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THE DEVELOPMENT OF AGGREGATION DIAGRAMS FOR HIGH-LEVEL PLANNING AT THE ESS

M. Serluca†, T. Friedrich, A. Jansson, C. Plostinar, ESS, Lund, Sweden

Abstract

Accelerator facilities are among the most complex projects, integrating advanced engineering systems and components. At the ESS, the need to visualise the intricate integration activities has led to the development of Aggregation Diagrams (ADs). The diagrams follow the facility breakdown structure with sections and system diagrams showing their integration of the devices with enabling and interfacing systems such as the vacuum, cooling, power suppliers and control systems. Commissioning diagrams have also been developed and are used to visualise the main steps and events in the commissioning of the accelerator. The main advantage of using ADs is to help in the activities planning, provide easy access to high-level plans and develop a standard tool that could be used among the different work packages. In this paper, we present the workflow on the development of ADs giving some examples of their use in the activities planning at the ESS.

INTRODUCTION

The European Spallation Source (ESS) is currently in its final phase of installation, integration, and commissioning of various parts of the facility. The laboratory began construction in 2014 from a green field and has faced challenges in coordinating complex activities related to site construction and installing interfacing systems. In this scenario, integration, seen as a sequence of activities with their dependencies, plays a crucial role in planning and minimizing delays in delivering project milestones. Local industries, universities, and international partners are collaborating to develop facility components.

The challenges related to integrating systems and sections of the accelerator and transitioning to operating the facility include several factors. Firstly, some systems are a technical novelty, and no established integration, conditioning, and commissioning procedures exist. Secondly, the complexity of interfaces and various engineering disciplines means that the sequential dependencies of integration and verification activities are not simple and self-explanatory. Thirdly, individuals with different technical backgrounds may only have partial visibility of overall integration aspects. Fourthly, differences in cultural dimensions can result in misunderstandings or omissions in information exchange. Finally, professional backgrounds and industry cultures can lead to significantly different understandings of terms like "integrated" or "tested."

These challenges have led the ESS accelerator division to investigate the possibility of developing a relatively simple graphical tool that can show the main activities related to integrating the accelerator systems and sections, along with the tasks linked to commissioning the Linac.

The accelerator and its future integration with the target, neutron instruments and related infrastructures represent complex systems on different layers, which can be partitioned by functionality or by location. Currently, a multitude of activities related to installation, testing, integration, conditioning, commissioning, and maintenance must be coordinated to ensure that all verification activities and plans are defined and executed, the results are reported, and they conform to technical specifications.

This paper provides an overview of the current state of development of a graphical tool that aims to facilitate the visualization of high-level plans, interdependencies, integration, and commissioning sequences in a user-friendly manner. In the next section, the facility is described, followed by a detailed explanation of the methodology used to create the diagrams and specific examples of system, and commissioning diagrams. The challenges encountered during the development of the tool are summarized, and the future plans for its implementation are presented.

THE ESS FACILITY

The European Spallation Source (ESS) facility includes the proton accelerator with a nominal power of 5 MW, the target system with its shielding and cooling infrastructure, and user stations [1]. The accelerator consists of various engineering systems required to generate, accelerate, manipulate, and transport the beam to the target and the Tuning Beam Dump (TBD).

Figure 1 presents the layout of the accelerator, which is divided into two sections: the Normal Conducting Linac (NCL) and the Super-Conducting Linac (SCL). The NCL begins with the ion source generator, followed by the low-energy beam transport (LEBT) section containing focusing magnets, devices to modify the beam temporal structure and diagnostic devices. The beam is then accelerated by the Radio Frequency Quadrupole (RFQ) up to 3.6 MeV and directed towards the Medium Energy Beam Transport (MEBT), which guides it to the entrance of the Drift Tube Linac (DTL). After the fifth DTL tank, the beam energy reaches 90 MeV and is then further accelerated up to 2 GeV using spoke cavities and medium and high beta elliptical cavities. Subsequently, the beam can either be directed to the TBD or sent to the target via the Accelerator to Target (A2T) transfer line. Different beam modes are utilized to assess the linac performance, protection systems, the target system, and user experiment neutron beamlines before entering the production mode.

