

A CONSOLIDATION ROADMAP FOR THE CERN POWER CONVERTERS

D. Nisbet [†], J.P. Burnet, CERN, Geneva, Switzerland

Abstract

At CERN the Electrical Power Converter group is responsible for the design and exploitation of more than 5000 power systems throughout the accelerator complex, powering predominantly magnet circuits, in addition to RF and electro-static systems. Currently, a variety of systems are in operation, in some cases these are over 30 years old. Furthermore, the group must maintain operationally a total of six hardware platforms, each with dedicated software. In light of this, a consolidation roadmap has been determined to rejuvenate the power converter complex and to reduce the total number of control platforms. This paper presents a summary of the CERN power converter equipment to be consolidated, and the roadmap to achieve consolidation.

INTRODUCTION

The CERN accelerator complex has been growing ever since the first systems began operation in the 1950's. Inevitably, the time comes when systems must be renewed to maintain accelerator availability. Further, as control platforms evolve periodically, the legacy systems eventually require replacing as obsolescence makes repair and replacement difficult, and multiple software platforms require to be maintained.

CERN POWER CONVERTERS

Table 1 summarises the number of power systems under the responsibility of the Technology (TE) department Electrical Power Converter (EPC) group. Table 2 summarises the control platforms used by these power systems. One can see a total of six families are in operation [1], reflecting many years of evolution at CERN, as with

Table 1: Synthesis by Age of the CERN Power Converters

Complex	Total		% of Total by Age		
	Qty	% of total	<5yr	>5yr <25yr	>25yr
PS Accelerator	983	17%	51%	40%	9%
PS	1894	33%	28%	63%	8%
SPS Accelerator	595	10%	3%	66%	31%
SPS Experiment	357	6%	2%	7%	91%
LHC Accelerator	1723	30%	0%	99%	1%
LHC Experiment	5	0.1%	0%	60%	40%
Total	5557		19%	67%	14%

[†] email address: david.nisbet@cern.ch

each new accelerator a new platform was implemented. The number of systems to be considered for consolidation can be defined as all systems not already included in an existing accelerator upgrade project, of which systems more than 25 years of age need particular attention.

Table 2: The CERN Power Converter Control Platforms

Platform	Description	Qty	%
FGC	Latest generation of CERN designed hardware	2307	40%
G64	Obsolete PS complex controls	1187	21%
PLC	Commercial PLC control	610	11%
Mugef	Old SPS complex hardware	595	10%
North Area	Old SPS complex hardware	354	6%
Industry	Industry standard hardware	669	12%

Consolidation Strategy

The TE department EPC group has defined a consolidation strategy as follows:

1. Improve the overall availability of the power equipment, anticipating end of life particularly in the case of electronics. In particular for equipment that are >25 years old, rejuvenate the equipment either by targeted partial renovation, or by complete replacement, ensuring adequate availability and maintainability for the future.
2. Reduce the diversity of hardware control platforms, facilitating the overall maintenance effort. The preferred platforms are FGC [2] and PLC.
3. Harmonise the software for the maintained hardware platforms.

CONSOLIDATION PROJECT

The strategy leads to the identification of 37% of the entire installation where the controls require to be consolidated, and 14% of the entire installation where the system is >25 years old and requires a total overhaul.

Complimentary to the consolidation need, some systems have been identified as requiring a functional upgrade to meet the evolving physics demands. In particular, the LHC Injector Upgrade (LIU) project affects many systems in the PS and SPS accelerator complex. Thus, it is necessary to further filter the systems to identify those not already being upgraded by an existing project.

Categorisation of Systems

Following several iterations, all systems are categorised into workunits that group coherent activities together and a weighted risk score (R_s) determined for systems not already part of an upgrade project. The weighted risk score assists in the determination of the priority of the activity.

The EPC group has created over 30 workunits to meet the project and consolidation requirements until 2020. Two forms typify the content of a workunit, one is to only change the power converter controls for a supported platform, and the other more extensive option is the replacement or renovation of the entire converter. The choice depends on a number of factors such as age, complexity, ease of controls upgrade, etc. In some cases the workunit cannot be clearly defined without a further comprehensive study, and this is reflected in the early definition of the activity.

Planning and Resources

For each workunit, a preliminary planning and resource estimate is made considering several constraints, in particular the general CERN accelerator schedules [3]. Annual resource requirements to match the planning, both financial and manpower, are also quantified.

An important part of the planning is the identification of a technical solution. In some cases a workunit is identified, however the technical solution is not evident. As such, additional resources are required to find an appropriate solution, which can be an additional barrier to starting the activity.

In an ideal environment, all workunits where adequate priority (i.e. a high risk score) is assessed would be approved. However in many instances the activity is competing for resources with other equally high priority activities. This can lead to the situation where a final decision on resources is delayed until clear evidence that the activity is necessary is demonstrated. In some instances, this is when a failure has the assessed impact. For example a failure of an old system leading to a fortnight stop of the accelerator complex demonstrates clearly that consolidation work is justified.

CONSOLIDATION ROADMAP

The power converter consolidation roadmap is aligned with the CERN shutdown schedule. The roadmap is composed of two phases, aligned with the CERN shutdowns known as Long Shutdown 2 (LS2, 2019 – 2020) and Long Shutdown 3 (LS3, 2024 – 2026). This has a number of benefits: work can be prepared over a period of 2 – 3 years, and adequate time is available for implementing the changes.

