Risks due to UPS malfunctioning

Impact on the Superconducting Circuit Protection System

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Acknowledgments: K. Dahlerup-Petersen, R. Denz, A. Funken, J. Gomez, V. Montabonnet, D. Nisbet, M. Zerlauth and HCC team

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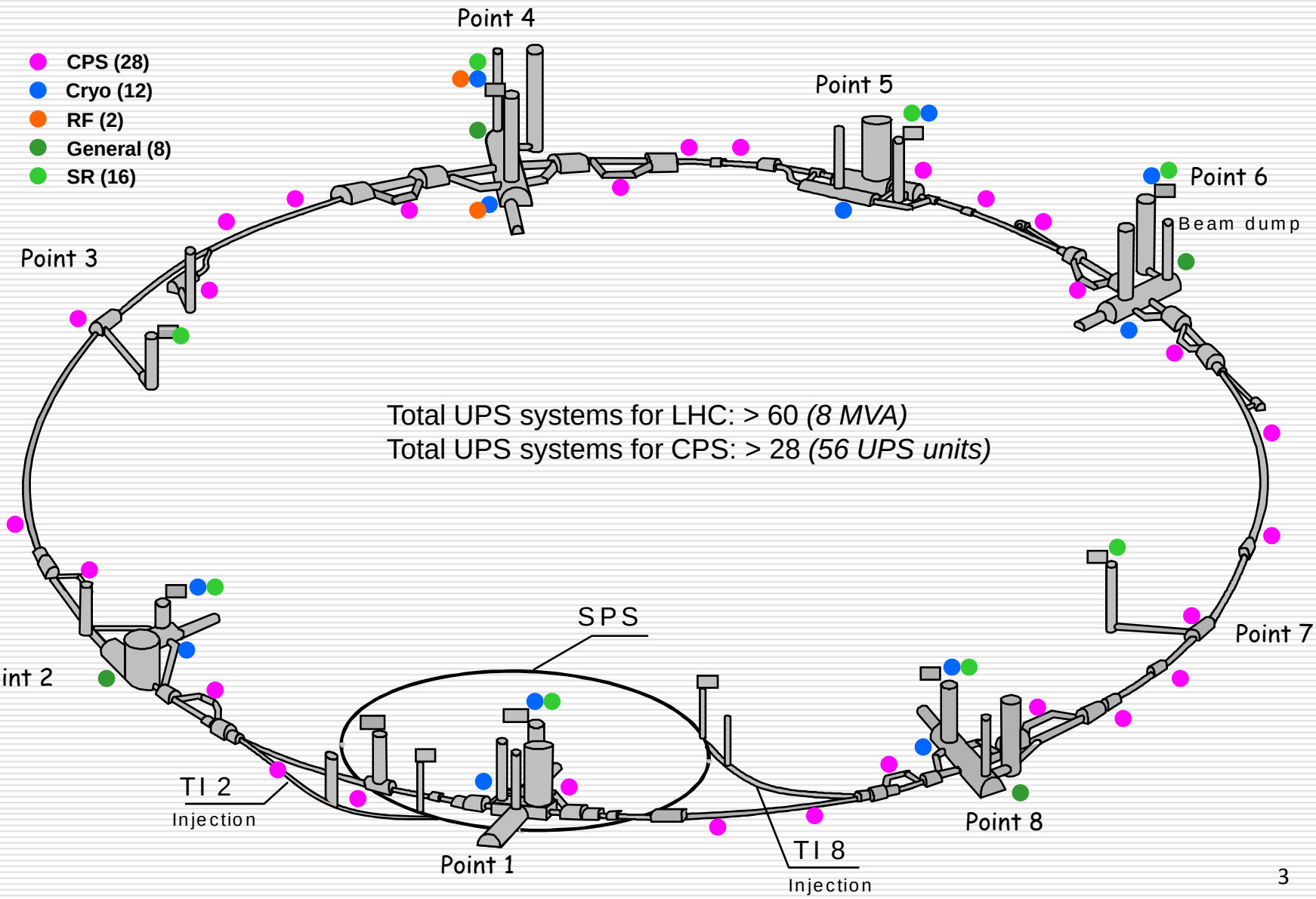
UPS overview



