



# HL-LHC IT String Day IV Warm Powering System

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*With the contribution of WP6B team and SY-EPC group*



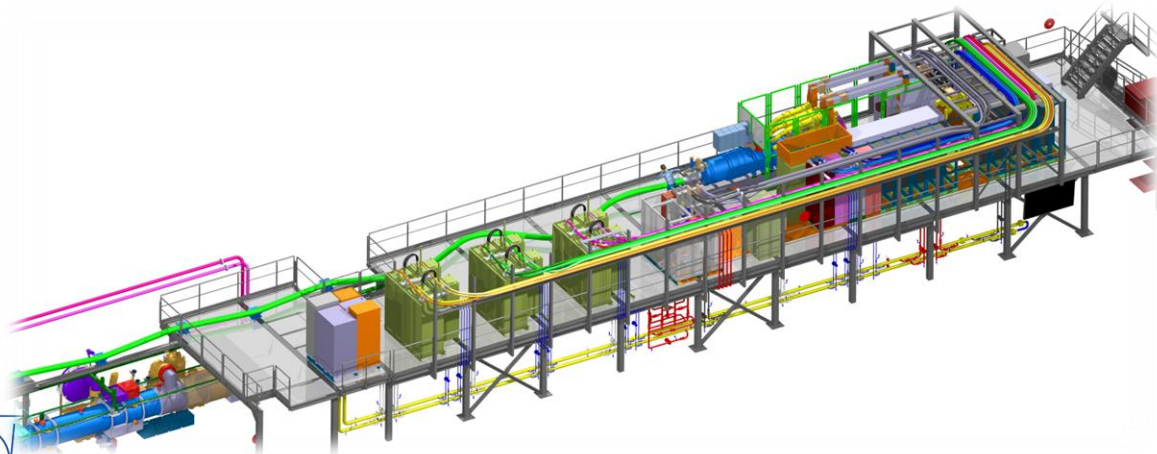
HL-LHC IT String Day IV - 30/7-018 - Kjell Johnsen Auditorium – 27 Sept 2024

# Outline

- HL-LHC String - The prototype of the IP sides
- Installation phase
- IST and SCT
- Next Steps
- Conclusion

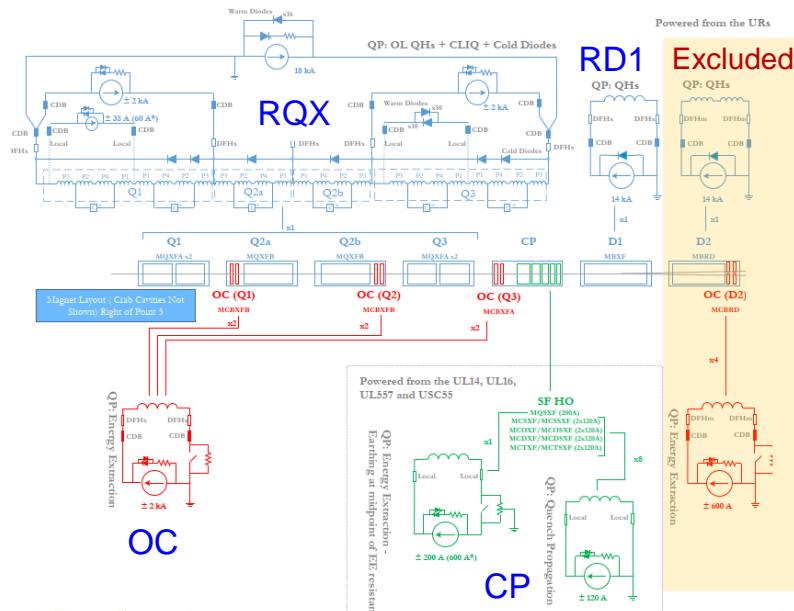
# HL-LHC String - The prototype of the IP sides

- HL-LHC String can be considered as the prototype of the IP sides (the pre-series will be the first IP side) and an unique opportunity to validate the different phases of LS3 (UR)
  - This will be the first opportunity to test all the equipment together
  - Opportunity to validate both hardware and software interfaces, identify issues and solve them before full deployment.



