documentation of all tests is appended to this document.

The estimated manpower that was required to perform the commissioning of the CNGC interlock system is shown in Table 1. The total commissioning time is around 55 hours (uncertainty of 10-20%). Although a large fraction of the tests were performed by a single person, about 30-40% of the tests involved 2 or more persons. Tests that could be easily automated represent approximately 12 hours. About 6-8 hours were used to repeat certain tests. An optimized and concentrated test sequence would probably result in a gain of time of around 10 hours. Taking all those factors together it can be concluded that in a near optimum situation all the tests may be performed in approximately 30 hours or four 8-hour shifts.

Table 1 : Estimated workload for the commissioning of the CNGS interlock system, grouped by interlock categories. The number of documents, the corresponding number of pages and the estimated testing time are given for each category.

System	Number of Documents	Number of Pages	Time (hours)
Beam instrumentation	14	28	24
Powering	18	39	18
Absorbers & targets	5	7	5
Kicker	2	4	2
Miscellaneous	5	7	6
Operation	2	11	-
Total	46	96	55

4. Operational experience

The overall operational experience with this large interlock system was extremely positive. No major problems were encountered during the commissioning and the transition to high intensity beam operation was smooth.

The performance and stability of the large number of powering interlocks from FMCMs (Fast Magnet Current Change Monitors [8]) and from the power converter current surveillance (performed by the ROCS front-end control system) was remarkable. Converter surveillance tolerances down to 0.1-0.2% could be maintained for the main dipole strings without intervention or changes for the entire 2006 run (provided of course that the PC setting itself was not changed). This achievement is due to the excellent noise performance and stability of the PC control and measurement system. The FMCMs were adjusted once at the beginning of the run and performed stably for many months. No false interlock due to FMCMs has been reported.

Problems have been observed for two types of interlocks, both related to the beam position:

- The first problem concerns the interlock on the circulating beam position in the SPS before extraction. The sensitivity on intensity/gain adjustment of the position measurement has been a recurrent problem, because the existing MOPOS acquisition system had to be (re)used for interlocking. An incorrect gain setting on the MOPOS system regularly inhibited the extraction. Such incorrect gain settings were due to problems with the front-end settings that were occasionally ‘lost’ by the FESA framework and to gain changes required to measure the first turn at injection. A new gain independent acquisition system (based on logarithmic amplifiers) will hopefully replace the MOPOS system for this task in 2007 or 2008.
- Fake position readings were observed occasionally on 2 transfer line BPMs near the CNGS target (with tolerances of ±0.5 mm), leading to latched position interlocks that required a manual reset. Such a case is described in the test on page MI-14. The origin seemed to be bad acquisitions, since the sum signal of the same BPMs was also abnormal at the same time. The problem always occurred after a period (few minutes) without beam. It did not occur after every period without beam. The effect has been clearly and repeatedly observed during two periods, but its cause is not understood.

The Safe Beam Flag (SBF) has been activated in August 2006 for all four BIC crates [9]. The measurement of the intensity is performed one second after the last injection into the SPS by the SPS high intensity BCT installed in LSS3. The intensity is transmitted to a CTG card installed in the BCT front-end crate that sends the information to the SPS MTG. The SBF itself is generated by the MTG by comparing the intensity to the limit for safe beams (set to 10^{12} charges) and distributed by the SPS machine timing system

The BIC supervision application was improved significantly with respect to 2004. The history buffer presentation has been greatly improved and a graphical display of the history buffer information was available for each BIC. An example is shown in Figure 2.

