CERN
CH-1211 Geneva 23
Switzerland

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MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE WARM MAGNET INTERLOCK SYSTEM COMMISSIONING

Abstract

This document describes the set of tests which will be carried-out to validate for operation the machine protection aspects of the **LHC Warm Magnet Interlock system.** The area concerned by these tests extends over the whole LHC machine for each of the two LHC beams. These tests include the Hardware Commissioning, the machine check-out and the tests with beam.

Prepared by :	***Checked by :***	***Approved by:***
Pierre Dahlen **Richard Mompo** **Iván Romera**	**Reyes ALEMANY FERNANDEZ** **Gianluigi ARDUINI** **Andy BUTTERWORTH** **Etienne CARLIER** **Bernd DEHNING** **Brennan GODDARD** **Eva Barbara HOLZER** **Verena KAIN** **Mike LAMONT** **Laurette PONCE** **Bruno PUCCIO** **Stefano REDAELLI** **Mariusz SAPINSKI** **Ruediger SCHMIDT** **Benjamin TODD** **Jan UYTHOVEN** **Jorg WENNINGER** **Christos ZAMANTZAS** **Markus ZERLAUTH** **Valerie MONTABONNET** **Hugues THIESSEN**	**Rüdiger Schmidt** **Jorg Wenninger** **Daniel Wollmann** **Markus Zerlauth**

History of Changes

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0.1	2007-06-18	12	First draft for circulation.
0.2	2007-09-07		Comments added by J Uythoven and A Macpherson.
0.3	2008-04-28		Document updated for release
0.4	2009-01-12	11	Update document with experience from 2008 commissioning
0.5	2009-01-14	11	Minor corrections prior to release for approval
0.6	2009-02-25	11	Including comments after approval round
			Update References
			Add additional verification in Test 1 of chapter 7.2: Verify that the user permit towards the BIS is removed before the power permit of the converter is removed.
1.0	2014-02-25	All	Update of procedure for post LS1 commissioning campaign

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1. INTRODUCTION

After the qualification for operation of the individual systems of a sector, validation and specific studies of each equipment as a whole will be carried-out in the context of the machine protection system (MPS) commissioning.

This document describes the sequence of tests which validate the interface of the LHC warm Magnet Interlock System and the LHC Beam Interlock System for the 8 individual Warm Magnet Interlock Controllers installed in the LHC.

2. SCOPE

This document covers the tests which will be carried-out to condition and validate for operation all **the components of the Warm Magnet Interlock System with the machine protection system for LHC beam 1 and 2.** The area concerned by these tests is the whole LHC ring. The equipments concerned are Power Converters and normal conducting magnets connected to the Warm Magnet Interlock Controller in the insertion regions to guarantee a beam dump request via hardwired links to the Beam Interlock System in case of powering failures.

3. PURPOSE

This document

1. Gives a comprehensive list of the components which will be the object of the tests (WIC, BIS).
2. Describes in detail the procedures which will be applied for these tests and their sequence.
3. List exit conditions from the procedures

Each test has in front one of the following letters, defining at which interval or at which occasion the described test needs to be repeated (in the column labelled Repetition):

N	Not to be repeated (eventually only executed at beginning of run, but not after Christmas or technical stops)
S	To be repeated only after longer shutdowns during a run (e.g. Christmas stops)
T	To be repeated after every Technical Stop (including longer shutdowns during a run)
P	Periodical repetition required, like 1 x per month; details to be defined in text
O	To be repeated when LHC optics/crossing scheme is changed

This document is meant to be the reference document for the checklist which will be used during the commissioning of the MPS. Results of the tests will be documented in the MTF database.

4. THE LAYOUT

4.1 THE ARCHITECTURE OF THE WARM MAGNET INTERLOCK SYSTEM

The The Warm magnet Interlock Controller (WIC) is based on the use of Programmable Logic Controllers (PLC). It protects the normal conducting magnets from overheating by interlocking the corresponding power converter when a fault occurs. The WIC will also inform the Beam Interlock System in case of powering failures in the magnets or power converters which in turn will inhibit the operation with beam.

Each of the 8 LHC systems has a dedicated connection to the Beam Interlock System, requesting a beam dump of the two beams in case of failures in the magnet powering of normal conducting circuits.