# HL-LHC String - The prototype of the IP sides

- HL-LHC String circuits
  - Identical to the machine w/o RD2 and its correctors
    - RD2 can be considered as a copy-paste of RD1
    - 600A correctors can be considered as a copy-paste of 2kA correctors



# HL-LHC String - The prototype of the IP sides

- HL-LHC String phases
  - Same phases as the machine
    - Installation
    - IST - SCT
    - Commissioning
    - Operation

SM18_HL-LHC_WP16_WORKINGplanningSTRING		14/08/2020	01/07/2027		
HL-LHC String	1,683d	14/08/2020	01/07/2027	14/08/2020	01/07/2027
Infrastructure	1,096d	14/08/2020	07/02/2025	14/08/2020	16/01/2025
Rack installation	743d	15/09/2021	25/09/2024	15/09/2021	23/09/2024
SY-EPC-6B	244d	01/08/2022	28/07/2023	SY-EPC	01/08/2022 28/07/2023
CDB 18kA rack	2w	21/10/2022	03/11/2022	SY-EPC	21/10/2022 03/11/2022
CDB 14kA rack	2w	21/10/2022	03/11/2022	SY-EPC	21/10/2022 03/11/2022
CDB 2kA racks	2w	21/10/2022	03/11/2022	SY-EPC	21/10/2022 03/11/2022
CDB control rack x2	1w	24/07/2023	28/07/2023	SY-EPC	24/07/2023 28/07/2023
CDB 0.6 kA Rack	1d	24/07/2023	24/07/2023	SY-EPC	24/07/2023 24/07/2023
18kA PC rack	4w	06/03/2023	31/03/2023	SY-EPC	06/03/2023 31/03/2023
0.06kA PC rack	4w	06/03/2023	31/03/2023	SY-EPC	06/03/2023 31/03/2023
DCCT Racks	4w	06/03/2023	31/03/2023	SY-EPC	06/03/2023 31/03/2023
14kA PC rack	4w	06/03/2023	31/03/2023	SY-EPC	06/03/2023 31/03/2023
2kA PC racks	8.2w	06/03/2023	04/05/2023	SY-EPC	06/03/2023 04/05/2023
0.2kA PC rack (0.6 kA baseline)	4w	06/03/2023	31/03/2023	SY-EPC	06/03/2023 31/03/2023
0.12kA PC racks	4w	06/03/2023	31/03/2023	SY-EPC	06/03/2023 31/03/2023
Gateway-FGC3 rack	4w	24/02/2023	23/03/2023	SY-EPC	24/02/2023 23/03/2023
RPAFE: Crowbar installation (WP6B)	1w	01/10/2024	07/10/2024	SY-EPC	01/10/2024 07/10/2024
SY-EPC electronics into rack installation in-situ	21.8w	30/06/2023	30/11/2023	SY-EPC	30/06/2023 30/11/2023
DC connections	415.5d	20/06/2022	28/02/2024	EN-EL	20/06/2022 28/02/2024
Final WCC lugs connection	3w	01/11/2023	21/11/2023	SY-EPC	01/11/2023 21/11/2023
Busbar	1.5w	19/02/2024	28/02/2024	SY-EPC	19/02/2024 28/02/2024
STRING operation	772.5d	01/12/2023	05/02/2027		01/12/2023 21/01/2027
Tests before cooling & cooling	449.5d	01/12/2023	06/10/2025		01/12/2023 19/09/2025
Protection Interface and Short Circuit Tests	65d	01/12/2023	14/03/2024		01/12/2023 14/03/2024
Individual system tests (PCs, CDBs and busbars)	2w	01/12/2023	14/12/2023	SY-EPC	01/12/2023 14/12/2023
Short-circuit tests / LHC-XMS-OP-0003	11w	15/12/2023	14/03/2024	TE-MPE, EN-CV, EN-EL, SY-EPC	15/12/2023 14/03/2024
PCs, CDBs, Busbars and associated equipment dismatlin	0d	01/07/2027	01/07/2027	SY-EPC	01/07/2027 01/07/2027

# HL-LHC String - The prototype of the IP sides

- New hardware in LHC machine
  - New power converters should be fully compatible with the LHC machine: software, BD and tool.