† maurizio.serluca@ess.eu

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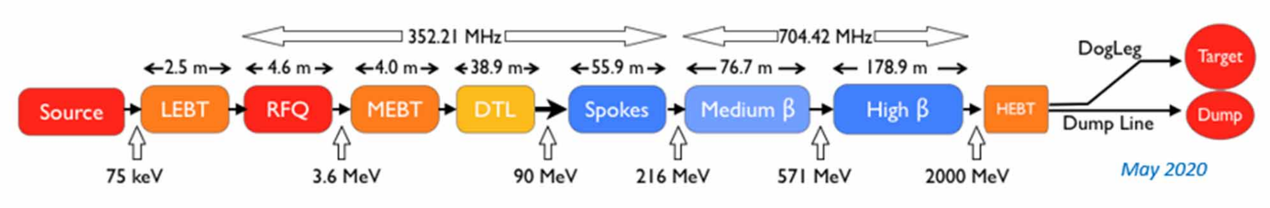

Figure 1: Layout of the ESS linac highlighting the sections with their length and operational frequency and the beam energy at the exit of each section. Blue boxes represent the cold parts of the linac, the remaining are warm sections.

METHOD DESCRIPTION

Guiding concepts: The utilization of specific tools for project and line management is commonplace and serves specific purposes with varying levels of detail. However, we have identified a communication gap among the engineering disciplines that these tools are not adequately addressing.

To bridge this gap, we have developed a cross-disciplinary approach that focuses on representing systems, key integration activities, and their interdependencies in a graphical format that is easy to understand and access. We intentionally avoided using specialised software or editing tools that require training and instead opted for a simple PowerPoint representation. For long-term usefulness, we show principally repeatable concepts of integration rather than work tasks.

Elements of interest: As key elements of interest, we have identified:

- Systems (with a certain maturity stage, such as ‘installed’, ‘locally tested’, ‘fully integrated’, …).

- Integration points (such as activities that realise a specific system integration).

- Events include executing a formal system verification (such as a system test specification) and passing a formal System Review, such as Test Readiness Review (TRR), System Acceptance Review (SAR) for functional evaluation and System Readiness Review (SRR) for safety evaluation as part of the verification process described in the ESS engineering handbook [2].

- Connections between building blocks, showing sequence: A(on the left) is preceding B(on the right); and dependency: B(on the right) is dependent on A(on the left).

Editing process: The editing process is structured into the following phases:

- Work is based on documentation: the initial version of the diagrams is created using only the available system documentation to avoid interfering with the system owners' activities. This method aims to replicate the perspective of new system users, including staff unfamiliar with the system or external analysts involved in the licensing process.

- After generating the initial draft diagram using existing system documentation, an iterative discussion process is employed with system owners and experts to refine the diagram. Through this process, any misunderstandings are clarified, and potential gaps in documentation, such as incomplete test specifications, can be identified. This enables system owners and managers to take appropriate actions to address any identified gaps.

- The diagram undergoes refinement to ensure that the system owner/expert can validate that it accurately represents the integration, verification, and commissioning strategy for its intended scope. Once this validation is accomplished, the diagram is updated, preserving knowledge about the appropriate integration and commissioning approach. This can be helpful for future re-commissioning needs, such as after system modifications or repairs, or for integrating similar systems to achieve energy upgrades in the future.

AD Description

The AD for integrating the Faraday Cup (FC) systems is presented in Fig. 2 as an example. The diagram uses boxes with full lines to highlight components and dashed lines to indicate enabling or integrating systems, along with black points and diamonds to denote integration and critical events that must be fulfilled before proceeding to the next step. The diagram serves as a simple visual aid for understanding the integration procedure of the Faraday cups in the accelerator and can be comprehended by various specialists. It also serves as a blueprint for similar systems, such as the Insertable Beam Stops (IBS) or other beam instrumentation. Additionally, the diagram includes Facility Breakdown Structure (FBS) tags and references the primary documentation, providing convenient access to information about the system and its subsystems.