UPS overview

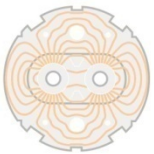
- Human Safety
  - Access*
  - Fire detection*, ODH*
  - Radiation Monitor*, etc…
- Beam Systems
  - Beam Instrumentation
  - BIC, FMCM
  - Beam Dump System
  - RF
  - Vacuum, etc…
- Technical Network, etc…

Standard Systems use in all CERN accelerators

- Cryogenic System
- SC Circuit Protection System
  - Power Converters
  - PIC
  - Energy Extraction System (EE)
  - CLQD, GQD and MPS

Specific Systems use in LHC

* = internal UPS



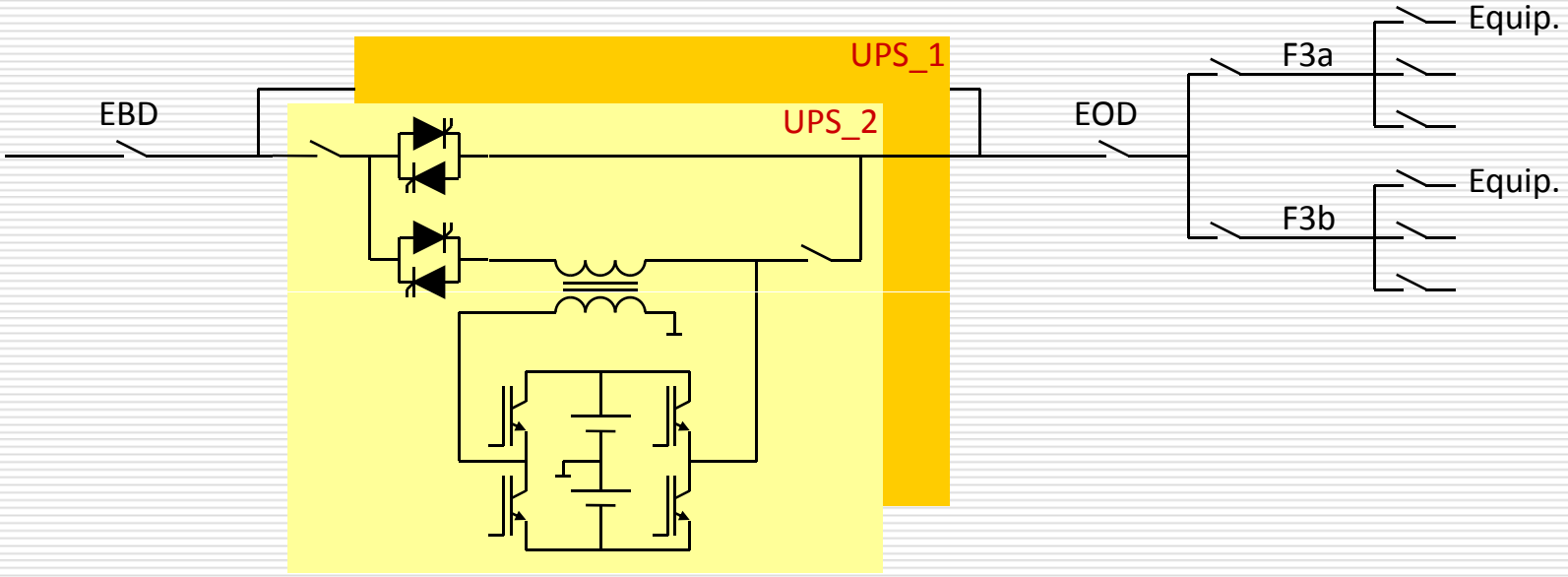
UPS for CPS

- Particularities of Superconducting Circuits
  - High current: up to 13 kA
  - High energy stored: up to 1.4 GJ
  - High current density: up to 1000A/mm2
  - High time constant: up to 400 sec (EE switches opened).
    - 250 s (4 min) for RB to decrease the current from 13 kA to 1 kA
    - 800 s (14 min) for RQX to decrease the current from 7 kA to 1 kA

    (UPS specification = 10 min. of autonomy)

- Functionalities require for CPS
  - Protect magnets
  - Protect Current Leads
  - Protect Bus-Bars
  - Slow Abort the PCs in case of cryogenic warning
  - Avoid to start without all systems fully operational
  - Save data for analyzing