FGC API



FGC Barcode  
Manager



FGC  
Commander



FGC Docs



FGC Portal



FGC Property  
Manager



FGC Remote  
Terminal



FortLogs



FRESCO



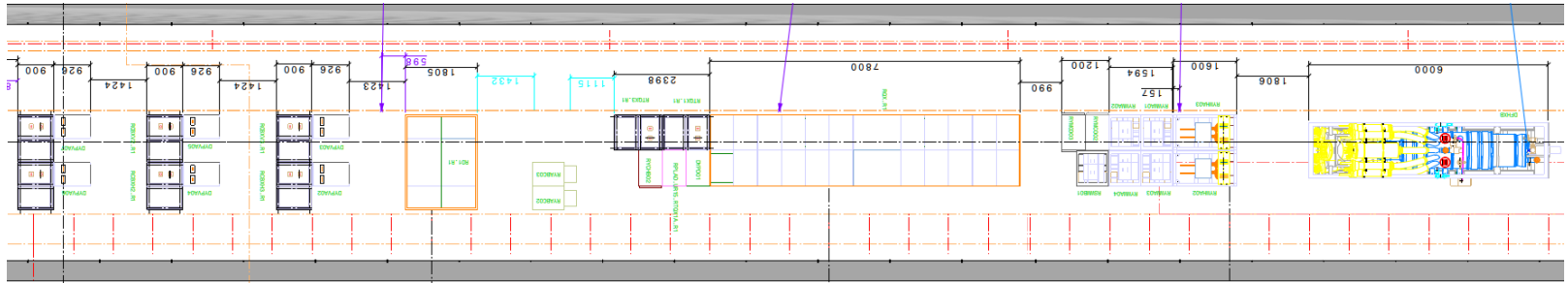
PowerSpy

The screenshot shows the 'Query' tool interface with a tree view on the left and a table of results on the right. The tree view is expanded to 'Power Converters' under 'IT-STRING'. The table lists 200 items, showing columns for Variable Name, System, Description, and Unit.

Variable Name	System	Description	Unit
RPAFE.SM18.RQX.SF.I_DIFF_MA	CMW	IT-STRING Power Converter RPAFE.SM18...	mA
RPAFE.SM18.RQX.SF.I_EARTH_CPCNT	CMW	IT-STRING Power Converter RPAFE.SM18...	%
RPAFE.SM18.RQX.SF.I_ERR_MA	CMW	IT-STRING Power Converter RPAFE.SM18...	mA
RPAFE.SM18.RQX.SF.I_MEAS	CMW	IT-STRING RPAFE.SM18.RQX.SF Power C...	A
RPAFE.SM18.RQX.SF.I_REF	CMW	IT-STRING Power Converter RPAFE.SM18...	A
RPAFE.SM18.RQX.SF.STATE_PC	CMW	IT-STRING Power Converter RPAFE.SM18...	-
RPAFE.SM18.RQX.SF.ST_FAULTS	CMW	IT-STRING Power Converter RPAFE.SM18...	-
RPAFE.SM18.RQX.SF.ST_WARNINGS	CMW	IT-STRING Power Converter RPAFE.SM18...	-
RPAFE.SM18.RQX.SF.V_MEAS	CMW	IT-STRING Power Converter RPAFE.SM18...	V
RPAFE.SM18.RQX.SF.V_REF	CMW	IT-STRING Power Converter RPAFE.SM18...	V
RPAFF.SM18.RD1.SF.I_DIFF_MA	CMW	IT-STRING Power Converter RPAFF.SM18...	mA
RPAFF.SM18.RD1.SF.I_EARTH_CPCNT	CMW	IT-STRING Power Converter RPAFF.SM18...	%
RPAFF.SM18.RD1.SF.I_ERR_MA	CMW	IT-STRING Power Converter RPAFF.SM18...	mA
RPAFF.SM18.RD1.SF.I_MEAS	CMW	IT-STRING Power Converter RPAFF.SM18...	A
RPAFF.SM18.RD1.SF.I_REF	CMW	IT-STRING Power Converter RPAFF.SM18...	A
RPAFF.SM18.RD1.SF.STATE_PC	CMW	IT-STRING Power Converter RPAFF.SM18...	-
RPAFF.SM18.RD1.SF.ST_FAULTS	CMW	IT-STRING Power Converter RPAFF.SM18...	-
RPAFF.SM18.RD1.SF.ST_WARNINGS	CMW	IT-STRING Power Converter RPAFF.SM18...	-
RPAFF.SM18.RD1.SF.V_MEAS	CMW	IT-STRING Power Converter RPAFF.SM18...	V
RPAFF.SM18.RD1.SF.V_REF	CMW	IT-STRING Power Converter RPAFF.SM18...	V

