RISKS DUE TO UPS MALFUNCTIONING

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Abstract

To ensure the safety of the LHC in case of partial or general electrical power failure, all components of the superconducting circuit protection system are powered by an Uninterruptable Power Supply (UPS). However, just as for the other systems of the machine, the UPS itself is not immune to malfunction. This paper will evaluate the impact of the UPS malfunction on the operation of the superconducting circuit protection system and the consequences for the protection of the machine.

INTRODUCTION

In case of partial or general electrical power failure, all systems assuring the protection of the people and the machine must continue to operate without interruption. Considering only the LHC ring (and excluding the experiments), there are more than 60 UPS networks with a total apparent power of more than 8 MVA. Among the systems powered by UPS, there are many systems that are found elsewhere in the accelerator complex at CERN, such as the safety systems (eg. access system, fire detection, etc ...), the systems related to the beam (eg BIC, Beam Dump System, etc ...), the technical networks, etc. The LHC BIC and Beam Dump System have already been extensively audited for reliability and thus this paper will not discuss these systems. However there are also systems highly specific to the LHC such as the cryogenic instrumentation and the superconducting circuits protection system. To reasonably limit the scope of the study, this paper presents the impacts of the UPS malfunction on the LHC superconducting circuit protection system.

SUPERCONDUCTING CIRCUIT PROTECTION SYSTEM

Unlike warm circuits, superconducting circuits require an active protection system because of the large energies stored in the magnets (> 1.4 GJ for the RB circuits), the high current densities in the superconducting cables (> 1 kA/mm2 for the RQ circuits) and the very large time constants (eg. for the Inner Triplet circuits, more than 14 min are needed to for the current to naturally decay from 7 kA to 1 kA).

The superconducting circuit protection system must not only ensure the protection of superconducting magnets. It must also ensure the protection of the current leads, the protection of the busbars between superconducting magnets and the busbars between magnets and current leads. It must stop the powering of the superconducting circuits in case of a cryogenic alarm and avoid the powering of the superconducting circuits if all the systems are not fully operational. Finally, it must record the post mortem data in case of any event trigger to allow the LHC to be restarted following a thorough analysis of the event.

The superconducting circuit protection system is composed essentially of the power converter (PC), the power interlock controller (PIC), the energy extraction system (EE), the superconducting magnet protection system (MPS), the current lead quench detector (CLQD) and the global quench detector (GQD).

SPECIFICITES OF UPS FOR CPS

The different superconducting circuit protection systems are supplied by 32 different UPS. To reduce the risk of malfunction of the UPS and to mitigate the impact on the operation of the superconducting circuit protection, several measures have been taken.

UPS redundancy

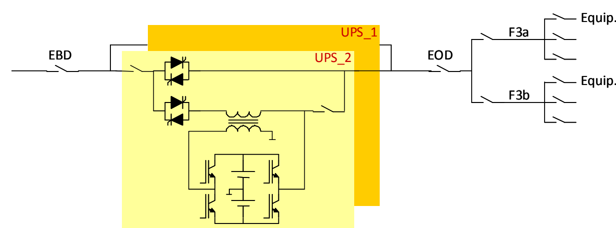

Figure 1: UPS system.

All UPS systems which supply the superconducting circuit protection systems are redundant. In case of failure of one UPS, the second UPS is able to take the entire load. Moreover, if the second UPS fails the components are supplied by the general electrical network. Three faults are necessary before the components of the superconducting circuit protection system are no longer powered.

However, this redundancy is limited to the UPS themselves and does not concern the electrical distribution network after the UPS system. In case of electrical protection triggering, the power for all or part of the UPS network can be lost.

Moreover, to take full advantage of the redundant UPS systems, all components must be able to be supplied by the normal electrical network. Thus they must be compatible with the nominal CERN network electrical characteristics (shown below):

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

Hence, transients should not be considered as a malfunction of the UPS system, but they must be considered as a normal transient condition of the UPS system.

Interface between UPS and PIC

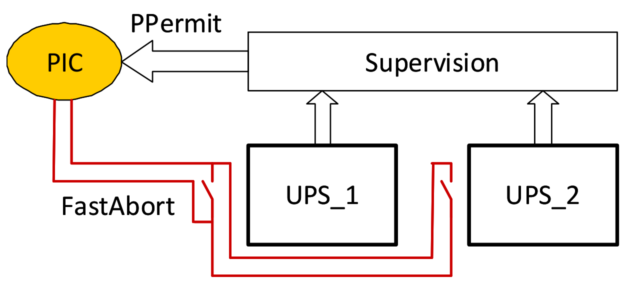

Figure 2: Interface between UPS and PIC.

All UPS systems supplying the superconducting circuit protection systems are connected to the PIC. A software link allows the PIC to check the alarms and faults of the UPS system before allowing the powering of the superconducting circuit. It is not possible to power a superconducting circuit if the UPS system is not fully operational. A hardware link ensures a stop of the powering of all superconducting circuits and a discharge of the energy stored in magnets if both UPS are at fault or issue an alarm.

