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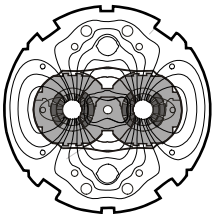

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Engineering Specification

INTERLOCKED EQUIPMENT OF THE CNGS AND LHC TRANSFER LINES

Abstract

The transfer lines from the SPS ring to the CNGS target (TT40 and TT41) and to the LHC (TT40, TT60, TI 2 and TI 8) are protected against beam induced damage by a beam interlock system. This document provides the list of interlocked equipment devices for those transfer lines.

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Table of Contents

1. INTRODUCTION 4
2. SCOPE 4
3. POWER CONVERTER CURRENT SURVEILLANCE 5
3.1 SPECIAL DCCT CHANNELS 14
4. FAST MAGNET CURRENT CHANGE MONITORS 15
5. FAST POWER CONVERTER INTERLOCK 16
6. NORMAL CONDUCTING MAGNET INTERLOCK SYSTEMS 16
7. KICKER MAGNET SURVEILLANCE 17
8. EXTRACTION SEPTA SURVEILLANCE 17
8.1 SEPTUM GIRDER SURVEILLANCE 17
8.2 MAGNET SURVEILLANCE 17
9. BEAM POSITION SURVEILLANCE 18
9.1 SPS BEAM POSITION 18
9.2 TRAJECTORY POSITION 20
10. BEAM LOSS MONITORS 21
10.1 EXTRACTION AREAS 21
10.2 TRANSFER LINES 22
11. BEAM PROFILE MONITORS 25
12. BEAM CURRENT TRANSFORMERS 27
13. VACUUM VALVES 28
14. COLLIMATORS 29
15. MOBILE DUMPS AND PERSONNEL PROTECTION DEVICES 30
16. SPECIAL CNGS DEVICES 30
17. EQUIPMENT TABLES 31
18. REFERENCES 32

1. INTRODUCTION

This document provides the list of equipment devices that are surveyed in the context of the beam interlock system for the SPS extractions, the LHC and the CNGS transfer lines [1].

The purpose of this document is to provide a detailed list of equipment in view of the interlock system commissioning and acceptance tests.

For each equipment type, the interlocking logic is described briefly.

This document is likely to be revised at regular intervals to take into account the evolution of interlock logic, signal names and device lists. Yearly to bi-yearly updates are expected at least in the first years of operation of CNGS and LHC. **The names of the BIC modules that are quoted in all tables will be finalized in the near future.**

2. SCOPE

This document covers interlocked equipment located in the following SPS transfer lines, see also Figure 1:

- TT40
- TT41
- TI 8 (excepted LHC injection elements)
- TT60
- TI 2 (excepted LHC injection elements)

This document also includes SPS ring equipment that is used for extraction or for extraction interlocking: orbit bumper dipoles, beam position monitors and beam loss monitors as well as beam current transformers.

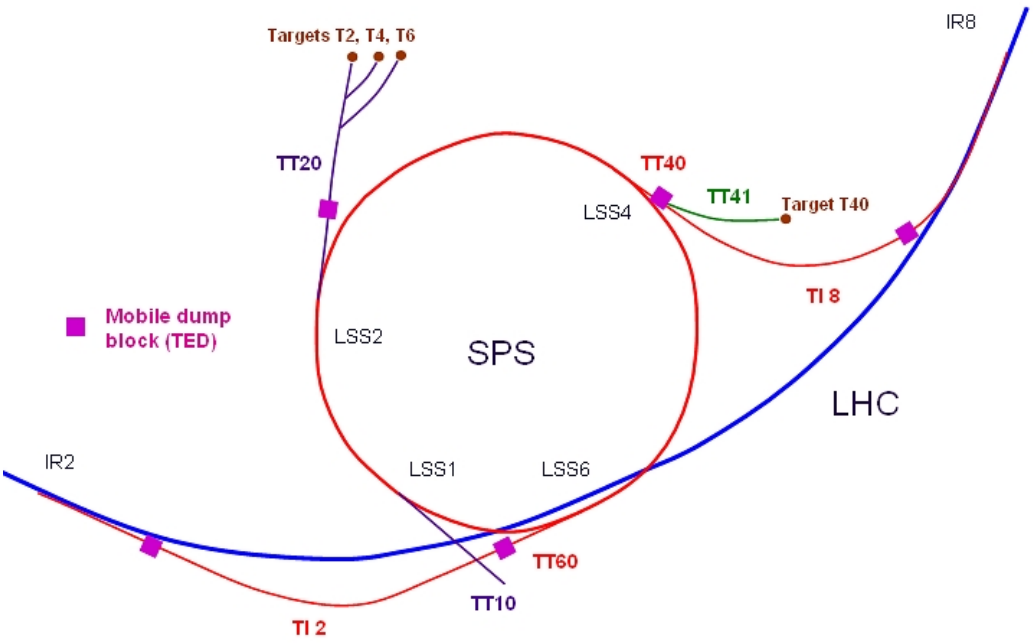

Figure 1 : Layout of the SPS ring and of the SPS transfer lines.

3. POWER CONVERTER CURRENT SURVEILLANCE

The section presents the complete list of power converters that are surveyed prior to extraction of beam to the LHC or to the CNGS target.

The converter current surveillance is performed within the SPS power converter control crates (ROCS/MUGEF front-ends) a few milliseconds before the time of extraction.

Estimated tolerances are provided for each converter. For orbit correctors (COD) the tolerance will be defined by operational experience. Presently a value corresponding to 1/10 of the maximum current (Imax/10) is assumed: this corresponds to a deflection of ≈10 μrad.

Table 1: List of surveyed power converters in SPS LSS4. All converters are controlled by the ROCS front-end crate M2SBA4.