# Installation

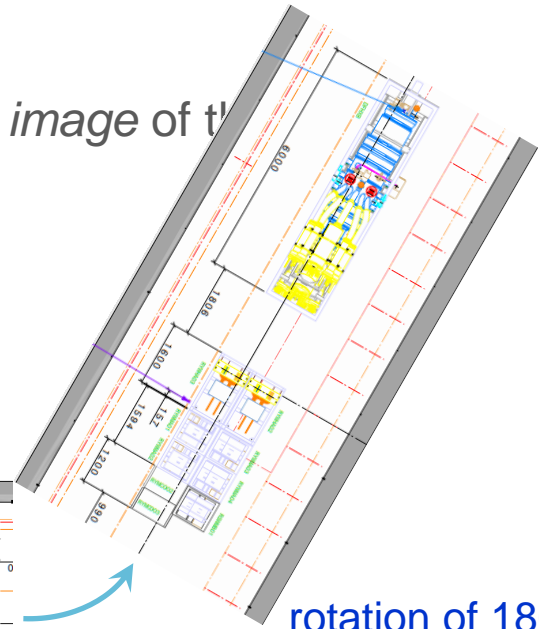
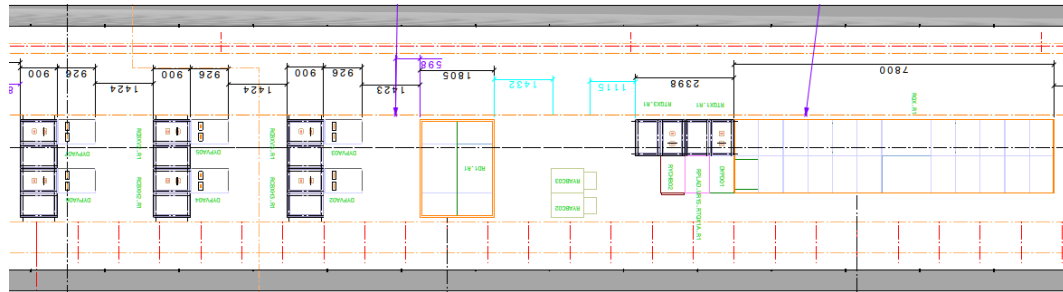
- HL-LHC String integration has to be done to be an *image* of the machine



