UNIFYING EFFORTS IN ELECTRICAL SAFETY FOR AN ACCELERATOR COMPLEX

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Abstract

Large research facilities with continuously evolving electrical installations and many stakeholders often face unique challenges in implementing electrical safety. The Electrical Safety Project at CERN aims to standardize methods and processes to improve electrical risk management during maintenance and operation of the CERN accelerator complex. The project focuses on several axes for improvement. Two of these are to clearly define the limits of responsibility along the powering supply chain among different teams that provide equipment for accelerators, and to build the electrical dependencies between equipment from the source to the load. The paper will report on the progress made by the Electrical Safety Project in these fields and on the proposed methodology towards their long-term implementation.

INTRODUCTION

Effective electrical risk management relies on technical measures and on clearly defined organizational responsibilities. Ambiguity in equipment responsibility increases the risk of missed safety actions and unauthorized interventions. Both unclear responsibilities and misidentification due to inconsistent on-site labelling can lead to personnel performing interventions that they are not authorised to perform.

The need for improvement is highlighted by previously reported electrical incidents. In 2025, five incidents involving operational equipment related to accelerator systems were recorded: two were caused by unauthorized interventions (dismantling equipment belonging to another unit, intervening in electrical racks without authorization), and one resulted from incorrect equipment identification (disconnection of cables in the wrong rack). Implementing mitigation actions at CERN is challenging due to the scale of the accelerator complex, legacy infrastructure and operational coactivity: The CERN accelerator complex comprises a geographically distributed and highly interconnected network of accelerator rings, transfer lines, and experimental areas, resulting in a very large number of electrical equipment with complex dependency chains. These installations were designed and commissioned over several decades, meaning documentation standards vary significantly, and inherent information decay leads to gaps especially on older installations. CERN operates in a context of strong coactivity between different internal organisational units and external stakeholders – organisational complexity being a known risk factor for accidents [1]. The Electrical Distribution Network work package of the Electrical Safety Project aims to put in place the methodology for defining clear responsibilities along the different powering scenarios, ensuring on-site identification, and to develop and implement a system to keep up to date the electrical dependencies between equipment within CERN's electrical distribution network.

This paper presents the methodology, the outcome of pilot tests carried out in field and the path towards implementation for these goals.

METHODOLOGY

Context within CERN

The scope covers equipment of the Accelerator Technology Sector (ATS) with potential electrical risk to people, excluding the power distribution grid. Extra low voltage (<50 V RMS AC or 120 V DC) connections are thus only considered when additional safety risks are present.

For achieving its goals, the work package closely collaborates with stakeholders across the organisation: Notably, Health and Safety experts provide input in defining roles and ensuring compatibility with internal and external safety practices. Specialists in the CERN digital infrastructure facilitate data storage in the electronic asset management (EAM) database and implement user interfaces to visualize and let users interact with the data. These relations are shown in the Fig. 1 below.

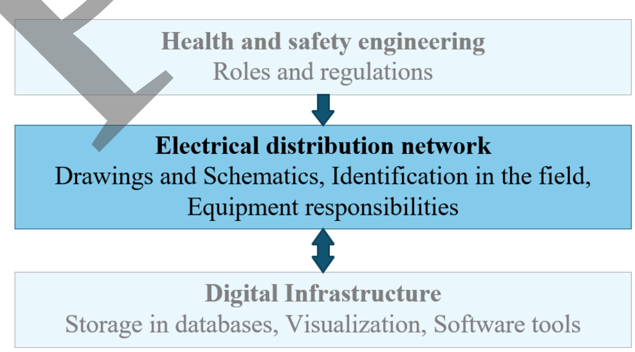

Figure 1: Context within the CERN.

Terminology

Two key roles were identified as critical for the clear identification of responsibility along the powering chain.

The Equipment Owner (EOw) is defined as the organisational unit responsible for the overall safety of their electrical equipment.

The Equipment Operator (EOp) is defined as the person (typically from within the Equipment Owner unit) trained on the equipment and its operation in the machine, who serves as a contact-person for facility coordinators, electrical safety teams, works and services supervisors (WSS) and other stakeholders, for matters related to electrical safety of their equipment. They maintain the relevant equipment documentation in the designated asset management and documentation databases. They are supported by a Deputy Equipment Operator (DEOp).

In addition to this, delegation and electrical dependencies of equipment contain critical information about risks and responsibilities along the powering chain.