Powering of the superconducting circuit protection systems

To mitigate the impact of a UPS system malfunction on the protection of the superconducting circuits of one sector, the different components of the superconducting circuit protection systems are supplied by 5 different redundant UPS systems (on average). For example, in the sector 78:

- From the cell 1L8 to the cell 8L8, the MPS are powered by the UPS of the UA83
- From the cell 9L8 to the cell 11L8, the MPS are powered by the UPS of the US85
- From the cell 12L8 to the cell 34L8, the MPS are powered by the UPS of the RE82 through 4 different branches.
- From the cell 34R7 to the cell 12R7, the MPS are powered by the UPS of the RE78 through 4 different branches.
- From the cell 11R7 to the cell 8R7, the MPS are powered by the UPS of the UJ76.

In case of a UPS system malfunction, only a part of the sector 78 magnets risk to be unprotected.

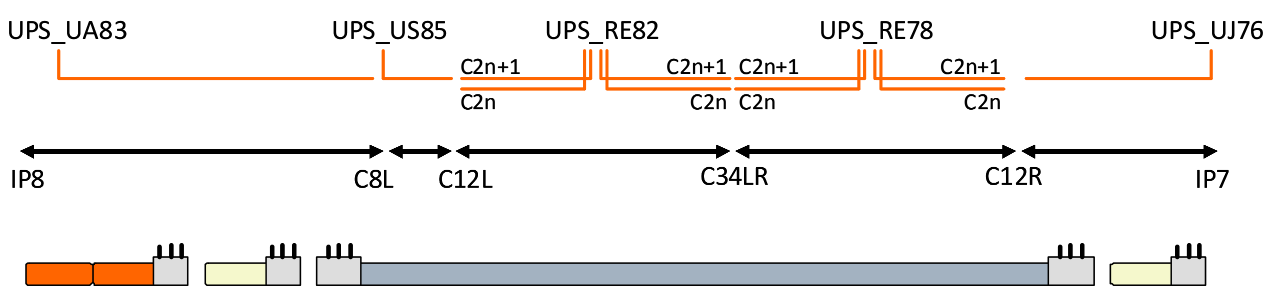

Figure 3: Powering of the Magnet Protection System in sector 78.

UPS MALFUNCTION

UPS system malfunction can be of two different types: a diagnostic malfunction or a power malfunction.

Diagnostic malfunction

A diagnostic malfunction of the UPS system can concern its supervision, its interlocks, etc… The worst case which can be encountered is that of a malfunction of its interlocks. In this case, the PIC can not stop the powering of the superconducting circuits before the total loss of the output power of the UPS system.

Power malfunction

A power malfunction of the UPS system can concern one phase, the three phases, part of the UPS network, etc... The worst case that may be encountered is the loss of power directly at the output of the UPS system. In this case, all components connected to the UPS system are not supplied.

IMPACT OF UPS MALFUNCTION

Only the worst case will be presented in this part: the total loss of power at the output of the UPS system. In this case all the equipments of the superconducting circuit protection system are not supplied.

Superconducting Circuit Protection System

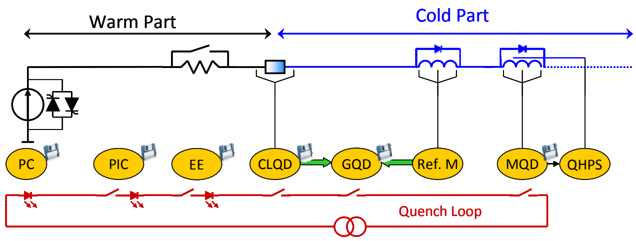

Figure 4: Superconducting Circuit Protection System.

The superconducting circuit protection system is composed of:

- Three independent protection systems:
  - The Magnet Protection System (MPS) composed of the Quench Detector (QD) and the Quench Heater Power Supplies (QHPS). This system protects individually each high current (> 1 kA) magnet.
  - The Current Lead Quench Detector (CLQD). This system protects each current lead of the superconducting circuits except for the 60A and 120A circuits. For these circuits the current leads are protected by the power converters.
  - The Global Quench Detector (GQD). This system protects the superconducting busbars and it is implemented on all 600A, RB, RQD and RQF circuits.
- The Energy Extraction System (EE).
- The Power Interlock Controller (PIC).
- The Power Converter (PC).

The different components of the superconducting circuit protection system are connected together through the Quench Loop.

Finally, the Post Mortem (PM) files are generated and stored locally inside the components.

Impact on the power converter

The power converters are composed of a voltage source (VS), two current sensors (DCCT) and a remote control system (FGC). Only the DCCT and FGC components of the high current circuits (> 1 kA) are supplied by UPS.

The power converters are controlled from the CCC through the technical network and a Gateway (the bridge between the technical network and the WorldFIP fieldbus).

In case of a loss of either the DCCT or FGC power, the power converter stops and the freewheel system fires (a diode or crowbar, that assures the continuity of current of the magnets). The system is an autonomous system that does not require external power to function. The superconducting circuit is fully protected; however the Post Mortem (PM) data of the power converter is lost.