Converter	Magnet	Acc. Zone	BIC module	Magnet type	Tolerance (‰)
MPSH4140	MPSH 41402	LSS4	BIC.TT40 (M2SBA4)	H Bumper	±2
MPSH4219	MPSH 42198				±2
MPLH4167	MPLH 41672				±2
MPLH4199	MPLH 41994				±2
MPSV4130	MPSV 41303			V Bumper	±2
MPSV4230	MPSV 42303				±2
MPLV4150	MPLV 41501				±2
MPLV4210	MPLV 42101				±2

Table 2: List of surveyed power converters in the TT40 transfer line. The MSE4183M converter is controlled by the ROCS front-end crate M1SBB4. All other converters are controlled by the ROCS front-end crate M1SBA4.

Converter	Magnet	Acc. Zone	BIC module	Magnet type	Tolerance (‰)
MSE4183M	MSE 4183 String	TT40	BIC.TT40 (M1SBB4)	H Septum	±1
MBHC4001M	MBHC 4001 String		BIC.TT40 (M1SBA4)	H Bend	±2
MBHA4003M	MBHA 4003 String			H Bend	±2
QTMD4001	QTMD 400100			Quad	±5
QTRF4002	QTRF 400200				±5
QTRD4003	QTRD 400300				±5
QTLF4004	QTLF 400400				±5
MDMH4001	MDMH 400104			H COD	≈ ± Imax/10
MDMV4000	MDMV 400097			V COD	≈ ± Imax/10
MDSV4002	MDSV 400293			V COD	≈ ± Imax/10

Table 3: List of surveyed main power converters in the TI8 transfer line. All converters connected to BIC crate BIC.TI8u are controlled by the ROCS front-end crate M1SBA4, except the dipole string MBSG 4100 (switchyard to CNGS/TT41) that is controlled by front-end crate M1SBB4. The converters connected to BIC crate BIC.TI8d are controlled by the ROCS front-end crate M1SSR8.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance (‰)
MBSG4100M	MBSG 4100 String	TT41	BIC.TI8u (M1SBB4)	H Bend	±1
MBI8160M	MBI 8160 String	TI8	BIC.TI8u (M1SBA4)	Main H Bend	±1
MCICH8040	MCICH 80407			H Bend	±2
MBIAV8110M	MBIAV 8110 String			V Bend	±2
MQID8010	MQID 80100			Quad	±5
MQIF8020	MQIF 80200				±5
MQID8030	MQID 80300				±5
MQIF8700M	MQIF 8700 String		BIC.TI8d (M1SSR8, upstream TED.87765)	Main Quad	±2
MQID8710M	MQID 8710 String			Main Quad	±2
MQIF8720	MQIF 87200			Quad	±5
MQID8730	MQID 87300				±5
MQIF8740M	MQIF 87404 String				±5
MQID8750	MQID 87500				±5
MQIF8760	MQIF 87600				±5
MQID8770	MQID 87700				±5
MBIAH8788M	MBIAH 8788 String		BIC.TI8d (M1SSR8, downstream TED.87765)	H Bend	±2
MBIBV8774M	MBIBV 8774 String			V Bend	±2
MQIF8780	MQIF 87800			Quad	±5
MQID8790	MQID 87900				±5
MQIF8800	MQIF 88000				±5
MQID8810	MQID 88100				±5
MSIB8813M	MSIB 8813 String			H Septum	±1

Table 4: List of surveyed horizontal COD power converters of the TI8 transfer line. Converters connected to BIC crate BIC.TI8u are controlled by ROCS front-end crate M1SBA4. Converters connected to BIC crate BIC.TI8d are controlled by ROCS front-end crate M1SSR8.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance
MCIAH8020	MCIAH 80204	TI8	BIC.TI8u (M1SBA4)	H COD	≈ ± Imax/10
MCIAH8080	MCIAH 80804				≈ ± Imax/10
MCIAH8100	MCIAH 81004				≈ ± Imax/10
MCIAH8160	MCIAH 81604				≈ ± Imax/10
MCIAH8180	MCIAH 81804				≈ ± Imax/10
MCIAH8240	MCIAH 82404				≈ ± Imax/10
MCIAH8260	MCIAH 82604				≈ ± Imax/10
MCIAH8320	MCIAH 83204				≈ ± Imax/10
MCIAH8340	MCIAH 83404				≈ ± Imax/10
MCIAH8400	MCIAH 84004		BIC.TI8d (M1SSR8)		≈ ± Imax/10
MCIAH8420	MCIAH 84204				≈ ± Imax/10
MCIAH8480	MCIAH 84804				≈ ± Imax/10
MCIAH8500	MCIAH 85004				≈ ± Imax/10
MCIAH8560	MCIAH 85604				≈ ± Imax/10
MCIAH8580	MCIAH 85804				≈ ± Imax/10
MCIAH8640	MCIAH 86404				≈ ± Imax/10
MCIAH8660	MCIAH 86604				≈ ± Imax/10
MCIAH8720	MCIAH 87204				≈ ± Imax/10
MCIAH8740	MCIAH 87408				≈ ± Imax/10
MCIAH8800	MCIAH 88004				≈ ± Imax/10