## UR integration

# Installation

- HL-LHC String integration has been done to be an *image* of the

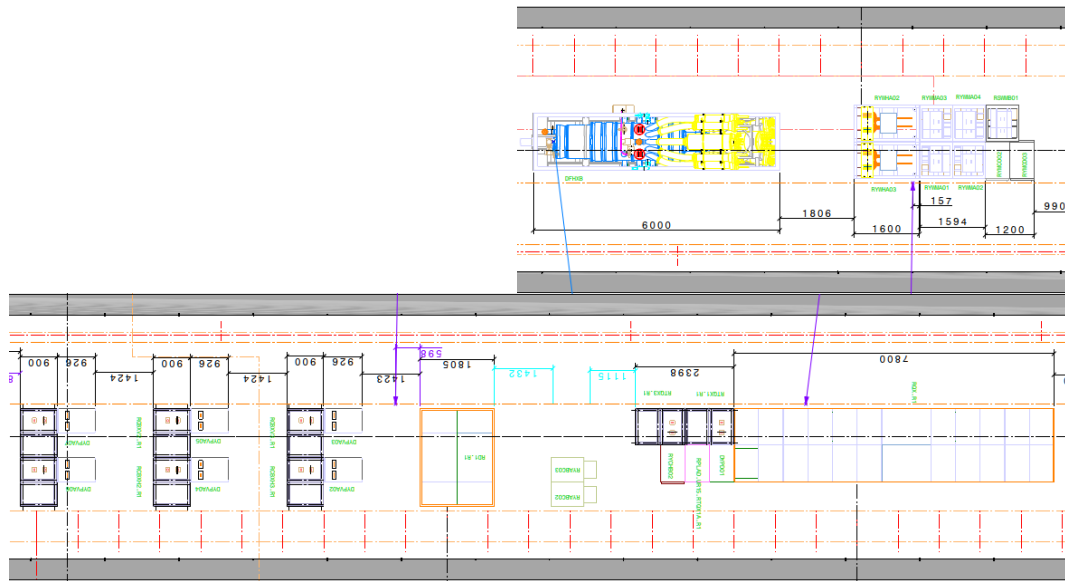


rotation of 180°  
of the CDB and DFHX



# Installation

- HL-LHC String integration has to be done to be an *image* of the machine



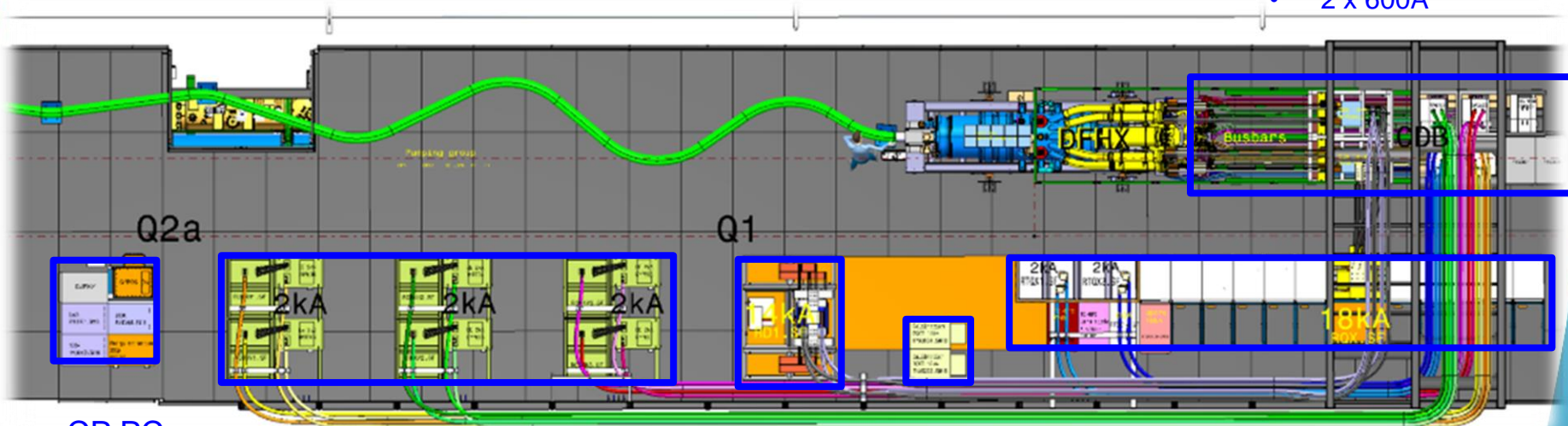
Warm Powering systems  
Integration

# Installation

- Hardware Installation (visible part)

## CDBs & WCBB

- 2 x 18kA
- 8 x 2kA
- 2 x 600A



## CP PCs:

- 1 x 200A
- 8 x 120A (not R2E)

## RCBX (OC) PCs:

- 6 x 2kA

## RD1 PC:

- Main: 14kA

## MEAS syst:

- RQX: 18kA
- RD1: 14kA

## RQX PCs

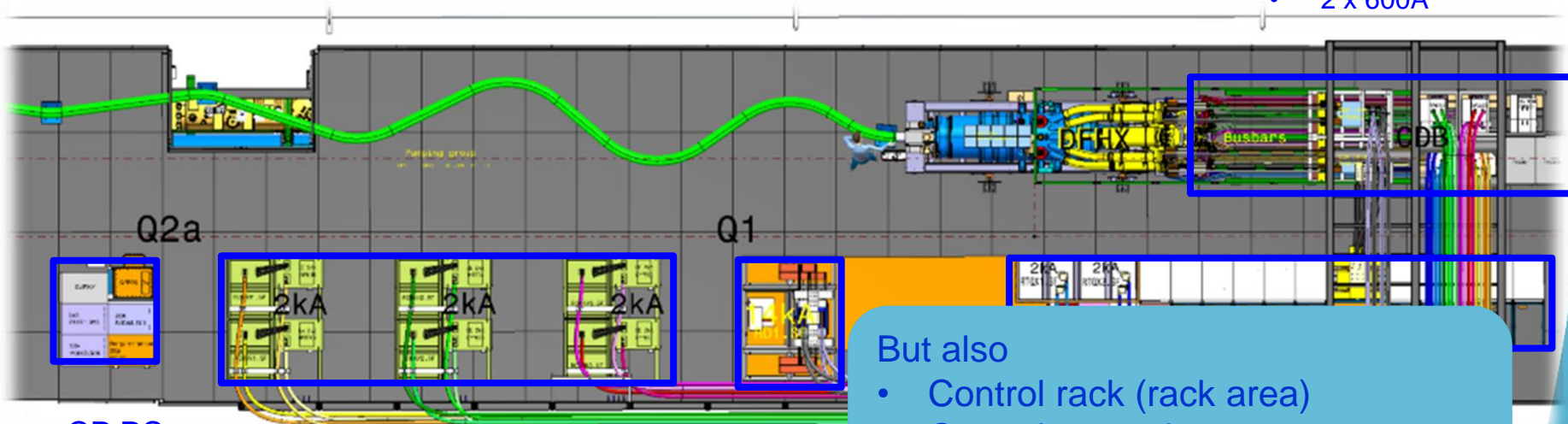
- Main: 18kA
- TRIM: 2 x 2kA & 35A

# Installation

- Hardware Installation (visible part)

## CDBs & WCBB

- 2 x 18kA
- 8 x 2kA
- 2 x 600A



### CP PCs:

- 1 x 200A
- 8 x 120A (not R2E)

### RCBX (OC) PCs:

- 6 x 2kA

### RD1 PC:

- Main:

### But also

- Control rack (rack area)
- Control networks
- Signal cables between equipment

# Installation

- Software Configuration (not visible part)
  - Important work never mentioned

The image displays a collage of screenshots from the FGC Commander software interface, illustrating various components of the installation and configuration process.