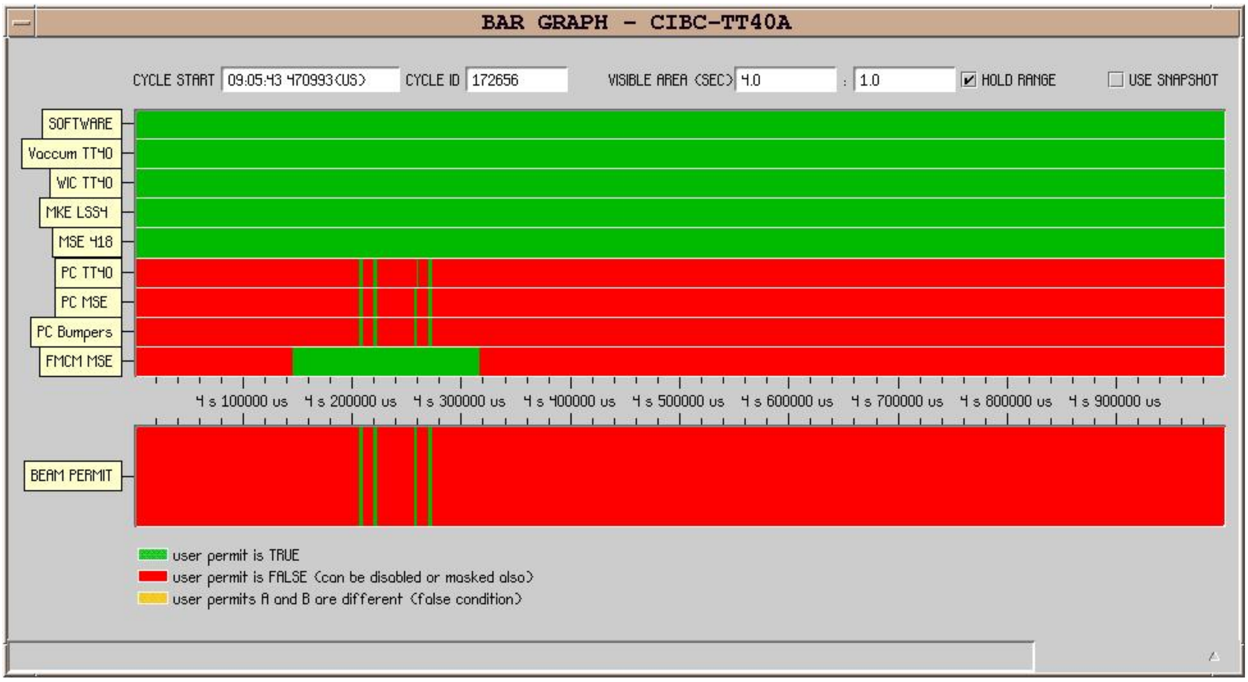

Figure 2 : Example for the graphical display of the history buffer information. In this case (for TT40A) a zoom of the signals is provided around the time of the two CNGS extractions. Red areas correspond to interlocks (User Permit FALSE).

5. Conclusions

The CNGS beam interlock system composed of four BICs and 31 client interfaces was commissioned in 50 to 60 hours. This time only includes the specified tests that were performed from CCC. It does not include the hardware tests to connect the clients.

All documentation and information for operation was made available on a WEB page. The test documentation is appended to this note.

No major problems were encountered during the commissioning and the transition to high intensity operation was smooth. Almost all interlock systems performed very well, with special mention for the powering interlocks (current surveillance & FMCM) that gave an outstanding performance. The SBF was introduced for the first time with success. The only problem was due to the beam position interlock in the SPS ring which became a major issue due to the simultaneous out-gassing problems of the SPS beam dump.

The following modifications will be foreseen for 2007 (or beyond):

- The interlock on the position of the circulating SPS beam just before extraction requires a new acquisition system that is not as sensitive to the beam intensity as the MOPOS system.
- The SBF will be generated based on the intensity measurement of the BCT in LSS3 and in LSS1 which requires an additional CTG card and a modification of the MTG logic.

6. Acknowledgements

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7. References

1. R. Giachino et al, *Architecture of the SPS Beam and Extraction Interlock Systems*, **CERN-AB-2003-010**.
2. B. Goddard et al, *Interlocking between SPS, CNGS, LHC transfer lines and LHC injection*, **LHC-CI-ES-0002**, EDMS No. 602470.
3. B. Puccio et al, *The beam interlock system for the LHC*, **LHC-CIB-ES-0001**, EDMS No. 567256.
4. B. Todd, *CIBU: Realization of the beam interlock system user interface*, AB Note in preparation.
5. B. Todd et al., *User Interface to Beam Interlock System*, AB Note in preparation.
6. J. Wenninger, *Interlocked Equipment of the CNGS and LHC Transfer Lines,* **LHC-CIB-ES-003,** EDMS No. 714582.
7. J. Wenninger, *Procedures for the Commissioning of the Beam Interlock System for the CNGS and SPS-LHC Transfer Lines*, **LHC-CIB-TP-001**, EDMS No. 735534.
8. M. Zerlauth et al., *Requirements for the Fast Magnet Current Change Monitors (FMCM) in the LHC and the SPS-LHC transfer lines*, **LHC-CIW-ES-0002**, EDMS No. 678140.
9. R. Schmidt and J. Wenninger, *LHC injection scenarios*, **LHC Project Note 287**, March 2002.

8. Appendix : test documentation

Table 2 : Index of interlock tests related to beam instrumentation.

Equipment	Zone	Date	Page
BI signal timing (BPM/BLM)	TT40/TT41	12-16.05.06	BI-1
Transfer line BLMs (no beam)	TT40/TT41	26.05.06	BI-3
BTV movement	TT40/TT41	19.05.06	BI-5
BPMs (no beam)	TT40/TT41	20.05.06	BI-7
Extraction BLMs (no beam)	LSS4/LSS6	31.05.06	BI-9
BPMs (no beam)	TT40/TT41	01.06.06	BI-13
BTV movement	TT40/TT41	06.06.06	BI-15
BI front-end reboot (BPM/BLM)	TT40/TT41	06.06.06	BI-17
Extraction BPMs	LSS4	10-14.07.06	BI-20
BLM ring LSS4	LSS4	10.07.06	BI-22
BPMs (beam)	TT40	14.07.06	BI-23
BCTs	LSS3/LSS4	14.07.06	BI-24
BPMs (beam)	TT41	15.08.06	BI-25
Transfer line BLMs (beam)	TT40/TT41	15.08.06	BI-27

Table 3 : Index of interlock tests related to powering.

Table 4 : Index of interlock tests related to beam obstacles and targets.

Table 5 : Index of interlock tests related to miscellaneous topics, including timing and operational experience. The last two tests concern LHC beams.

Equipment	**Zone**	**Date**	**Page**
Vacuum valves	TT40/TT41	11.05.06	MI-1
CNGS fire alarm	TT41	22.05.06	MI-2
Extraction timing and pre-pulse	LSS4/TT40/TT41	10.07.06	MI-3
Timing event tests (beam instr.)	LSS4/TT40/TT41	27.07.06	MI-6
Beam and surveillance stability	LSS4/TT40/TT41	24-25.07.06	MI-7
MKE.418 kicker voltage and SPS beam position scans	LSS4	26.06.06	MI-9
Safe beam flag and masking	LSS4/TT40/TT41	01.08.06	MI-11
MKE.418 kicker energy tracking	LSS4	16.08.06	MI-12
CNGS pilot run experience	LSS4/TT40/TT41	30.08.06	MI-14
MKE.418 kicker energy tracking (LHC)	LSS4	08.11.06	MI-23
TT40 collimator beam impact test	LSS4/TT40	09.11.06	MI-24