Table 5: List of surveyed vertical COD power converters of the TI8 transfer line. Converters connected to BIC crate BIC.TI8u are controlled by ROCS front-end crate M1SBA4. Converters connected to BIC crate BIC.TI8d are controlled by ROCS front-end crate M1SSR8.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance
MCIAV8010	MCIAV 80104	TI8	BIC.TI8u (M1SBA4)	V COD	≈ ± Imax/10
MCIAV8070	MCIAV 80704				≈ ± Imax/10
MCIAV8130	MCIAV 81304				≈ ± Imax/10
MCIAV8150	MCIAV 81504				≈ ± Imax/10
MCIAV8210	MCIAV 82104				≈ ± Imax/10
MCIAV8230	MCIAV 82304				≈ ± Imax/10
MCIAV8290	MCIAV 82904				≈ ± Imax/10
MCIAV8310	MCIAV 83104				≈ ± Imax/10
MCIAV8370	MCIAV 83704				≈ ± Imax/10
MCIAV8390	MCIAV 83904				≈ ± Imax/10
MCIAV8450	MCIAV 84504		BIC.TI8d (M1SSR8)		≈ ± Imax/10
MCIAV8470	MCIAV 84704				≈ ± Imax/10
MCIAV8530	MCIAV 85304				≈ ± Imax/10
MCIAV8550	MCIAV 85504				≈ ± Imax/10
MCIAV8610	MCIAV 86104				≈ ± Imax/10
MCIAV8630	MCIAV 86304				≈ ± Imax/10
MCIAV8690	MCIAV 86904				≈ ± Imax/10
MCIAV8710	MCIAV 87104				≈ ± Imax/10
MCIAV8770	MCIAV 87704				≈ ± Imax/10
MCIAV8789	MCIAV 87891				≈ ± Imax/10
MCIAV8810	MCIAV 88104				≈ ± Imax/10
MCIAV8811M	MCIAV 8811 String				≈ ± Imax/10

Table 6: List of surveyed power converters in SPS LSS6. All converters are controlled by ROCS front-end crate M3SBA6.

Converter	Magnet	Acc. Zone	BIC module	Magnet type	Tolerance (‰)
MPSH6140	MPSH 61402	LSS6	BIC.TT60 (M3SBA6)	H Bumper	± 2
MPSH6219	MPSH 62199				± 2
MPLH6167	MPLH 61672				± 2
MPLH6199	MPLH 61996				± 2
MPSV6130	MPSV 61303			V Bumper	± 2
MPSV6150	MPSV 61503				± 2
MPSV6210	MPSV 62103				± 2
MPSV6230	MPSV 62303				± 2

Table 7: List of surveyed power converters in the TT60 transfer line. The septa converters MST6177M and MSE6183M are controlled by ROCS front-end crate M3SBA6. Converter MBB6104M is controlled by ROCS front-end crate M4SBA6. All other converters are controlled by ROCS front-end crate M2SBA6.

Converter	Magnet	Acc. Zone	BIC module	Magnet type	Tolerance (‰)
MST6177M	MST 6177 String	TT60	BIC.TT60 (M3SBA6)	H Septum	± 1
MSE6183M	MSE 6183 String			H Septum	± 1
MBB6104M	MBB 6104 String		BIC.TT60 (M4SBA6)	H Bend	± 1
MDAV6100	MDAV 6100		BIC.TT60 (M2SBA6)	V COD	≈ ± Imax/10
MDLH6102	MDLH 6102			H COD	≈ ± Imax/10
MDLV6103	MDLV 6103			V COD	≈ ± Imax/10
MDLH6101	MDLH 6101			H COD	≈ ± Imax/10
MDSH6103	MDSH 610337			H COD	≈ ± Imax/10
QTLD6101	QTLD 610100			Quad	± 5
QTLF6102	QTLF 610200				± 5
QTLD6103	QTLD 610300				± 5
QTLF6104	QTLF 610400				± 5
QTLD6105	QTLD 610500				± 5
QTLF6106	QTLF 610600				± 5

Table 8: List of surveyed power converters in the TI2 transfer line. All converters connected to BIC crate BIC.TI2u are controlled by ROCS front-end crate M1SBA7. Converters connected to BIC crate BIC.TI2d are controlled by ROCS front-end crate M1SSR2.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance (‰)
MBI2213M	MBI 2213 String	TI2	BIC.TI2u (M1SBA7)	Main H Bend	± 1
MQIF2580M	MQIF 2580 String			Main Quad	± 5
MBB2015M	MBB 20150			H Bend	± 1
MBIAV2063M	MBIAV 2063 String			V Bend	± 2
MQID2010	MQID 20100			Quad	± 5
MQIF2020	MQIF 20200				± 5
MQID2030	MQID 20300				± 5
MQIF2040	MQIF 20400				± 5
MQID2050	MQID 20500				± 5
MQIF2060	MQIF 20600				± 5
MBIBH2931M	MBIBH 2931 String		BIC.TI2d (M1SSR2, upstream TED.29133)	H Bend	± 2
MBIAV2685M	MBIAV 2685 String			V Bend	± 2
MBIAV2911M	MBIAV 2911 String			V Bend	± 2
MQIF2840M	MQIF 2840 String			Main Quad	± 5
MQID2850M	MQID 2850 String			Main Quad	± 5
MQIF2860	MQIF 28600			Quad	± 5
MQID2870	MQID 28700				± 5
MQIF2880	MQIF 28800				± 5
MQID2890	MQID 28900				± 5
MQIF2900	MQIF 29000				± 5
MQID2910	MQID 29100				± 5
MQIF2920	MQIF 29200		BIC.TI2d (M1SSR2, downstream TED.29133)	Quad	± 5
MQID2930	MQID 29300				± 5
MQIF2940	MQIF 29400				± 5
MQID2950	MQID 29500				± 5
MSIB2952M	MSI 2955 String			H Septum	± 1