The consolidation roadmap must take into consideration ongoing and future projects to upgrade the facilities. An important criteria actually considered is the upgrade of the injector complex for future LHC operation. Known as the LHC Injector Upgrade, this project affects all of the accelerators used to prepare the LHC beams. As such, consolidation need only be considered for systems that are not being upgraded. In several cases, consolidation is complementary to an upgrade, ensuring a homogeneous power converter system and control platform in the same accelerator.

Taking into consideration the number of systems requiring consolidation, and the areas where the LIU project is implementing upgrades, the priority is to consolidate where the work is complementary to existing activities,

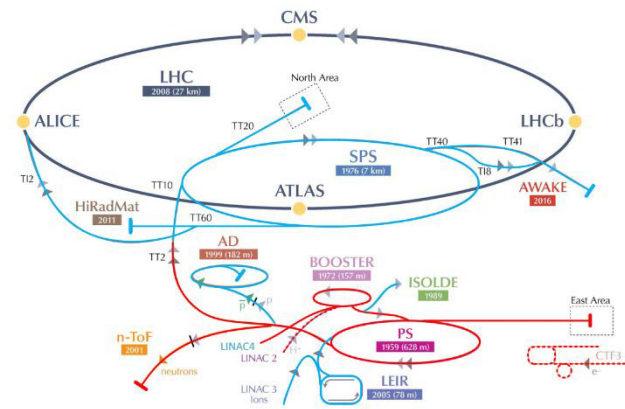


Figure 1: Consolidation of the CERN accelerator power converters (Phase I and II).

thus benefiting from ‘economy of scale’ (often making more of the same can lead to reduced unit cost and little additional effort). Also, the risk scoring naturally gives a priority to the accelerator components as unavailability of these systems affects all upstream users. This leads to a first phase of activity where consolidation is focused on the proton beam acceleration to the LHC. The desire would be to align this with LIU project and complete the consolidation for LS2, however insufficient manpower is available to implement all the change on this timescale. As such the choice has been made to implement a partial consolidation in the SPS, with the complete work scheduled for LS3.

The remainder of the consolidation is then implemented during a second phase. Thus the completion of the SPS consolidation, and the implementation of the consolidation of the tertiary experimental areas, is scheduled for LS3.

Phases I and II can be visualised on Figure 1. The map drawn in red represents Phase I, and the map drawn in light blue represents Phase II. It is to be noted that although the SPS will run to LS3 with a partial consolidation, the controls infrastructure has already undergone a first harmonisation with a common software layer (known as FGCD) interfacing to the controls environment. As such future changes with upgrades to the FGC hardware will be much more straightforward to implement.

Table 3: The Work Required to Achieve the Consolidation

Complex	Upgrade Project	Consolidation end-LS2 (Phase 1)	Consolidation end-LS3 (Phase 2)
PS Accelerator	514	83	94
PS Experiment	140	74	240
SPS Accelerator	0	322	271
SPS Experiment	0	12	345
LHC Accelerator	172	0	0
Total	826	491	950

Implementation of the consolidation roadmap over such an extensive area induces a non-negligible amount of work. A summary of the changes required is given in Table 3. A total of 826 systems are affected by several upgrade projects, such as the LIU project and HL-LHC project. To implement the Phase I changes, a further 491 systems require to be added or modified. The remaining 950 systems are implemented during Phase II. More than 90% of the systems being consolidated during LS2 are also over 25years old.

One can see that the LHC is not yet affected by a need for consolidation, being still a relatively recent machine. Never-the-less a few of the older LHC power systems are being considered for renovation in the coming years, typically systems that were originally used in the LEP era. Consideration for consolidation of the LHC power converters will be required when LS4 approaches (towards 2030).

The implementation of the two phase roadmap will meet the CERN power converter objective of reducing the number of supported control platforms. This is demonstrated in Table 4 where the evolution of the power converter controls until LS3 is shown. The total number of generic control families will reduce from six to three, greatly facilitating the task of hardware and software maintenance. The average age of the equipment will also be reduced, improving the reliability of the equipment through rejuvenation of the technology and in many instances improving the performance through the use of the latest power conversion techniques.

Table 4: The Evolution of the Power Converter Controls

Platform	Qty 2017	Qty end-LS2 (Phase 1)	Qty end-LS3 (Phase 2)
FGC	38% (2176)	57% (2908)	79% (3892)
G64	20% (1153)	7% (358)	0% (0)
PLC	11% (610)	12% (610)	12% (610)
Industry	12% (669)	9% (455)	9% (455)
Mugef	10% (595)	5% (272)	0% (0)
North Area	6% (354)	7% (354)	0% (0)
Total	5557	4957	4957

CONCLUSION

A synthesis of the CERN power converter installation has been given and a roadmap described that reduces the number of control platforms and rejuvenates the overall installation. The roadmap will lead to a reduction in control families by LS3, suppressing three aging proprietary platforms. By implementing the changes in two phases, synchronised with the CERN Long Shutdowns, the activities can be matched with available resources while achieving a homogeneous and more maintainable installation.

REFERENCES

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