A total of 8 BIS User Interfaces (CIBUS) are installed in the LHC for the WIC to transmit the beam dump requests issued by the WICs (see Figure 4 as a configuration example). The signals are exchanged via hardwired links between the WIC and the BIS User Interface, using current loops for a fail-safe transmission of the signal. A list of the BIS User interfaces to be connected to the WIC is given at the end the document (APPENDIX I - List of connections between WIC and BIS).

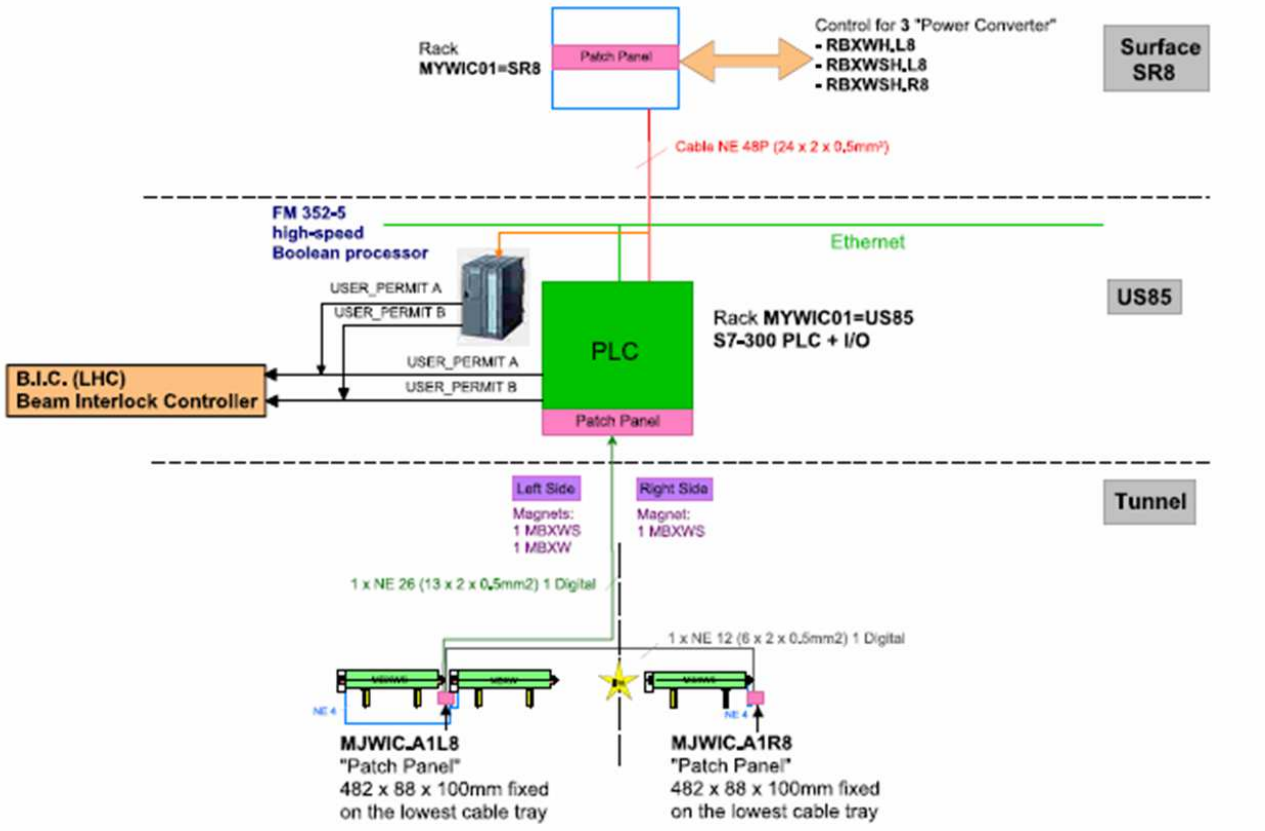

Figure 1: Principle of the Warm Magnets Interlock System for point 8 in the LHC with FM 352

4.2 REDUNDANT USER PERMIT SIGNALS

All normal conducting magnets in the LHC are considered essential for continuous beam operation and any failure in the magnet powering should result in an immediate dump of the particle beams. In case of an overheating magnet, the WIC will first issue a beam dump request and only switch off the power converter 1-2 seconds later to avoid possible effects on the beam trajectory. In case of a power converter failure the WIC will issue the beam dump request without any delay.