Table 9: List of surveyed horizontal COD power converters in the TI2 transfer line. All converters connected to BIC crate BIC.TI2u are controlled by ROCS front-end crate M1SBA7. Converters connected to BIC crate BIC.TI2d are controlled by ROCS front-end crate M1SSR2.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance
MCIAH2080	MCIAH 20804	TI2	BIC.TI2u (M1SBA7)	H COD	≈ ± Imax/10
MCIAH2100	MCIAH 21004				≈ ± Imax/10
MCIAH2160	MCIAH 21604				≈ ± Imax/10
MCIAH2180	MCIAH 21804				≈ ± Imax/10
MCIAH2240	MCIAH 22404				≈ ± Imax/10
MCIAH2260	MCIAH 22604				≈ ± Imax/10
MCIAH2320	MCIAH 23204				≈ ± Imax/10
MCIAH2340	MCIAH 23404				≈ ± Imax/10
MCIAH2400	MCIAH 24004				≈ ± Imax/10
MCIAH2420	MCIAH 24204				≈ ± Imax/10
MCIAH2480	MCIAH 24804				≈ ± Imax/10
MCIAH2500	MCIAH 25004				≈ ± Imax/10
MCIAH2560	MCIAH 25604				≈ ± Imax/10
MCIAH2580	MCIAH 25804				≈ ± Imax/10
MCIAH2640	MCIAH 26404		BIC.TI2d (M1SSR2)		≈ ± Imax/10
MCIAH2660	MCIAH 26604				≈ ± Imax/10
MCIAH2720	MCIAH 27204				≈ ± Imax/10
MCIAH2740	MCIAH 27404				≈ ± Imax/10
MCIAH2800	MCIAH 28004				≈ ± Imax/10
MCIAH2820	MCIAH 28204				≈ ± Imax/10
MCIAH2880	MCIAH 28804				≈ ± Imax/10
MCIAH2900	MCIAH 29004				≈ ± Imax/10

Table 10: List of surveyed vertical COD power converters in the TI2 transfer line. All converters connected to BIC crate BIC.TI2u are controlled by ROCS front-end crate M1SBA7. Converters connected to BIC crate BIC.TI2d are controlled by ROCS front-end crate M1SSR2.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance
MCIAV2030	MCIAV 20304	TI2	BIC.TI2u (M1SBA7)	V COD	≈ ± Imax/10
MCIAV2050	MCIAV 20504				≈ ± Imax/10
MCIAV2110	MCIAV 21104				≈ ± Imax/10
MCIAV2130	MCIAV 21304				≈ ± Imax/10
MCIAV2190	MCIAV 21904				≈ ± Imax/10
MCIAV2210	MCIAV 22104				≈ ± Imax/10
MCIAV2270	MCIAV 22704				≈ ± Imax/10
MCIAV2290	MCIAV 22904				≈ ± Imax/10
MCIAV2350	MCIAV 23504				≈ ± Imax/10
MCIAV2370	MCIAV 23704				≈ ± Imax/10
MCIAV2430	MCIAV 24304				≈ ± Imax/10
MCIAV2450	MCIAV 24504				≈ ± Imax/10
MCIAV2510	MCIAV 25104				≈ ± Imax/10
MCIAV2530	MCIAV 25304				≈ ± Imax/10
MCIAV2590	MCIAV 25904				≈ ± Imax/10
MCIAV2610	MCIAV 26104				≈ ± Imax/10
MCIAV2670	MCIAV 26704		BIC.TI2d (M1SSR2)		≈ ± Imax/10
MCIAV2690	MCIAV 26904				≈ ± Imax/10
MCIAV2750	MCIAV 27504				≈ ± Imax/10
MCIAV2770	MCIAV 27704				≈ ± Imax/10
MCIAV2830	MCIAV 28304				≈ ± Imax/10
MCIAV2850	MCIAV 28504				≈ ± Imax/10
MCIAV2890	MCIAV 28904				≈ ± Imax/10
MCIAV2910	MCIAV 29104				≈ ± Imax/10
MCIAV2950	MCIAV 29504				≈ ± Imax/10

Table 11: List of surveyed power converters in the TT41 transfer line. Converter MBG4101M is controlled by the ROCS front-end crate M1SBA4. All other converters are controlled by the ROCS front-end crate M1SBB4.

Converter	Magnet	Acc. zone	BIC module	Magnet type	Tolerance (‰)
MBI8160M	MBG 4101 String	TT41	BIC.TT41 (M1SBA4)	Main Bend	± 1
MBSG4100M	MBSG 4100 String		BIC.TT41 (M1SBB4)	H Bend	± 1
QTLD4101	QTLD 410100			Quad	± 5
QTGF4102	QTGF 410200			Quad	± 5
QTGD4103M	QTGD 4103 String			Main Quad	± 2
QTGF4104M	QTGF 4104 String			Main Quad	± 2
QTGD4117	QTGD 411700			Quad	± 5
QTGF4118	QTGF 411800			Quad	± 5
QTGD4119	QTGD 411900			Quad	± 5
QTGF4120	QTGF 412000			Quad	± 5
QTGD4121	QTGD 412100			Quad	± 5
QTS4122M	QTS 412200			Quad	± 5
	QTL 412204			Quad	± 5
QTL4123M	QTL 4123 String			Quad	± 5
QTS4124M	QTS 412400			Quad	± 5
	QTL 412404			Quad	± 5
MDGH4102	MDGH 410206			H COD	≈ ± Imax/10
MDGH4106	MDGH 410606			H COD	≈ ± Imax/10
MDGH4108	MDGH 410806			H COD	≈ ± Imax/10
MDGH4112	MDGH 411206			H COD	≈ ± Imax/10
MDGH4114	MDGH 411406			H COD	≈ ± Imax/10
MDGH4118	MDGH 411806			H COD	≈ ± Imax/10
MDGV4103	MDGV 410306			V COD	≈ ± Imax/10
MDGV4105	MDGV 410506			V COD	≈ ± Imax/10
MDGV4109	MDGV 410906			V COD	≈ ± Imax/10
MDGV4111	MDGV 411106			V COD	≈ ± Imax/10
MDGV4115	MDGV 411506			V COD	≈ ± Imax/10
MDGV4117	MDGV 411706			V COD	≈ ± Imax/10
MDSV4121	MDSV 412153			V COD	≈ ± Imax/20
MDSH4122	MDSH 412243			H COD	≈ ± Imax/20
MDSV4124	MDSV 412419			V COD	≈ ± Imax/20
MDSH4124	MDSH 412421			H COD	≈ ± Imax/20

3.1 SPECIAL DCCT CHANNELS

The main dipoles strings of TI8 (MBI) and TT41 (MBG) are powered by the same converter located in SPS building BA4.