UPS redundancy



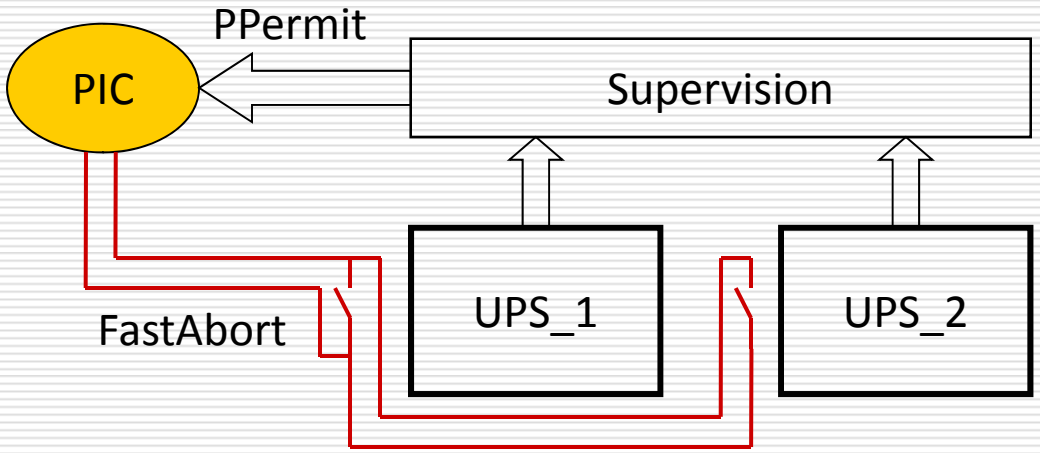
- Each UPS can deliver the requested power (10 min of autonomy)
- 2 orders of redundancy
  - If one UPS fails the load is supplied by the second UPS
  - If the second UPS fails the load is supplied by the electrical network
- Weak point = breakers (the number of breakers must be optimized and selectivity must be guaranteed)
- Characteristics of UPS Network = Characteristics of General Network *(see next slide)*

- Main Parameters of the LHC 400/230V Electrical Network
  - Nominal values
    - Nominal voltage: 400/230 V ± 10 %
    - Nominal frequency: 50 Hz ± 0.5 Hz
    - THD: 5 %
    - Voltage unbalance: 2 %
  - Transients
    - Peak mains surges: 1200 V for 0.2 ms
    - Mains over voltage: 50 % of Un for 10 ms
    - Voltage drops: 50 % of Un for 100 ms

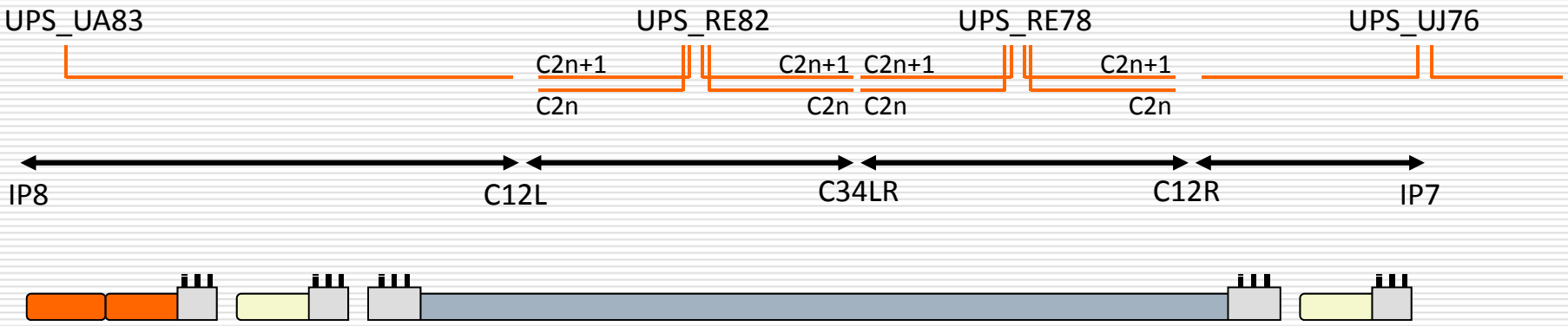
Transients = Normal Operation

EDMS # 113154: Main Parameters Of The LHC 400/230V Distribution System (G. Fernqvist / J. Pedersen)

- UPS connected to the PIC
  - Software link for PPermit
    - "Not possible" to start in case of one UPS warning /fault
  - Hardware link for Energy Extraction (Fast_Abort)
    - Fast abort in case of two UPS warnings/faults (eg. batteries mode)