To comply with the specification of the BIS User Interface [1], two completely independent USER_PERMIT_A and USER_PERMIT_B signals are provided by the WIC as shown in Figure 2. A USER_PERMIT = FALSE on either of these lines will result a simultaneous beam dump request of both by the Beam Interlock System.

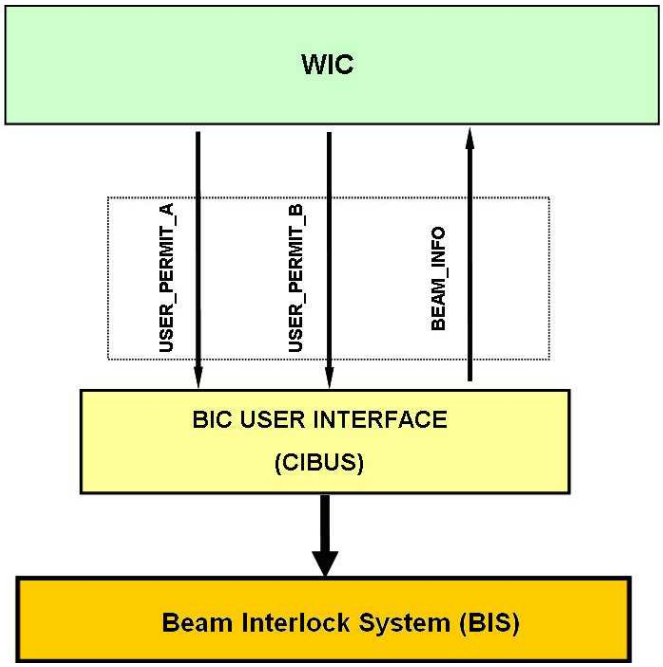

Figure 2: Signal exchange between the WIC and the CIBUS of the Beam Interlock System (BIS)

4.3 INTERNAL REDUNDANCY FOR THE USER_PERMIT SIGNALS

The safety of the link between the Warm Magnet Interlock System and the BIS is based on the redundancy of the USER_PERMIT signals.

As described in Figure 3, if a powering failure occurs in any of the power converters connected to a warm magnet interlock controller, it will be processed by two independent systems, a high-speed Boolean Processor (FM-352) and the PLC of the WIC.

In case an over temperature is detected in one of the normal conducting magnets, the PLC has the time to first request a beam dump and only afterwards shut down the

power converter, thus avoiding the magnetic field decaying while the beams are still present.

As the response time of the PLC is not sufficiently fast for all failure scenarios, a high-speed Boolean Processor based solution has been chosen to realise the redundant signal path for the beam dump request. The response time is about 1 microsecond for the Boolean Processor, whilst it is in the order of some 100 milliseconds for the PLC. This fast reaction time is required due to the fact that in the case of a powering failure, the power converter will immediately shut down itself and the beam dump request has to be relayed as quickly as possible to the BIS.

- Boolean Processor: This device provides 12 digital inputs and 8 digital outputs, and triggers a beam dump request in case of a power converter failure.
- PLC: the PLC reads inputs coming from both, the magnets and power converters and will trigger a beam dump request in case an overheating is detected in a magnet or a power converter reports an internal failure.