Two special MuGef channels in front-end crate M1SBA4 are used to monitor independently the current in the MBG (TT41) and MBI (TI8) branches of the shared power converter (Figure 2). The ROCS channel names are DCCT3_TI8 and DCCT3_CNGS. The associated USER_PERMIT signals are connected to the BIC.TI8u and BIC.TT41 modules.

The surveillance of the current is performed with the same logic that is also used for all other converters presented in the previous section.

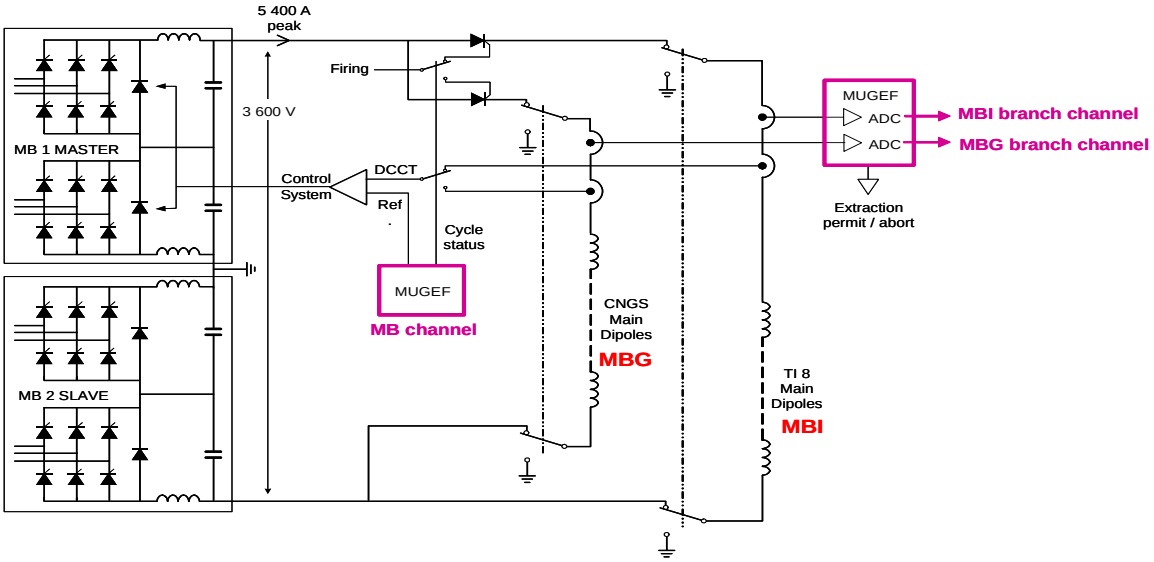

Figure 2 : The MBG and MBI dipoles strings are powered by a single converter equipped with internal switches. Two dedicated DCCTs, one for each magnet string, are used to define in which branch the current is flowing. The DCCTs are assigned special ROCS channels (without converter) that are used to perform the current surveillance.

4. FAST MAGNET CURRENT CHANGE MONITORS

Fast Magnet Current change Monitors (FMCM) are installed on highly critical dipole circuits where the time constants of the current decay in case of powering failures are very short and where the current surveillance performed within the ROCS crate (see section 3) may not be sufficiently fast for all failure cases.

Table 12: List of FMCM devices installed in the SPS transfer lines. Both CIF.BA4.MBG and CIF.BA4.MBI survey converter MBI8160M that is shared by the TT41 and TI8 main dipole magnet strings.

FMCM	Converter	Acc. Zone	BIC module
CIF.BB4.MSE	MSE4183M	TT40	BIC.TT40
CIF.BA4.MBHC	MBHC4001M		BIC.TT40
CIF.BA4.MBHA	MBHA4003M		BIC.TT40
CIF.BA4.MBG	MBI8160M	TT41	BIC.TT41
CIF.BB4.MBSG	MBSG4100M		BIC.TT41
CIF.BA4.MBI	MBI8160M	TI8	BIC.TI8u
CIF.SR8.MBIAH	MBIA8788M		BIC.IR8
CIF.SR8.MSIB	MSIB8813M		BIC.IR8
CIF.BA6.MST	MST6177M	TT60	BIC.TT60
CIF.BA6.MSE	MSE6183M		BIC.TT60
CIF.BA7.MBB	MBB2015M	TI2	BIC.TI2u
CIF.SR2.MBI	MBI2213M		BIC.TI2d
CIF.SR2.MBIBH	MBIBH2931M		BIC.TI2d
CIF.SR2.MSIB	MSIB2952M		BIC.IR2

5. FAST POWER CONVERTER INTERLOCK

The most critical electrical circuits of the transfer line in terms of time-constants will also be protected by an additional interlock signal based on the fast internal interlock sum signal of the associated power converter. The list of converters corresponds essentially to the list of circuits equipped with FMCMs. Signals from converters that are part of the same transfer line and that are installed in the same building will be grouped to reduce the number of BIC user inputs.

Table 13: List of power converters providing a fast internal interlock sum signal. Two separate signals must be provided to the TT41 and TI8 BIC modules from converter MBI8160M.

Converter	Building	Acc. Zone	BIC module
MSE4183M	SPS BB4	TT40	BIC.TT40
MBHC4001M MBHA4003M (grouped)	SPS BA4		BIC.TT40
MBI8160M	SPS BA4	TT41	BIC.TT41
MBSG4100M	SPS BB4		BIC.TT41
MBI8160M	SPS BA4	TI8	BIC.TI8u
MBIA8788M	LHC SR8		BIC.IR8
MSIB8813M	LHC SR8		
MST6177M MSE6183M (grouped)	SPS BA6	TT60	BIC.TT60
MBB2015M	SPS BA7	TI2	BIC.TI2u
MBI2213M	LHC SR2		BIC.TI2d
MBIBH2931M	LHC SR2		BIC.TI2d
MSIB2952M	LHC SR2		BIC.IR2

6. NORMAL CONDUCTING MAGNET INTERLOCK SYSTEMS

The normal conducting magnets of the transfer lines are protected by a dedicated powering interlock system (WIC) to survey the magnet temperatures. This system protects all transfer lines magnets with the exception of the septum magnets (section 8.2). The architecture and test procedures for those systems are described in [2, 3]. The interface of the WIC system to the transfer line interlock systems is performed by the Interlock Controller PLC. Some of the PLCs provide inputs to more than one BIC module as shown in Table 14 below.