**FGC Commander Main Interface:** Shows a menu bar with options like Connect, Disconnect, Select, Gateway, FGC, Config, Database, and Analysis. Below the menu is a table with columns: PL, OP, VS, PC, I\_REF, I\_MEAS, V\_REF, V\_MEAS. The table lists various equipment units and their status (e.g., OFFLINE).

**Equipment Report - SY-EPC DATABASES:** A window titled "SY-EPC DATABASES" showing an "Equipment Report" for "RPAFF.SM18.RD1.SF". It includes fields for Installation Name, Other Name, Model, Barcode & Execution, Reference, Machine 1, Area, Building, Room, and Rack.

**RADE System Classes:** A window showing a list of system classes with columns for Date, Time, Class, and Status. It includes a "Basket" section for adding items.

**Table Data:** A table with columns: LK, SM, RD, IL, Value 1, Value 2, Value 3, Value 4. The table lists various equipment units and their associated values.

**Table Data:** A table with columns: Group, Name, Value, Unit. It lists equipment units and their values.

**RADE System Classes Table:**

Date	Time	Class	Status
2007	May 14	92.000	OK
2007	May 13	92.000	OK
2007	May 12	92.000	OK
2007	May 11	92.000	OK
2007	May 10	92.000	OK
2007	May 09	92.000	OK
2007	May 08	92.000	OK
2007	May 07	92.000	OK
2007	May 06	92.000	OK
2007	May 05	92.000	OK
2007	May 04	92.000	OK
2007	May 03	92.000	OK
2007	May 02	92.000	OK
2007	May 01	92.000	OK
2007	Apr 30	92.000	OK
2007	Apr 29	92.000	OK
2007	Apr 28	92.000	OK
2007	Apr 27	92.000	OK
2007	Apr 26	92.000	OK
2007	Apr 25	92.000	OK
2007	Apr 24	92.000	OK
2007	Apr 23	92.000	OK
2007	Apr 22	92.000	OK
2007	Apr 21	92.000	OK
2007	Apr 20	92.000	OK

**Table Data:**

Group	Name	Value	Unit
	I dcct	13000	Am

**Table Data:**

LK	SM	RD	IL	Value 1	Value 2	Value 3	Value 4
LK	SM	RD	IL	110.00	110.00	0.31	0.31
LK	NL	FS	FO	0.00	0.10	0.00	0.00
LK	NL	FS	FO	0.00	0.15	0.00	0.00
LK	NL	FS	FO	0.00	0.15	0.00	0.00
LK	NL	FS	FO	0.00	0.06	0.00	0.00
LK	NL	FS	FO	0.00	0.15	0.00	0.00
LK	NL	FS	FO	0.00	-0.02	0.00	0.00
LK	NL	FS	FO	0.00	-0.01	0.00	0.00
LK	NL	FS	FO	0.00	0.00	0.00	0.00