UPS for CPS



- 4 redundant UPS systems to protect 1 sector
  - 1 UPS in UA => IT, IPQ and IPD
  - 1 UPS in RE => C12L to C34L (77 MB and 24 MQ)
  - 1 UPS in RE => C34R to C12R (77 MB and 24 MQ)
  - 1 UPS in UJ => IT, IPQ and IPD

As for any other systems, the UPS systems can malfunction

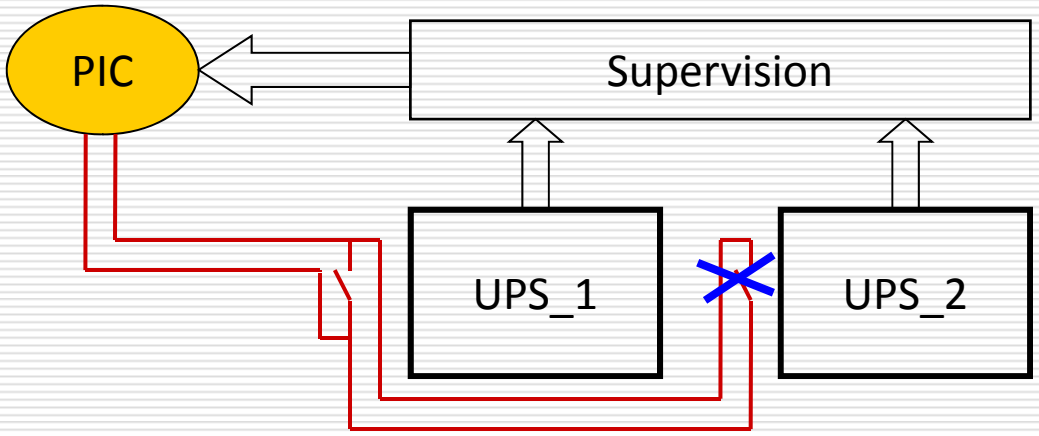
- Diagnostic malfunction
  - Supervision malfunction
  - Interlock malfunction
  - Etc…

} Interlock malfunction

- Power malfunction
  - Degradation of the output voltage
  - 1 phase loss
  - 3 phases loss
  - Partial network loss
  - Etc…