Table 14: List of WIC control PLCs.

WIC PLC	Acc. Zone	BIC module
CIW.BA4.TI8	TT40 TI8	BIC.TT40 BIC.TI8u
CIW.BB4.CNGS	TT41	BIC.TT41

CIW.BA7.TI2	TT60 TI2	BIC.TT60 BIC.TI2u

7. KICKER MAGNET SURVEILLANCE

All extraction kicker magnets provide a status signal to the interlock system.

Table 15: List of extraction kicker magnets.

Kicker magnets	Acc. Zone	BIC module
MKE.416 (5 magnets)	LSS4	BIC.TT40
MKE.616 (4 magnets)	LSS6	BIC.TT60

8. EXTRACTION SEPTA SURVEILLANCE

8.1 SEPTUM GIRDER SURVEILLANCE

The position of extraction septa girders are interlocked to prevent extraction with the girder is not in appropriate position and state with respect to the beam.

Table 16: List of septum girders.

Girder	Septa magnets	Acc. Zone	BIC module
Extraction septa LSS4	MSE.418 (6 magnets)	LSS4	BIC.TT40
Extraction septa LSS6	MST.617 (2 magnets) MSE.618 (5 magnets)	LSS6	BIC.TT60

8.2 MAGNET SURVEILLANCE

The extraction septum protection system surveys temperatures and cooling of the extraction septa magnets and of their protection devices (TPSG).

The protection system provides a signal to the interlock system that is sent 10 ms before the associated power converter is switched off.

Table 17: Extraction septum magnet surveillance systems.

Septa magnets	Acc. Zone	BIC module
MSE.418 (6 magnets)	LSS4	BIC.TT40
MST.617 (2 magnets) MSE.618 (5 magnets)	LSS6	BIC.TT60

9. BEAM POSITION SURVEILLANCE

9.1 SPS BEAM POSITION

The beam position in the SPS is verified before extraction to ensure that the extraction bump is correct and that the energy offset due to a mismatch of the SPS 200 MHz RF frequency is acceptable. The energy offset is detected by the average horizontal offset of the beam in the arcs around the extraction areas.

Table 18: List of position monitors that are part of the SPS bumped beam position interlock for LSS4 and LSS6. The front-end systems are BMU40S (LSS4) and BMU60S (LSS6).

Monitor	Acc. Zone	BIC module	Tol (mm)
BPCE.41801	LSS4	BIC.TT40	± 0.5
BPCE.41705			± 0.5
BPCE.41931			± 0.5
BPCE.61805	LSS6	BIC.TT60	± 0.5
BPCE.61705			± 0.5
BPCE.61931			± 0.5

Table 19: List of position monitors used to evaluate the average radial position in sextant 4 of the SPS. The tolerance on the average is ± 1 mm. The front-end system is BMU40S.

Monitor	Acc. Zone	BIC module
BPH.40209	SPS Sextant 4	BIC.TT40
BPH.40409		
BPH.40609		
BPH.40809		
BPH.41009		
BPH.41209		
BPH.41409		
BPH.41608		
BPH.42008		
BPH.42209		
BPH.42409		
BPH.42609		
BPH.42809		
BPH.43009		
BPH.43209		
BPH.43409		
BPH.43609		

Table 20: List of monitors used to evaluate the average radial position in sextant 6 of the SPS. The tolerance on the average is ± 1 mm. The front-end system is BMU60S.

Monitor	Acc. Zone	BIC module
BPH.60209	SPS Sextant 6	BIC.TT60
BPH.60409		
BPH.60609		
BPH.60809		
BPH.61009		
BPH.61209		
BPH.61409		
BPH.62009		
BPH.62209		
BPH.62409		
BPH.62609		
BPH.62809		
BPH.63009		
BPH.63209		
BPH.63409		
BPH.63609		
BPH.60209		

9.2 TRAJECTORY POSITION

The beam trajectory of the CNGS beam in TT40 and TT41 is verified to ensure that the beam is well inside the aperture and that the beam hits the target within 0.5 mm of the target axis.

Table 21: List of BPMs that are part of the CNGS trajectory position interlock. The front-end system is BMU40T.

Monitor	Acc. Zone	BIC module	Tol (mm)
BPK.400099	TT40	BIC.TT41	± 4
BPK.400207			± 4
BPK.400307			± 4
BPK.400407			± 4
BPG.410107	TT41		± 4
BPG.410205			± 4
BPG.410405			± 4
BPG.410505			± 4
BPG.410705			± 4
BPG.410805			± 4
BPG.411005			± 4
BPG.411105			± 4
BPG.411305			± 4
BPG.411405			± 4
BPG.411605			± 4
BPG.411705			± 4
BPG.411905			± 4
BPG.412005			± 4
BPG.412211			± 4
BPG.412321			± 4
BPG.412424			± 0.5
BPG.412444			± 0.5
BPKG.412449			± 0.5

10. BEAM LOSS MONITORS

The extraction areas of the SPS and all the concerned transfer lines are equipped with Beam Loss Monitors (BLMs) to inhibit beam extraction in the event of excessive beam losses.

10.1 EXTRACTION AREAS

BLMs installed in the extraction areas of LSS4 and LSS6 generate a beam dump of the circulating SPS beam.