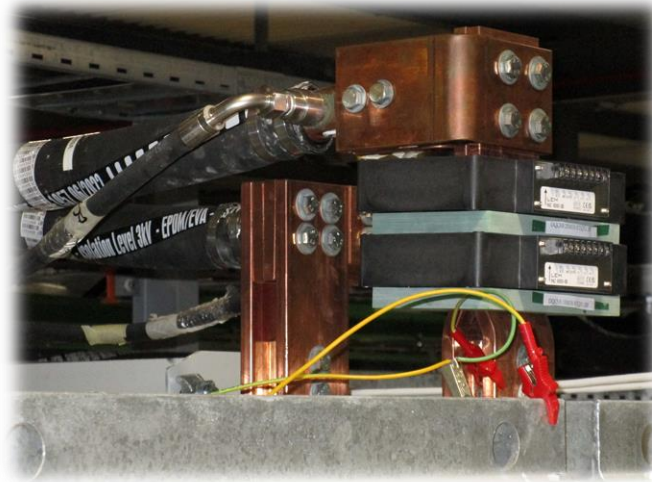
# Installation

- Schedule
  - HL-LHC String: 1.5 year of installation
    - First equipment has been installed in October 2022 (CDB)
    - Last equipment has been installed in March 2024 (WCBB)
  - LHC machine: 2 months per IP side
  - Why this difference?
    - HL-LHC String use machine equipment and it is ahead of the machine
      - Design was not finalized when the production started
    - PCs and CDBs have been installed when they were needed (partial installation)
      - CBD racks have been installed for WCC installation w/o control part
      - PCs have been installed in different campaign
      - 1<sup>st</sup> SCT tests have been done w/o WCBB
      - Some equipment is still missing: 18kA crowbar, DCCT, etc...

# Installation

- Schedule
  - Why this difference?
    - Some interfaces were not defined before installation (time consuming)

**Water Cooled  
Cabled**



**Monitoring  
Current Sensors**

**PC Connections**

# Installation

- Schedule
  - What was the impact?
    - More time and resources than planned (several installation campaigns).
    - Challenging to plan the activities effectively. The installation team has spent more time in transit than working in the field.
  - Lessons learned
    - Detailed integration is essential for a brief installation
    - Time should be estimated and added for contingencies
    - The installation of the first IP side will take more time than the other 3
      - Difference between HL-LHC String and IP sides
      - Validate the modifications implemented in the String

# IST and SCT

- IST and SCT
  - What was planned?
    - Two different phases with first IST and after SCT
    - The ideal scenario when everything works well
      - Equipment fully tested before installation.
      - No issues or minor issues.
  - What was done?
    - IST and SCT have been done in parallel
    - Part of reception tests has been done in the HL-LHC String
      - Validation and reception tests of CDB control have been done in the HL-LHC String
      - Validation of the WCBB design has been done in the HL-LHC String
      - First time that the 18kA power converter reached nominal current with 10 subPCs in parallel



# Next Step

- Finalize the installation
  - Reinstall power modules in 14kA and 18kA power converters
    - Currently, only one set of modules is available, share between SM18 and PHall
    - The power modules have been removed and installed in EPC test area for performance validation of the 14kA and 18kA power converters
  - Installation of missing items
    - 18kA crowbar, not needed for the 1<sup>st</sup> phase (IST and SCT)
    - Second DCCT for 18kA, 14kA and 2kA PCs
    - Etc...
  - Modify the HL-LHC String to be as close as possible of the machine
    - Remove one MEAS Rack (done)
    - Modify AC distribution to improve the safety procedure (done)
    - Update the WCBB&WCP to be compliant with the specification (insulation)

# Next Step

- Finalize the installation
  - Schedule
    - Installation/Modification will be done in an unique campaign
    - The campaign is planned on May and June 2025
    - 3 weeks of IST/SCT are needed to requalify the power converter and to validate the modifications