} Total Loss of the output power

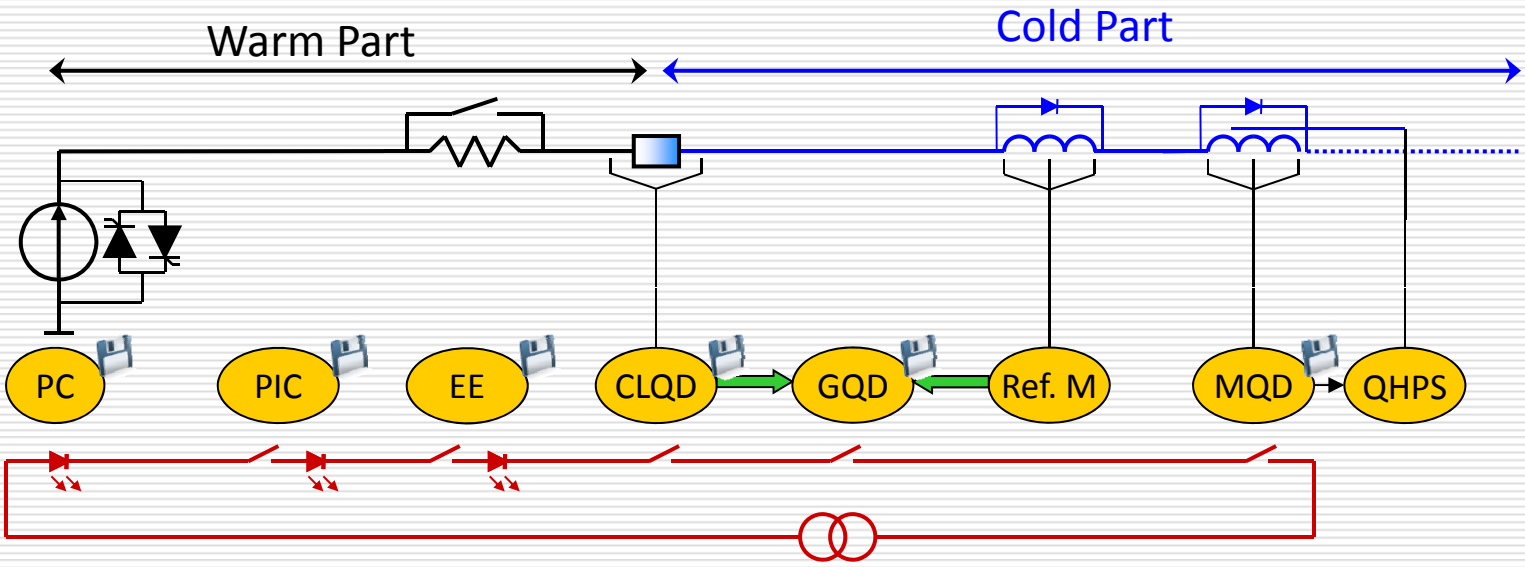
Interlock malfunction



- If the interlock system of one UPS does not work
  - The PIC does not stop the powering if the second UPS stops working (UPS system in by-pass).

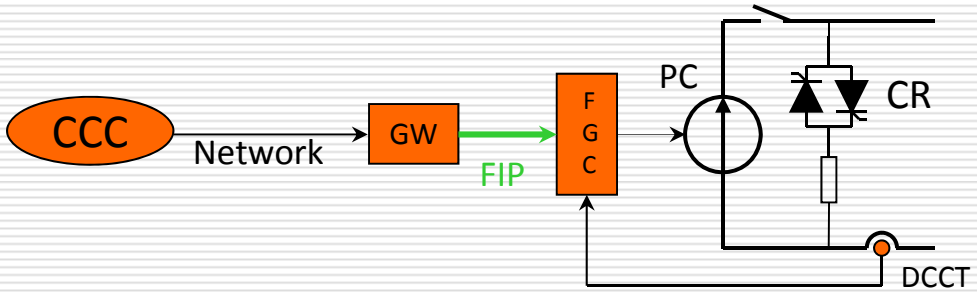
No action before loss of the UPS system output power

Power malfunction



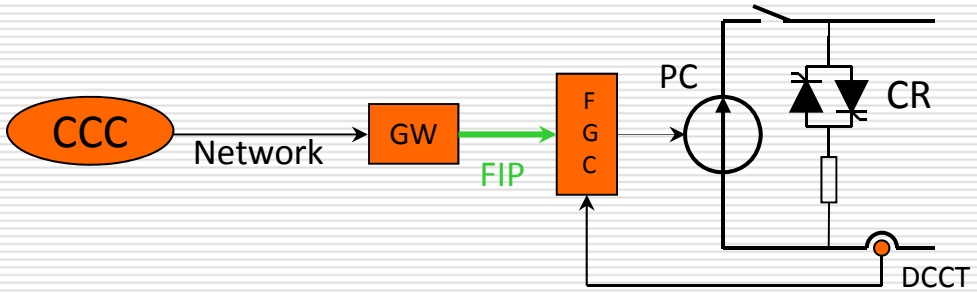
- SC Circuit Protection System
  - Three protection systems
    - The Magnet Protection System (MQD + QHPS)
    - The CL Protection System
    - The Global Protection System
  - The Energy Extraction System
  - The PIC
  - The PC

Impact on PC (1)



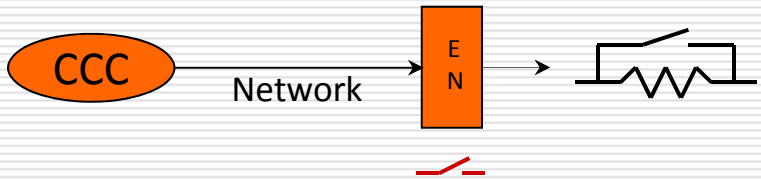
- UPS for power converter
  - Only DCCTs and FGC for high current power converters are on UPS (MB, MQ, IPQ, IPD and IT). The power part is not supplied by UPS
  - Gateway and computing network are on UPS to assure the control of the PCs

Impact on PC (2)



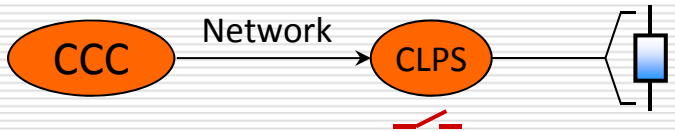
- Loss of FGC and DCCT
  - The power converter switches off
  - The CR fires (not need power)
  - PC PM data is lost
  - The quench loop does not open (except if water failure)
- Loss of GW
  - After 10mn, all power converters connected on this GW switch off
  - Their CR fire
  - PC PM data is stored inside FGCs
- Loss of Computing Network
  - The control of the PC is lost (Only PC with PIC can be switched off).
  - The 60A PCs can not be switched off