Table 22: BLMs for the extraction area in LSS4. The front-end system is BLR41S. The interlock is presently connected to the SPS emergency dump system through the SPS ring BIC module installed in BA4.

Monitor	Acc. Zone	BIC module
BLM.41835	LSS4 Extr.	BIC.SPS4
BLM.41839		
BLM.41854		
BLM.41859		
BLM.41874		
BLM.41879		
BLM.41884		
BLM.41897		

Table 23: BLMs for the extraction area in LSS6. The front-end system is BLR61S. The interlock is presently connected to the SPS emergency dump system through the SPS ring BIC module installed in BA6.

Monitor	Acc. Zone	BIC module
BLM.61631	LSS6 Extr.	BIC.SPS6
BLM.61634		
BLM.61637		
BLM.61651		
BLM.61771		
BLM.61774		
BLM.61779		
BLM.61794		
BLM.61832		
BLM.61837		
BLM.61852		
BLM.61857		
BLM.61872		

10.2 TRANSFER LINES

BLM installed in the transfer lines are used to inhibit further extractions. The associated interlocks will be latched until a reset is performed.

The BLM list for TI2 is a preliminary version that will be updated in the future. In particular the BLM positions near collimators are likely to change.

Table 24: BLMs for the TT40 transfer line. The front-end system is BLMI40T.

Monitor	Acc. Zone	BIC module
BLM.400103	TT40	BIC.TT40
BLM.400117		
BLM.400206		
BLM.400306		
BLM.400316		
BLM.400406		

Table 25: BLMs for the TT41 transfer line to the CNGS target. The front-end system is BLMI41T.

Monitor	Acc. Zone	BIC module
BLM.410024	TT41	BIC.TT41
BLM.410145		
BLM.410307		
BLM.410607		
BLM.410707		
BLM.410907		
BLM.411107		
BLM.411507		
BLM.411807		
BLM.411907		
BLM.412007		
BLM.412243		

Table 26: BLMs for the TI8 transfer line. The front-end systems are BLMI40T (BIC.TI8u) and BLR87T (BIC.TI8d).

Monitor	Acc. Zone	BIC module
BLMI.80104	TI8	BIC.TI8u
BLMI.81755		
BLMI.82104		
BLMI.82304		
BLMI.82904		
BLMI.83104		
BLMI.83704		
BLMI.83904		
BLMI.84504		
BLMI.84704		BIC.TI8d
BLMI.85304		
BLMI.85504		
BLMI.86104		
BLMI.86304		
BLMI.86904		
BLMI.87104		
BLMI.87319		
BLMI.87423		
BLMI.87441		
BLMI.87519		
BLMI.87645		
BLMI.87704		
BLMI.87720		
BLMI.87804		
BLMI.87840		
BLMI.87904		
BLMI.88004		
BLMI.88123		
BLMI.88126		
BLMI.C6R8		
BLMI.B6R8		
BLMI.A6R8		
BLMI.5R8		

Table 27: BLMs for the TI2 transfer line. The front-end systems are BLR70S (BIC.TI2u) and BLR23S (BIC.TI2d)

Monitor	Acc. Zone	BIC module
BLMI.20103	TI2	BIC.TI2u
BLMI.20203		
BLMI.20600		
BLMI.20644		
BLMI.20903		
BLMI.21503		
BLMI.21703		
BLMI.22303		
BLMI.22903		
BLMI.23103		
BLMI.23303		
BLMI.23903		
BLMI.24103		
BLMI.24703		
BLMI.24903		
BLMI.25503		
BLMI.25703		
BLMI.26103		BIC.TI2d
BLMI.26503		
BLMI.26903		
BLMI.27303		
BLMI.27703		
BLMI.27903		
BLMI.28303		
BLMI.28703		
BLMI.28903		
BLMI.29103		
BLMI.29320		
BLMI.29403		
BLMI.29503		
BLMI.29538		
BLMI.29556		
BLMI.29573		
BLMI.4L2B1		

11. BEAM PROFILE MONITORS

The position of profile monitors is interlocked to prevent high intensity beam extraction when the profile monitors are moving from one screen position to the next and to prevent high intensity beam extractions where thick Alumina screens are in the path of the beam.

Table 28: Beam profile monitors installed in the extraction area of LSS4 and in TT40. The front-end system is BTV41S.

Monitor	Acc. Zone	BIC module
BTVE.41831	LSS4 Extraction	BIC.TT40
BTVE.41895		
BTV.400105	TT40	
BTV.400222		
BTV.400343		

Table 29: Beam profile monitors installed in TT41. The front-end system is BTV41T.

Monitor	Acc. Zone	BIC module
BTVG.410406	TT41	BIC.TT41
BTVG.410706		
BTVG.411006		
BTVG.411906		
BTVG.412108		
BTVG.412424		
BTVG.412434		
BTVG.412445		

Table 30: Beam profile monitors installed in TI8.

Monitor	Acc. Zone	BIC module
BTVI.81204	TI8	BIC.TI8u
BTVI.81306		
BTVI.84304		BIC.TI8d
BTVI.84404		
BTVI.84604		
BTVI.87437		
BTVI.87604		
BTVI.87750		
BTVI.88119		

Table 31: Beam profile monitors installed in LSS6 and in TT60.

Monitor	Acc. Zone	BIC module
BTVE.61772	LSS6	BIC.TT60
BTVE.61798		
BTVE.61831		
BTVE.61876		
BTV.610018	TT60	
BTV.610252		
BTV.610317		

Table 32: Beam profile monitors installed in TI2.

Monitor	Acc. Zone	BIC module
BTVI.20506	TI2	BIC.TI2u
BTVI.24404		
BTVI.24604		
BTVI.24704		
BTVI.26506		BIC.TI2d
BTVI.26606		
BTVI.26706		
BTVI.29124		
BTVI.29528		

12. BEAM CURRENT TRANSFORMERS

SPS Beam Current Transformers (BCT) are used to limit the allowed intensity at extraction.