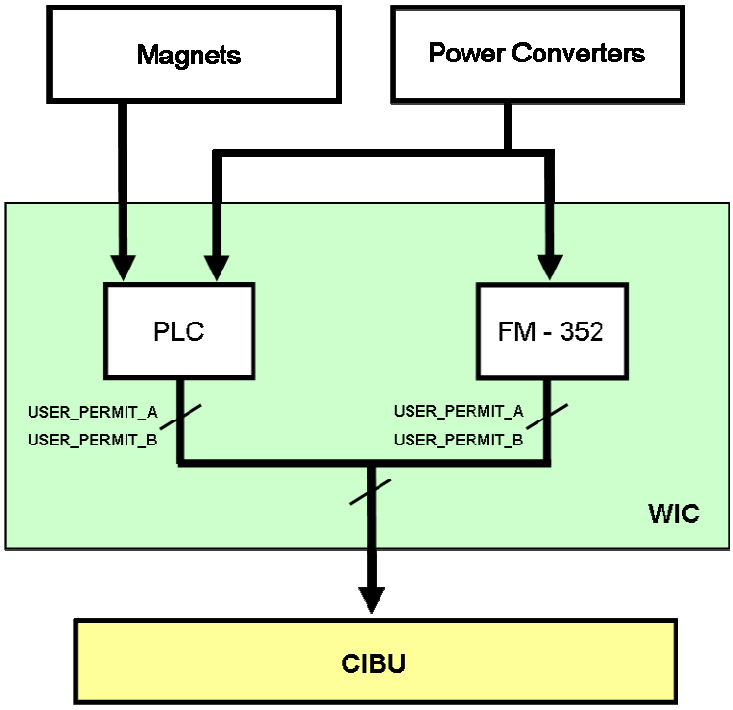

Figure 3: Internal Redundancy for the User Permit Signals

5. INDIVIDUAL SYSTEM TESTS

The magnet protection functionality of the Warm Magnet Interlock System will be fully commissioned together with the power converters and normal conducting magnets during the corresponding hardware commissioning phase [2]. The commissioning of the interfaces between the Warm Magnet Interlock Controller and the Beam Interlock Controller is described in section 7. As indicated previously, every WIC and Power Converter in an insertion region needs to be installed, commissioned and fully operational before these final tests can be performed.

6. LINKS TO OTHER EQUIPMENT

For the tests, the WIC system requires a functional AC supply through the UPS network as well as Ethernet connectivity. The SCADA system needs to be fully functional.

Each interlock controller in addition receives information from the following systems which need to be fully functional:

PC: The power converters are connected to WIC via hardwired links. Any failure provoked by a power converter is detected by the WIC which will trigger a beam dump request.

Magnets: Connected to the WIC via hardwired links. Any over temperature detected by one of the thermo switches on the magnets is read by the WIC, which will trigger a beam dump request. All magnets need to be installed, the interlock cables connected and eventual water cooling needs to be operational.

The WICs require no other inputs and only sends outputs to the BIS as described in chapter 4.2). As such, no additional tests are required in this section. In particular, no additional action is foreseen by the WIC when it receives a BEAM_INFO = FALSE.

7. SYSTEM TESTS DURING THE MACHINE CHECKOUT

The integral system should be tested from the CERN Control Centre (CCC), simulating as much as possible future operation with beam. These tests are ideally performed automatically in order to minimize the test times required and to facilitate further maintenance.

Tests to be carried out are: Beam dump triggered by PC event; Beam dump triggered by over-temperature in a magnet and operator request (removal of power permit).

7.1 ENTRY CONDITIONS REQUIRED TO PERFORM TESTS

- Successful completion of the individual system tests and hardware commissioning phases of all Warm Magnet Interlock Controllers of the concerned insertion region.
- Nominal operating conditions for all electrical circuits connected to the warm magnet interlock controllers subject to the test. The tests can be performed at zero current; only the control part of the power converters needs to be fully operational.
- The Logging System must be available
- BIS operational in the insertion region
- Mains network and UPS supplies operational in the insertion region

7.2 DESCRIPTION OF THE TESTS

Once all faults are cleared and all power converters in the insertion region are switched on, any of the following conditions will provoke a beam dump request in an interlock controller:

- Failure of magnet powering (Internal converter failure)
- Over temperature in a magnet (Magnet temperature above the limit of 65ºC)
- Operator request via the Supervision Application

The following three steps have to be performed to successfully commission the interface of the WIC with the Beam Interlock System:

Test		Action	Group(s) Responsible
1	N*	Test beam dump triggered by over-temperature in a magnet. <u>Circuit by circuit (for every magnet) connected to the WIC:</u> • Verify that all **Power Converters** are **without Fault** and that **no CMD_FABORT_WIC** command is **sent** • Verify **USER_PERMIT TO BIS** is **OK** • Enable signal to simulate an over temperature in the magnet (**CMD_MAG_OVERTEMP_TEST)** • Check that **ST_MAG_OVERTEMP** signal for this magnet are removed and that the power converter receives a **CMD_FABORT_WIC** for a few seconds • Check that **USER_PERMIT TO BIS** has been removed BEFORE the power permit of the power converter is removed • Validate the according trigger of the WIC event in the BIS history buffer and determine the time delays (for both the A and B beam permit channels). • Validate that the output of the FM352 stays TRUE during the test	TE/MPE

Test		Action	Group(s) Responsible

2	N*	Test beam dump triggered by PC event:
		<u>For every Power Converter connected to the WIC:</u>
		• Verify that:
		  ○ All **Power Converters** are **without Fault** and that **no CMD_FABORT_WIC** command is **sent**
		  ○ All **ST_FAILURE_WIC** signals are **OK**
		  ○ **USER_PERMIT TO BIS** is **OK**
		• Send **CMD_FABORT_WIC** to the PC
		• Check that:
		  ○ **CMD_FABORT_WIC** has been received by the converter
		  ○ **ST_FAILURE_WIC** is **NOT OK**
		  ○ **USER_PERMIT TO BIS** has been removed
		• Validate the according trigger of the WIC event in the BIS history buffer and determine the time delays (for both the A and B beam permit channels).
		• Validate that the output of the FM352 changes to FALSE when the powering failure is triggered. Validate that the time response of the FM352 is as expected in the order of a few us.
			TE/MPE
			TE/EPC

3	N*	Confirm that an operator can set the WIC USER_PERMIT to FALSE.
		• Verify that:
		  ○ All **Power Converters** are **without Fault** and that **no CMD_FABORT_WIC** command is **sent**
		  ○ All **ST_FAILURE_WIC** signals are **OK**
		  ○ **USER_PERMIT TO BIS** is **removed** upon the operator request
			TE/MPE

7.3 EXIT CONDITIONS AND STATUS AFTER THE SYSTEM TESTS

After these tests, the machine protection aspects of the Warm Magnet Interlock System have been validated for all the systems that may trigger a Beam Dump request connected through the WIC.

(*) A priori there is no need to repeat these tests after technical stops or Christmas shutdowns in case no modifications have been applied to the systems concerned. Once the tests are fully automated within the ACCTEST framework the tests could be repeated on a more frequent basis as the necessary time will considerably decrease.

8. TESTS WITH BEAM

To validate the interfaces between the Warm Magnet Interlock System and the BIS there is in principle no need to perform any tests with beam. However, to study the time delays (e.g. after a powering failure until the completion of the beam dump) a number of studies could be performed with low beam intensity to evaluate the overall performance of the Machine Protection Systems at the new energy and intensity levels.

Beam tests defined for the FMCM [3] will serve to validate in parallel for a second time the WIC channels.

9. REFERENCES

[1] B. Todd and B.Puccio; 'Beam Interlock System – Interfacing to the Beam Interlock System'; EDMS Doc Nr. 636589

[2] P.Dahlen, B. Bellesia et al.; 'General Procedure for the Commissioning of the Warm Electrical Circuits'; EDMS Doc: LHC-MW-HCP-0002

[3] I.Romera, M. Zerlauth et al.; 'MPS Aspects of the Fast Magnet Current Change Monitor Commissioning'; EDMS Doc: LHC-OP-MPS-008

APPENDIX I - LIST OF CONNECTIONS BETWEEN WIC AND BIS

Point	WIC Name	CIBUS Location	BIC Name
1	CIW.US15.LR1	MYWIC01=US15W2	CIB.US15.L1
2	CIW.UA23.LR2	MYWIC01=UA23	CIB.UA23.L2
3	CIW.UJ33.LR3	MYWIC01=UJ33	CIB.UJ33.U3
4	CIW.UA47.LR4	MYWIC01=UA47	CIB.UA47.R4
5	CIW.USC55.LR5	MYWIC01=USC55	CIB.USC55.L5
6	CIW.US65.LR6	MYWIC01=US65	CIB.UA63.L6
7	CIW.TZ76.LR7	MYWIC01=TZ76	CIB.TZ76.U7
8	CIW.UA83.LR8	MYWIC01=UA83	CIB.UA83.L8