Impact on EE system



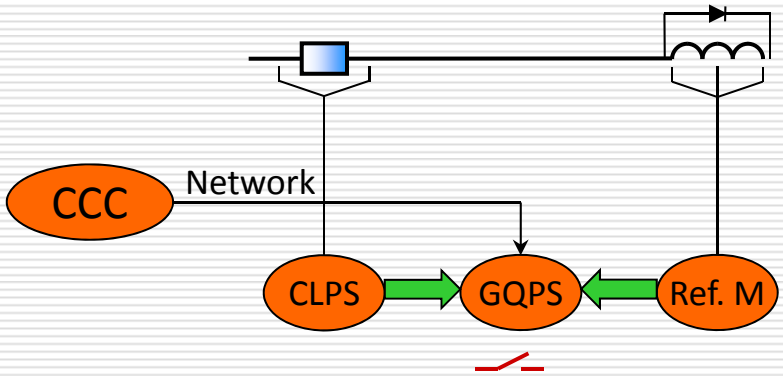
- Loss of EE system Electronic
  - The Energy Extraction Switch opens
  - The Quench Loop opens
    - The power converter switches off and its CR fires
  - The EE system PM data is lost
- Loss of communication with the CCC
  - Nothing happens
  - The EE system remains fully operational

Impact on CLPS system



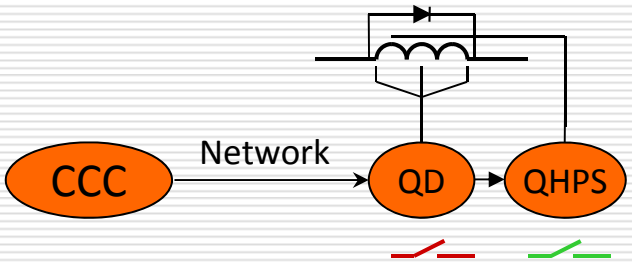
- Loss of CLPS Electronic
  - The Quench loop opens
    - The EE switch opens
    - The power converter switches off and its CR fires
  - The CLPS PM data is lost
- Loss of the communication with the CCC
  - Nothing happens
  - The CLPS remains fully operational

Impact on GQPS system



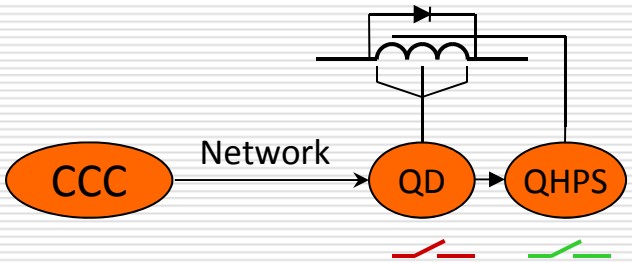
- Loss of GQPS Electronic
  - The Quench loop opens
    - The EE switch opens
    - The power converter switches off and its CR fires
  - The GQPS PM data is lost
- Loss of the communication with the CCC
  - Nothing happens
  - The GQPS remains fully operational

Impact on MQPS system (1)



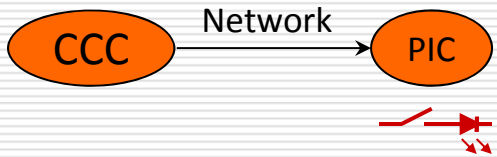
- MQPS
  - Implemented only for the high current circuits (MB, MQ, IPQ, IPD and IT)
  - For the IPQ, IPD and IT circuits, the MQPS protects also the busbars
  - Single phase powering
- QHPS
  - The QHPS are not in the Quench Loop and can be only fired by the QD
  - 4 QHPS per magnets and 1 is needed to protect correctly the magnet
  - The QHPS are connected to the Power Permit

Impact on MQPS system (2)