Figure 3 depicts an illustration of a commissioning diagram for the upcoming commissioning phase at ESS [3], where the beam is intended to reach the DTL tank 4 Faraday cup. The previous step, which involved commissioning up to the temporary cup downstream of DTL tank 1 [4], is deemed fulfilled at the starting point of this phase. Key activities in this phase include conducting internal TRRs, executing verification plans for new systems that have not yet encountered the beam, and re-verifying all previously commissioned systems and equipment. Upon successfully passing the system reviews SAR and SRR, the probe beam can be directed to its destination and verification activities with the beam for diagnostic and machine protection can be carried out. Dotted-dashed lines are used to depict optional sequences, specifically beam modes with higher power and pulse length, that are not necessary to complete the commissioning step but would be beneficial in executing the next steps in the verification plans for all the involved systems. The document ESS numbers, as well as general verifications and specifications, are listed as requirements that must be fulfilled to declare the commissioning phase concluded.

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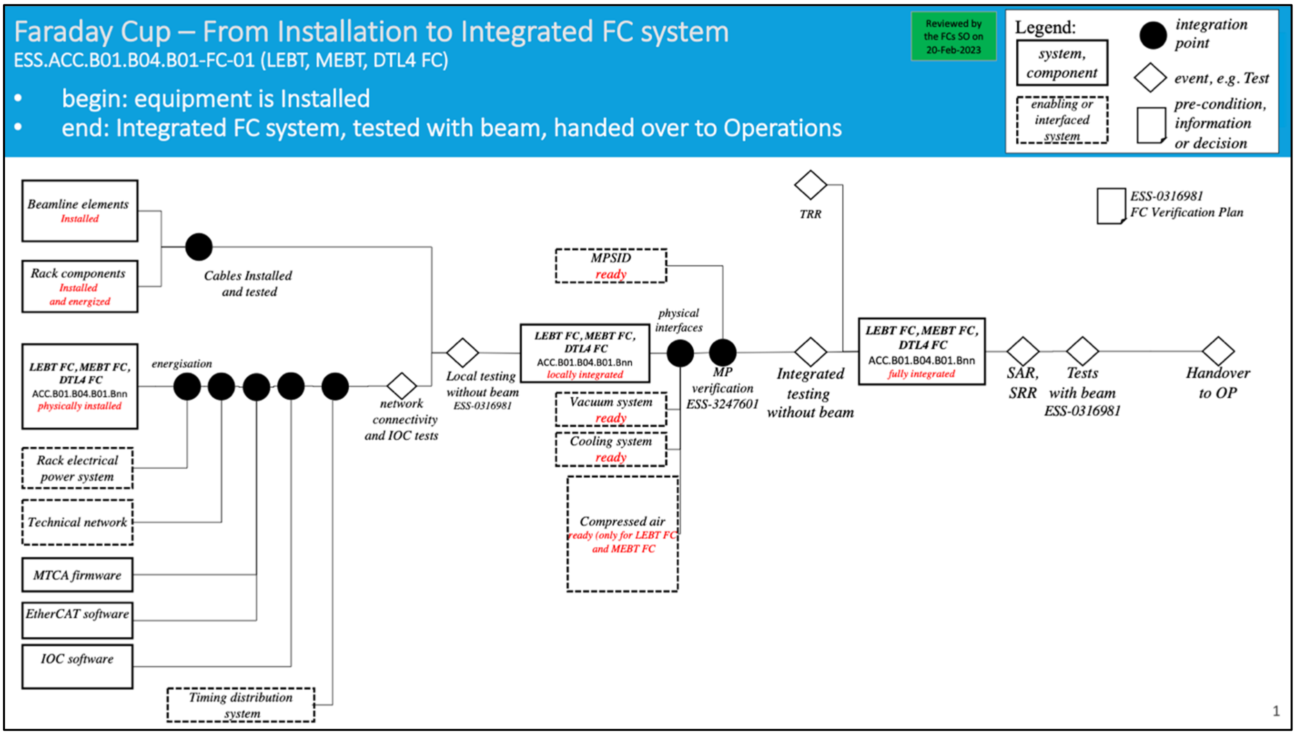

Figure 2: Example of a system AD showing how the Faraday cup is integrated into the accelerator.

