SuperRail - Current Status of the First Commercial HTS DC Cable System in a Railway Grid

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Objective – The SuperRail project aims to reinforce the power supply at Paris Montparnasse railway station using high-temperature superconducting (HTS) cable technology. It addresses increasing power demands and space limitations by installing two 60-meter-long, 1.5 kV - 3.5 kA HTS DC cables, avoiding the need for disruptive civil engineering work.

Findings – Before the installation, comprehensive testing at SNCF Railway Test Agency validated the system's capability to deliver the required 4.5 MW of nominal power and 10.5 MW of inrush power, while withstanding the short-circuit currents.

Originality – SuperRail is the first commercial application of HTS DC cable technology within a commercially operated railway electric grid, utilizing existing infrastructure and demonstrating the viability of this technology in challenging urban environments.

Keywords - Superconducting cable system, railway electric grid, type test, qualification.

1. Introduction

The demand for rail transport is rapidly increasing, necessitating substantial upgrades to electrical infrastructure. Traditional reinforcement methods using resistive power cables can be difficult in dense urban areas, due to space limitations and the prohibitive costs and disruption associated with civil works. HTS cables can provide a technically viable and economically competitive alternative due to their high-power density, enabling the transmission of large amounts of power through existing right of ways.

2. Project Objectives and Specifications

The SuperRail project is the first commercial installation of an HTS cable system in a commercially operated railway grid. The primary objective is to reinforce the electric power supply at Montparnasse railway station by connecting the Vouillé traction substation to the railway tracks (Figure 1). The system is designed to deliver a nominal power of 4.5 MW at 1500 V DC (3000 A) and handle inrush power of up to 10.5 MW (7000 A) during train acceleration. The system must also withstand short-circuit currents of 67 kA for 100 ms. Two 60-meter-long HTS cables are installed in parallel to ensure redundancy and reliability. The cables are installed within existing conduits, imposing constraints on cable outer diameter (< 80 mm), bending radius (< 1.7m), and hydraulic gradients [1].

Figure 1 – SuperRail, the first commercial HTS DC cable system in a railway grid.

3. HTS Cable System Components

Each HTS cable is rated at 1500 V and 3500 A, and is designed to withstand the full short-circuit current. The cables' cores are made of a copper former, 2G HTS tapes conductor layers, Polypropylene Laminated Paper (PPLP) insulation, and a copper screen. It is cooled down with subcooled liquid nitrogen and enclosed within a vacuum-insulated flexible double-wall cryostat. Custom-designed terminations manage heat losses.

4. Testing and Qualification

A 35-meter HTS cable type test loop was installed at the SNCF Railway Test Agency (Figure 2) [2]. The testing program included: thermal cycles, pressure tests, dielectric and lightning impulse tests, nominal current tests, system losses characterization, fault current test, and V-I characterization. Here are the key test findings:

- The system withstood 5 thermal cycles, simulating a 40-year lifespan.
- The system handled pressure up to 18.5 bar.
- The system successfully passed dielectric and lightning impulse tests.
- The system maintained stable performance at 1500 A DC for 30 minutes.
- The losses measured for the type test loop confirm the sizing of the cooling system to be installed in Montparnasse.
- The system recovered within 10 minutes after fault currents up to 40 kA for 200 ms, suggesting satisfactory performance at 67 kA for 100 ms.
- The critical current was not degraded after all tests.

The tests confirmed that the cable system meets its design specifications.

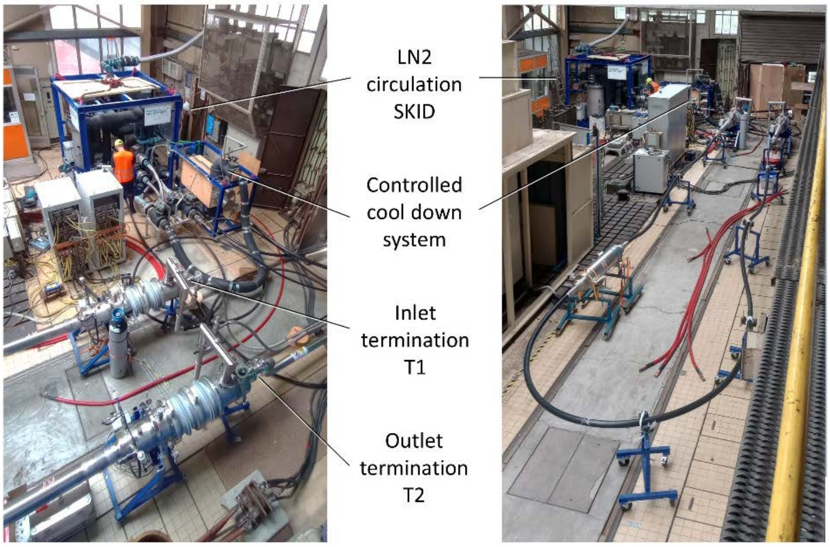

Figure 2 - SuperRail HTS cable type test loop installed at the SNCF Railway Test Agency.

5. Future Prospects

The SuperRail project demonstrates the potential for HTS technology to address electrical infrastructure challenges in dense urban areas. To anticipate future projects, computational tools to simulate HTS cables in railway electric grids are being developed at the GREEN laboratory at the University of Lorraine [3-5]. And studies are being conducted by the GeePs laboratory at CentraleSupélec University Paris-Saclay to integrate superconducting transformers and cryogenic power converters with the HTS cable system [6, 7]. Note that the project has also highlighted the need for the establishment of norms and standards for HTS cable systems [8, 9].

6. Conclusion

The SuperRail project is expected to be completed in 2025, contingent on successful operational testing. This project is a pivotal step in demonstrating the viability of HTS cable systems for real-world applications, particularly in challenging urban environments. The SuperRail project serves as a milestone for the broader adoption of superconducting technology in railway and other power transmission systems.

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