Risks due to UPS malfunctioning

*Impact on the Superconducting Circuit Protection System*

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Total UPS systems for LHC: > 60 (8 MVA)
Total UPS systems for CPS: > 28 (56 UPS units)
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...**

- **Cryogenic System**

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

* = internal UPS

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Standard Systems use in all CERN accelerators

Specific Systems use in LHC
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
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
UPS for CPS

- 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 (e.g. 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...

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

- Interlock malfunction

- Total Loss of the output power
Impact of UPS malfunction

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
Impact of UPS malfunction

Power malfunction

- Warm Part
- Cold Part

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

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- 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
- **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

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- **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
* 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?