Delegations are the formal authorisations given by the Equipment Owner that specific tasks (e.g. operation, maintenance) on their equipment can be performed by another unit. They require bilateral validation.

Electrical Dependencies document powering relations (upstream and downstream) and other equipment interfaces carrying electrical risk (such as induced voltage relations).

This information is delivered through the three deliverables of the work package: agreement documents, supporting data and tools, and an improved onsite identification.

Deliverable 1: Responsibilities along the Electrical Distribution Network

To document the ownership and delegated activities, eight Operation and Maintenance Agreement Documents are drafted per equipment type: magnets, beam transfer installations, radio frequency equipment, sources targets and interceptors, cooling and ventilation equipment, cryogenics, and vacuum pumps. Often, the responsibilities were previously only passed on by verbal agreements. Collecting them in a single document provide an opportunity to establish clear responsibilities. It also provides, for the first time, an organisation-wide documentation of all such responsibilities.

For each of these eight documents, typical powering chain scenarios were identified. Then, for each powering chain the following were created: a description of the circuit, a schematic overview showing the equipment and its relations, and a list of Equipment Owners. For each equipment, delegated activities were listed along with the conditions under which they may be undertaken.

These documents are maintained by the Equipment Owners, but as these are general and relatively stable rules, changes are not expected to occur often.

	Single owner installations	**Multi-owner installations**
Standard cable (off-the-shelf)	EOw in contained installations, Electrical Engineering group in shared environments	Electrical Engineering group
Special cable (manufactured to specification)	EOw	EOw that specified the cable

Figure 2: Cable Ownership decision matrix.

Equipment ownership for cables, as a key component of the complex distribution network, was analysed in detail. An agreement has been reached where ownership depends on installation environment and cable type. For this, the electrical engineering group takes ownership of off-the-shelf cables in shared environments (like cable trays or underground cabling between buildings), while the user groups take ownership of cables either within a contained single-user installation, or manufactured as per their specification. The decision matrix is shown in Fig. 2.

Deliverable 2: Drawings and Schematics

Data structures for recording ownership, operation and maintenance delegations on equipment, and electrical dependencies between equipment, have been developed in the existing asset management database.

For each equipment, this information is listed with a link to the applicable Operation and Maintenance Agreement document. For one-off cases where no general agreement exists, this acts as a primary source of information. The data is maintained by the Equipment Operator of the equipment.

This information can be uploaded through a dedicated upload utility tool and accessed either through the web interface of the underlying EAM database, or the purpose-built 'Electrical Safety Portal'. This portal summarizes ownership information, lists delegations and shows electrical relations in a dependency graph. For each such dependency, relevant information (such as cable type and voltage level) is displayed. A screenshot can be seen in Fig. 3.

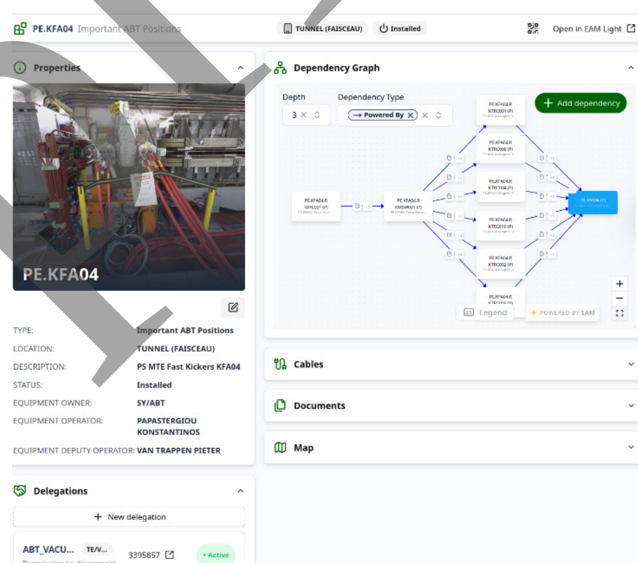

Figure 3: Screenshot of the prototype Electrical Safety Portal

Deliverable 3: Labelling in the Field

To allow easy on-site identification and provide easy access to the relevant safety information, an equipment label was developed, as shown in Fig. 4. The labels aim to unify labelling standards across CERN accelerator complex and to provide key electrical safety information at a glance. It contains the name of the equipment, and a QR-code based link to the corresponding page of the 'Electrical Safety Portal'. Delegations are indicated either explicitly (e.g. 'Operation delegated to … group') or via a reference to the Electrical Safety Portal for more complex cases.