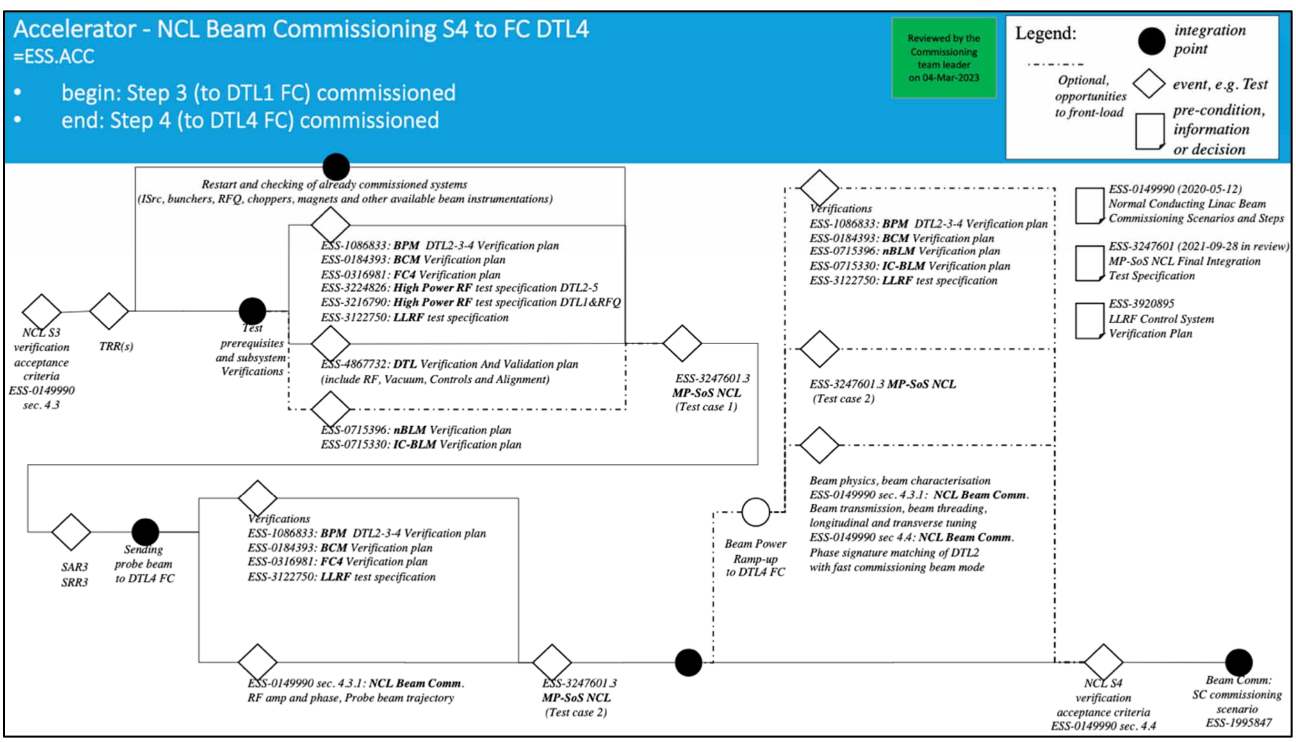

Figure 3: Example of a commissioning AD showing the commissioning step up to the DTL tank 4 Faraday Cup.

CONCLUSION

The primary objective of this project has been to establish a standardised method to describe sequences and identify dependencies by using ADs to compare various system and section diagrams. ADs offer a simple visualisation tool to help coordinate and plan the accelerator project activities. This is particularly useful in the project's early stages as they help identify problems and clarify interfaces, planning and installation logic. We believe this generic approach would be a good model to be adopted at other facilities where complex integration of systems is necessary.

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REFERENCES

[1] R. Garoby *et al.*, "The European Spallation Source Design", *Physica Scriptia*, vol. 93, no. 1, Dec. 2017. doi:10.1088/1402-4896/aa9bff

[2] ESS Handbook for Engineering Management - ESS-0092276, Collaboration Home for ESS - CHESS.

[3] R. Miyamoto *et al.*, "Status and Plan of the European Spallation Source proton linac beam commissioning", presented at the 14th Int. Particle Accelerator Conf. (IPAC'23), Venice, Italy, May 2023, paper WEOGB1, this conference.

[4] C. Plostinar *et al.*, "Status of the Normal Conducting Linac at the European Spallation Source", in *Proc. IPAC'22*, Bangkok, Thailand, June 2022, pp. 2673-5490. doi:10.18429/JACoW-IPAC2022-WEPOTK001