The hadron BCT (Bct.318) installed in SPS LSS3 is used to dump beams that exceed a predefined intensity level after the last injection from the PS. This BCT also provides the SPS Safe Beam Flag (SBF) that is used for maskable USER_PERMITs.

A high sensitivity ion BCT (BCT.414) installed is LSS4 is used to provide an additional intensity interlock for beams extracted through the LSS4 extraction channel to the CNGS target or to TI8. This BCT is however limited to a maximum of 7×10^{11} charges.

Table 33: SPS BCTs used for intensity interlocking. BCT.318 is connected to the SPS Ring Emergency Beam Dump. The front-end systems are BCT40S and BCT30S.

Monitor	Acc. Zone	BIC module
BCT.41436	LSS4	BIC.TT40
BCT.31832	LSS3	SPS Ring Emergency Beam Dump

13. VACUUM VALVES

All vacuum valves installed in the transfer lines are interlocked to prevent beam passage when a valve is not out of beam. Vacuum valves installed in TI2 and TI8 located behind the downstream TEDs are connected the LHC injection BIC modules.

The vacuum valves installed behind the downstream TED dumps of TI2 and TI8 are connected to the LHC injection BIC modules of IR2 and IR8.

Table 34: List of vacuum valves in the transfer lines.

Valve	Acc. Zone	BIC module
VVGSA.400000	TT40	BIC.TT40
VVGSA.80110	TI8	BIC.TI8u
VVGSA.80159		
VVGSA.82405		
VVGSA.84605		
VVGSA.86805		
VVGSA.88061		BIC.IR8
VVGSA.88134		
VVGSA.410124	TT41	BIC.TT41
VVGSA.410146		
VVGSA.411306		
VVGSA.412428		
VVGSA.610000	TT60	BIC.TT60
VVFA.610213		
VVGSA.20100	TI2	BIC.TI2u
VVGSA.22805		
VVGSA.25205		
VVGSA.27605		
VVGSA.29528		BIC.IR2

14. COLLIMATORS

Collimators are installed in the TI2 and TI8 transfer lines to protect the LHC ring against failures and poor quality beam from the SPS.

The position of the collimators will be interlocked.

Table 35: List of collimators installed in TI8 and TI2.

Collimator	Acc. Zone	BIC module
TCDIP.81755	TI8	BIC.TI8u
TCDIH.87441		BIC.TI8d
TCDIH.87904		
TCDIH.88121		
TCDIV.87645		
TCDIV.87804		
TCDIV.88123		
TCDIP.20607	TI2	BIC.TI2u
TCDIV.29012		BIC.TI2d
TCDIH.29050		
TCDIH.29205		
TCDIV.29234		
TCDIH.29465		
TCDIV.29509		

15. MOBILE DUMPS AND PERSONNEL PROTECTION DEVICES

The mobile dump blocks (TED) of the transfer lines are used by the interlock system to perform intelligent masking of interlock channels that are downstream of a TED that is in position DUMP (aligned with the beam). The beam must be inhibited when the TED block is moving between the IN (DUMP) and OUT position (≈ 30 seconds).

The personnel protection devices (TBSE and CNGC shutter) are used as safety devices for access to the tunnel. Since such devices must not be hit by beam, their position is interlocked to ensure beam passage only when the devices are OUT of beam.

Table 36: List of mobile dumps (TED) and personnel protection devices.

Device	Acc. Zone	BIC module
TED.400354	TT40	BIC.EXT2
TED.87765	TI8	BIC.EXT2
TBSE.80243	TI8	BIC.TI8u
TBSE.410113	TT41	BIC.TT41
CNGS Shutter	TT41 (TCC4)	BIC.TT41
TED.610321	TT60	BIC.EXT1
TED.29133	TI2	BIC.EXT1

16. SPECIAL CNGS DEVICES

For the CNGS primary and secondary beam, the following devices are also interlocked:

- The T40 target assembly.
- The CNGS magnetic horns.
- The cooling circuit of the CNGS secondary beam hadron dump.

17. EQUIPMENT TABLES

Table 37: This table gives the number of devices for distributed equipment that are surveyed as part of the transfer lines interlock system. This table does not include small systems (in size) like septum girders, kickers, special DCCTs for the shared TI8/CNGS converter, BCTs and special devices for CNGS.

	LSS4	TT40	TI8	TT41	LSS6	TT60	TI2	**Total**
Septum converters		1				2		**3**
Dipole converters	8	2	6	2	8	1	7	**34**
Quad. converters		4	15	14		6	19	**58**
COD converters		3	42	16		5	47	**113**
Total converters	8	10	63	32	8	14	73	**208**
FMCM		3	3	2		2	4	**14**
Fast PC interlock		3	3	2		2	4	**14**
TEDs & PPDs		1	2	2		1	1	**7**
Vacuum valves		1	6	4		2	5	**18**
Collimators			7				7	**14**
Beam Position Monitors	20			23	20			**63**
Beam Loss Monitors	8	6	33	12	13		34	**106**
Profile monitors	2	3	9	8		3	10	**35**
Total	**38**	**27**	**126**	**85**	**41**	**24**	**136**	**479**

18. REFERENCES

1. B. Goddard et al, *INTERLOCKING BETWEEN SPS, CNGS, LHC TRANSFER LINES AND LHC INJECTION*, **LHC-CI-ES-0002**, EDMS No. 602470.
2. P. Dahlen, *Procedures for the commissioning of the normal conducting magnet interlock system in the TT41 transfer line*, **CNGS-2006-03 rev.0.2**, EMDS No. 699907.
3. M. Zaera-Sanz et al, *Procedures for the commissioning of the normal conducting magnet interlock system in the SPS-LHC transfer line TI 8,* **LHC-D-TP-0001 rev 0.2**, EDMS No. 599492.