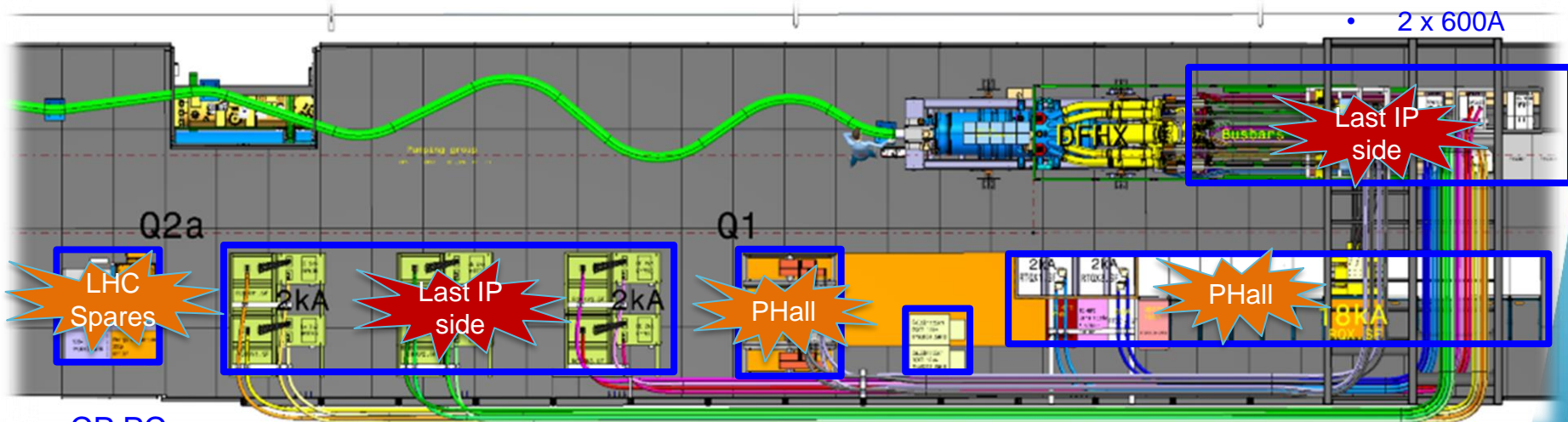
# Next Step

- HL-LHC String De-installation

- All HL-LHC String equipment is needed for the machine
- String dismantlement should be done >6 months before the last IP side

### CDBs & WCBB

- 2 x 18kA
- 8 x 2kA
- 2 x 600A



### CP PCs:

- 1 x 200A
- 8 x 120A (not R2E)

### RCBX (OC) PCs:

- 6 x 2kA

### RD1 PC:

- Main: 14kA

### MEAS syst:

- RQX: 18kA
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### RQX PCs

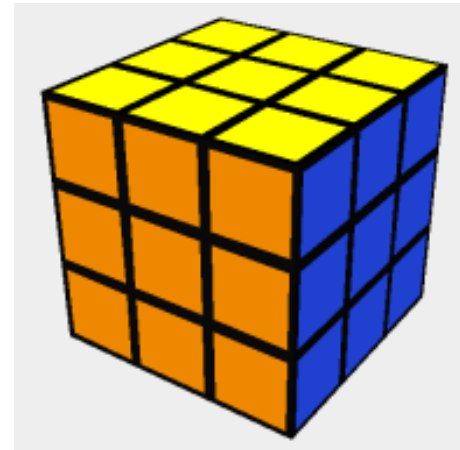
- Main: 18kA
- TRIM: 2 x 2kA & 35A

# Conclusion

- HL-LHC String is done with machine equipment
  - Huge constraints (time and resources) for the teams
    - Manufacturing and Installation of the HL-LHC (String) equipment have been done in parallel with the design and development phases
    - Equipment should be updated before the installation of the last IP side
    - Each issues identified during HL-LHC String operation need to modify the equipment in the UR if it is possible

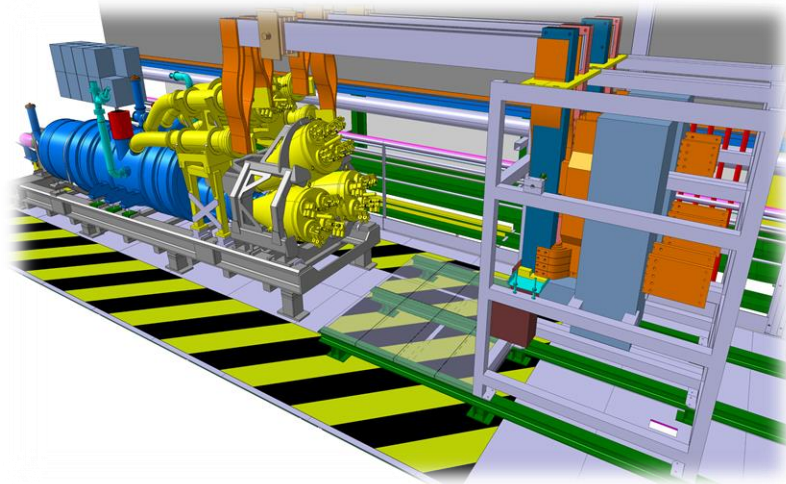
# Conclusion

- Installation and commissioning of the new facility are as the Rubik's Cube
  - They seem easy but they are complex
  - Training is crucial
    - HL-LHC String can be considered as a prototype where we discover all the issues that we didn't imagine
    - 1<sup>st</sup> IP can be considered as a pre-series with new issues due to the difference between HL-LHC String and the LHC
    - The 3 last IP sides will be normally more easy



# Conclusion

- The main challenge of the UR installation will be the installation of the WCBBs and DFHX/Ms
  - Several different interfaces in the same small area
    - WCBB and ACC
    - Cryogenic and Instrumentation
    - etc...



# Conclusion

- Main challenges and results of the powering test?
  - Validation of the WCBBs with the DFHX and final design of the WCPs
  - Validation of the RQX crowbar
  - Validation of the decoupled current loops for the RQX circuit
  - Evaluate the impact of the Flux Jumps / Voltage spikes on the control and the accuracy

# Conclusion

- String Facility is an iceberg







***Thank you***

