System Acceptance Review Report for the ESS Raster Scanning Magnet System Pre-Series

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Abstract

This note will assess the maturity level of the pre-series design and hardware with respect to the requirements and expectations of European Spallation Source (ESS). The document evaluates the provided documentation, test data, and verification analyses, but also how the pre-series maturity level relates to the imminent production-series phase.

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1 Introduction

The document concerns the completeness of the ESS Raster Scanning Magnet System (RSMS) pre-series hardware as it was delivered to Aarhus University (AU) ultimo 2017. As will be discussed, the delivered product is found to match the idea of a pre-series, far beyond the level of a simple proof of concept. Given that the hardware is deemed a pre-series, it seems natural to also consider the hardware's technical maturity with respect to proceeding with the production of the full-scale series. The process of maturing the design, *e.g.* developing and testing several coil designs, has after all been with the intent of eventually providing the most suitable and optimized full-scale system for ESS.

2 Verification

The current document relates closely to the verification that is documented and evaluated in the Factory Acceptance Test (FAT) data [1], FAT evaluation [2] and Site Acceptance Test (SAT) report [3]. All planned FAT and SAT verification steps have been completed and documented. In particular the FAT evaluation and the SAT report not only displays the raw data but also provide interpretations and impact estimations of the obtained results. The system's consistency with stakeholder expectations can be concluded from these discussions. The pre-series system is tested using acceptance criteria that match the ESS requirements or better. In all FAT test steps but a few, the hardware passes the acceptance criteria [2]. Based on beam physics and general considerations, it is estimated, however, that the few minor performance shortcomings are acceptable and do not compromise the ESS performance to any relevant degree.

2.1 Interfaces

As far as reasonable and technically possible, the interfaces of the RSMS have been explored during the SAT. By testing the supplies with the ESS timing hardware, a Timing EVent Receiver (EVR), one of the most critical interfaces have been verified through the extensive SAT program. Controlling the supplies from a remote line through the SCPI protocol has also been tested, albeit as a device in the AU control system; not from an actual EPICS IOC. Vacuum interfaces have not been physically tested, but the vacuum chamber have been inspected during installation by three delegates from the ESS vacuum group.

The system was intended to not require any form of active cooling, except cooling fans in power supply crates. During the FAT, it was found, however, that active cooling of the termination box was necessary at current amplitudes above $\simeq$ 200 A (with 340 A being the system maximum). This is one of the few pre-series experiences where the system does not meet expectations. Danfysik and ESS has since agreed to water-cool the backplate of the termination box, and cooling loop parameters have been supplied to Danfysik by ESS.

3 Hardware Appearance

The completed hardware was intended to be a pre-series, not a prototype, hence the system should ideally be as complete as the production series, at least in terms of functional performance, to the extent that its reduced quantity allows. The delivered hardware features a high-quality finishing, as one would only expect in a final delivery:

- The Raster Scanning Magnets (RSMs) comprise parts—coils, ferrites, housing, *etc.*—that are produced to a state that is common in modern accelerator components. All high-voltage terminals are covered and almost fully enclosed, cf. list of Change Requests (CRs).
- The power supply crates are standard units with engraved signal and power connector labels, and industry-standard interconnecting cables. All solutions are as would be expected in a final delivery.
- The support bulk parts feature precision-machined surfaces (where relevant) and a homogeneous sealing paint. No parts appear refurbished or improvised.

One minor caveat with respect to the hardware's impression may be that the built-in panel PC of the Control Crate (CC) is not built into the CC crate but has its own panel. This is however mentioned as a design CR, since the pre-series design would necessitate excessive rack space in the full-scale production.

4 Documentation

The supplier has besides the aforementioned FAT reports delivered several documents describing the system in detail:

- Preliminary, Conceptual and Detailed Design Report
- Interface specification document for the RSMS power supplies
- CAD models of hardware and schematics of electronics
- Operation and service manual containing instructions on installation and preventive maintenance procedures, decommissioning, risk analysis, *etc.*

All documents listed above have openly been shared with system stakeholders as early as possible and in most cases revised several times in collaboration with these. The technical level of the documents are considered to be at no less than the level expected from a professional large-scale supplier of accelerator components.

5 Pre-Series Change Requests

A list of pre-series design CRs has continuously been compiled, capturing also the comments from the stakeholders who reviewed the design or had a chance to inspect the hardware in the AU test lab during the SAT phase. While the list of CRs currently contains $\gtrsim 20$ items, the majority are classified as minor details that may not have a significance for the system performance or usage. They can however conveniently be amended in the production-series design. It is estimated that the pre-series hardware could be retrofitted and refurbished to feature the amendments for a modest investment.

6 Conclusion

The delivered hardware is here reported to not only comply with stakeholder expectations in terms of technical performance (as verified through detailed testing in FAT and SAT),

but also level of documentation, overall appearance, *etc.* The RSMS performance has during the SAT been scrutinized in a number of test steps, notably the long-term testing with an accumulated duration of 50×24 hours. The general motivation of the pre-series has been to evaluate if the existing design is mature and performs as required to allow full-scale production. The technical documentation, drawings, and experimental testing now exists at a level sufficiently advanced to recommend this.

Unless significant design changes are introduced between the pre- and production-series, it is believed that the pre-series components could even be reused in the production-series delivery or be used as complete spare parts, with no or only minor modifications to the hardware's delivered state.

7 Acronyms

AU Aarhus University

CC Control Crate

CR Change Request

ESS European Spallation Source

EVR Timing EVent Receiver

FAT Factory Acceptance Test

IOC Input / Output Controller

RSM Raster Scanning Magnet

RSMS Raster Scanning Magnet System

SAT Site Acceptance Test

SCPI Standard Commands for Programmable Instruments

References

[1] Danfysik, H. D. Thomsen, and S. P. Møller, "Factory Acceptance. Test Procedure For ESS RSMS-PS Serial No. 1700703 and 1700704," tech. rep., ESS, 2017.

[2] H. D. Thomsen and S. P. Møller, "Evaluation of the Factory Acceptance Test of the ESS Raster Scanning Magnet System Pre-Series," tech. rep., ESS, 2018.

[3] H. D. Thomsen and S. P. Møller, "Site Acceptance Test Report for the ESS Raster Scanning Magnet System Pre-Series," tech. rep., ESS, 2018.