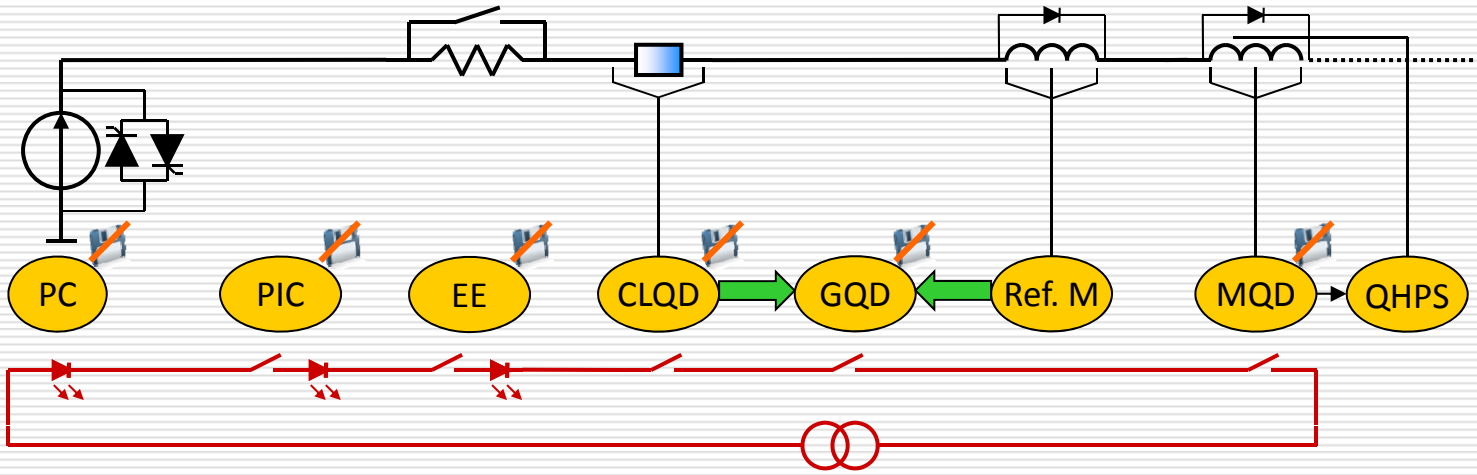
- Loss of QD/QHPS (same single phase feeder)
  - The Quench loop opens
    - The EE switch opens
    - The power converter switches off and its CR fires
  - The MQPS PM data is lost
  - **To avoid a "sector quench" in case of UPS loss the QHPS are not fired.** The consequence is **the magnet is not protected during the current decay.**
- Loss of the communication with the CCC
  - Nothing happens
  - The MQPS system remains fully operational

Impact on PIC



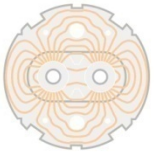
- PIC Level
  - All HW interlock loops of this PIC open
    - All EE switches of concerned circuits open
    - All power converters of concerned circuits switch off and their CR fire
  - The PIC PM data after the event is lost
- Loss of the communication with the CCC
  - Slow Abort after 30 seconds
    - The currents of concerned circuits decays to 0 A
  - The PIC remains fully operational

Resume



	PC	PIC	EE	CLQD	GQD	MPS*	
13kA	ok	ok	ok	ok	ok	**nok**	Pb with MPS
IT	ok	ok	-	ok	-	**nok**	
IPQ/IPD	ok	ok	-	ok	-	**nok**	
600A-EE	ok	ok	ok	ok	ok	-	No Issue
600A-NoEE	ok	ok	-	ok	ok	-	
120A	ok	ok	-	ok	-	-	
60A	½ ok	-	-	ok	-	-	Issue with PC control

* **To avoid a "sector quench" in case of UPS loss the QHPS are not fired.**
The consequence is **the magnet is not protected during the current decay.**



Actual Situation

- Tested
  - UPS IST
  - Devices IST
- No tested
  - Devices on UPS network (verification on going during AUG tests)
  - UPS with theirs loads

Conclusions

- UPS has not been tested with its load. Tests of UPS systems (with load) are recommended.
- New devices will be installed on UPS network (nQPS system). "AUG tests" in operational conditions are recommended.
- UPS is important for the LHC safety. Annual tests after each shut down are recommended.
- High Current magnets are not protected in case of UPS powering failure. This issue must be clarified by MPWG (to fire or not to fire?).
- QHPS are not interlocked. This issue must be clarified by MPWG (software interlock could be implemented?).
- The PM files are lost in case of UPS powering failure.
- 10 min of UPS autonomy are not enough to protect correctly the RQX circuits (1.8 kA after 10 min). 20 min of autonomy are recommended.
- What is the situation for the other systems?