In case of a loss of the Gateway, all the power converters connected to this Gateway stop after 10 min. The superconducting circuits are fully protected and all PM data is saved inside the FGC, ready to be retrieved manually or when the Gateway is restored.

In case of loss of the technical network it is not possible to control the power converters from the CCC. However, the superconducting circuits remain fully protected and it is possible to stop the converters via the PIC (with the exception of the 60A circuits).

Impact on the Energie Extraction System

Only the control electronics of the energy extraction system is supplied by UPS.

In case of loss of control of the electronics of the energy extraction system, the switches will open and the power converter will switch off. The energy stored in the magnets will be discharged. The superconducting circuit is fully protected. Only the PM data of the energy extraction system is lost.

Impact on the CLQD

The CLQD measures the voltage across the cold part of the current leads and opens the quench loop if this voltage is greater than 3 mV. The CLQD must be powered to maintain the quench loop closed. The loss of the supply of the CLQD will be interpreted as a quench of the current leads, thus the circuit remains fully protected. Only PM data of the CLQD is lost.

Impact on the GQD

The GQD measures the resistive voltage of the superconducting circuit and opens the quench loop if this voltage exceeds a defined threshold. The GQD must be supplied to maintain the quench loop closed. The loss of the powering of the GQD will be interpreted as a quench of the superconducting busbars, thus the circuit remains fully protected. Only PM data of the GQD is lost.

Impact on the MPS

The MPS is composed of the Quench Detector (QD) and the Quench Heater Power Supplies (QHPS). Only the QD can fire the QHPS.

In case of loss of the supply of the QD and the QHPS (all components are powered by the same single-phase electric feeder) the quench loop will open but the QHPS will not be activated. The power converter will stop, the switches of the energy extraction system will open, but the magnet will not be properly protected during the decay of the current. This decay could take several minutes. Moreover, the PM data of the MPS will be lost.

The decision not to fire the QHPS in case of a loss of UPS power was taken to avoid quenching a half arc in case of UPS.

Impact on the PIC

The loss of the power of a PIC will generate the stop of all power converters connected to the PIC and the opening of all energy extraction systems of associated circuits. The superconducting circuits remain fully protected. Only PM data of the PIC is lost.

Resume

Table 1: Impact of UPS malfunction

Circuit type	PC	PIC	EE	CLQD	GQD	MPS
13kA	ok	ok	ok	ok	ok	**nok**
IT	ok	ok	-	ok	-	**nok**
IPQ IPD	ok	ok	ok	ok	ok	**nok**
600A EE	ok	ok	ok	ok	ok	-
600A noEE	ok	ok	ok	ok	ok	-
120A	ok	ok	ok	ok	ok	-
60A	**½ ok**	-	-	ok	-	-

The main risks of a UPS system malfunction are:

- The loss of the PM data.
- The non protection of the high current magnets during the decay of the current.

ACTUAL SITUATION OF UPS SYSTEMS

All UPS systems installed in the LHC that supply the superconducting circuit protection systems have been tested individually, but without their loads.

The verification that all critical components of the superconducting circuit protection systems are correctly powered by the UPS network has not been done (this verification is on going).

CONCLUSION

This paper is based on the initial configuration of the superconducting circuit protection system. It does not take into account the improvements of the system, particularly the new quench protection system (nQPS), which will detect the symmetrical quench and which will better detect the resistive voltage in the superconducting busbars.

The UPS powering of the superconducting circuit protection systems have not been tested with their loads. Future commissioning tests of the UPS in operational conditions are strongly recommended.

New components will be installed on the UPS networks during the shut down 2008-2009. The requalification of the UPS system and their networks is strongly recommended before the repowering of the superconducting circuits.

The UPS are important for the protection of superconducting circuits. Annual tests after each shut down are recommended.

The high current magnets are not correctly protected in case of UPS failure. This issue must be analyzed by the next MPWG.

The QHPS are not interlocked. This issue must be analyzed by the next MPWG.

PM data is lost in case of loss of the UPS failure.

Actually, 10 min of autonomy is requested for the UPS systems which power the superconducting circuit protection systems. These 10 min. are not enough to protect the Inner Triplet circuits during their full current decays. 20 min. of autonomy are recommended for these circuits.

REFERENCES

[1] J. Gomez and J. Petersen, “Underground Uninterrupted Power Supply (UPS) for the LHC”, EDMS Document No 356521.

[2] B. Puccio, R. Schmidt and M. Zerlauth, “Hardware Interlocks Between the Powering Interlock System, UPS and AUG”, EDMS Document No 490992.

[3] J. Gomez, “UPS-PIC Interface”, EDMS Document No 771798.

[4] G. Fernqvist and J. Pedersen, “Main Parameters of the LHC 400/230 V Distribition System”, EDMS Document No 113154.

[5] D. Bozzini, R. Denz, K. Dahlerup-Ptersen, H. Thiesen, A. Vergara, M. Zerlauth, “Failure Scenarios for the Electrical Circuits”, EDMS Documents No 722413.