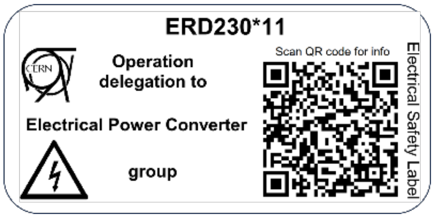

Figure 4: Example of an equipment label.

Illustration on a Real Use-Case

The powering chain of normal conducting magnets is shown in Fig. 5. The concepts explained in the previous sections will be shown on this example.

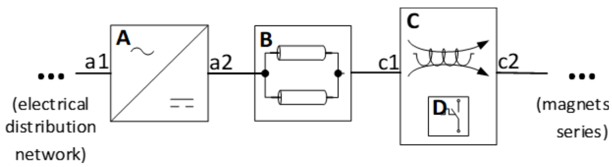

Figure 5: Example of a typical powering chain, extracted from the normal conducting magnets powering scenario (e.g. SPS dipole magnets).

A power converter (A) in a surface building is connected via a cable system (B) to a normal-conducting magnet (C) in the accelerator tunnel which contains a thermal switch (D). The Equipment Owner of the power converter and the magnet including thermal switch are the power converter group and magnet group, respectively. Following the agreement on cable ownership, the owner of the cable system B is the electrical engineering group, as it is a standard off-the-shelf cable in the shared environment of underground cable trays. The Equipment Operator varies based on location but is a member of the respective groups who is trained on the operation and documentation of these equipment elements. Both the power converter group and the magnet group receive a delegation on the cable B authorizing them to connect/disconnect the cable from their respective ends a2/c1, and the magnet group to repair cables terminations at interface c1.

IMPLEMENTATION

Preparatory Phase for Implementation

In the year-end technical stop from November 2024 to April 2025, a pilot was performed, to estimate the required effort for the methodology implementation, and identify potential challenges. Three uses cases on real scenarios were selected – one experimental area (East Area), one surface building installation (SH18) and one accelerator ring segment (antimatter decelerator).

Data quality and up-to-date documentation were found to be the key challenges. Common issues included information becoming outdated when responsibilities change, rack-mounted equipment not always being formally recorded, and the persistence of duplicate or placeholder entries created before complete data availability. These observations reflect the complexity of the environment, where multiple stakeholders contribute to the same datasets, often with differing practices and levels of familiarity with the tools. In addition, legacy records and historical inconsistencies continue to influence the current state of need for clearer, harmonized procedures for creating, updating, and maintaining records across groups. The Electrical Safety Project seeks to address this by providing structured and practical guidelines, while encouraging each group to designate a trained data officer responsible for ensuring consistency, coordination, and long-term data quality. This provides a crucial human-in-the-loop component, as the use of technical tools such as the portal can only ever be as useful as the data provided and administrative processes to maintain said data.

The pilot results validate the proposed methodology as a viable and effective approach for managing electrical safety, contingent on improvements in underlying data quality.

At the time of writing, eight operation and maintenance agreement documents have been drafted (split based on the groups involved), covering a total of twenty-two powering scenarios.

Strategy to Full Implementation

A series of communication days are being organized, to explain the terminology to the groups, provide a platform for feedback, and train personnel involved in data maintenance.

The Electrical Safety Project aims to have all eight of the Operation and Maintenance Agreement Documents approved among the stakeholders by the start of the CERN Long Shutdown 3 (LS3) in June 2026. In parallel, the database documentation will be gradually rolled out. This database rollout will continue throughout LS3, and will prioritize documenting new and consolidated installations as works are being performed on them.

CONCLUSION

Clear identification of equipment and well-defined responsibilities are essential for electrical safety in complex installations such as CERN. The pilot implementation highlighted significant gaps in data quality, while confirming the proposed methodology as a practical and effective approach to address these challenges. In the near term, efforts will focus on finalizing agreement documents, deploying supporting tools such as the Electrical Safety Portal, and improving data quality. In the longer term, the methodology will be progressively integrated into operational processes across the accelerator complex. This approach aims to ensure sustainable improvements in electrical safety through increased transparency, consistency, and accessibility of critical information.

REFERENCES

[1] K. L. Vibke Milch, "Interorganizational complexity and organizational accident risk: A literature review," *Saf. Sci.*, vol. 82, pp. 9-17, Feb. 2016. doi:10.1016/j.ssci.2015.08.010