AP Oral | Large Scale Applications

Tue. Dec 2, 2025 3:00 PM - 4:31 PM JST | Tue. Dec 2, 2025 6:00 AM - 7:31 AM UTC Room C(103)

[AP2] Electrical power devices

Chair:Antonio Morandi(Università di Bologna), Naoko Nakamura(NIFS)

3:00 PM - 3:30 PM JST | 6:00 AM - 6:30 AM UTC

[AP2-01-INV]

DC Superconducting Cables for present and future power needs

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3:30 PM - 4:00 PM JST | 6:30 AM - 7:00 AM UTC

[AP2-02-INV]

SuperLink: 110 kV HTS Cable for Munich's Power Supply

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4:00 PM - 4:30 PM JST | 7:00 AM - 7:30 AM UTC

[AP2-03-INV]

Environmental Perspective of HTS Cable System Refer to Singapore Power Grid

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4:30 PM - 4:31 PM JST | 7:30 AM - 7:31 AM UTC

[AP2-04] Cancelled

DC Superconducting Cables for present and future power needs

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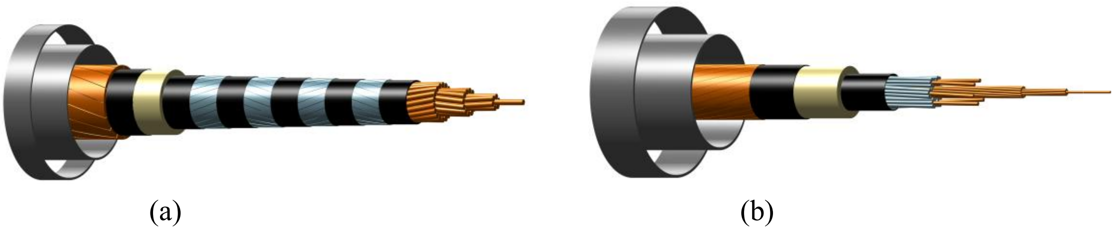
Abstract: Superconducting power cables, including liquid nitrogen-cooled power cables based on ReBCO-coated conductors as well as gas-helium or liquid hydrogen-cooled power cables based on MgB_2, offer ultra-high transport capacity combined with exceptional efficiency and compactness. Typical layouts of HTS and MgB_2 cables are shown in Figure 1. Their adoption has the potential to transform future power transmission and distribution grids. HTS power cables can be designed for both DC and AC operation across various voltage levels, from medium voltage (MV) to high voltage (HV). This versatility positions them as a key element for a wide range of applications, including the connection of massive and widespread offshore wind power to onshore substations and the development of supply infrastructures for power- and current-intensive facilities such as data centers or metallurgical industries. Additionally, HTS cables are a critical enabler for upgrading existing AC grids in densely populated areas, eliminating the need for extensive new civil infrastructure.

This contribution presents the fundamental concepts and layouts of HTS and MgB_2 power cable technology and reviews their current state of development. It also explores future research directions, focusing in detail on the emerging trends in power grids. These include high-power-density DC corridors as well as AC corridors aimed at increasing the capacity of existing sub-transmission grids. Further examples involve power- and current-intensive DC power supply applications such as those in the metal industry, data centers, railway systems, and high-energy



(a) (b)

Figure 1. Typical superconductor cables' layouts a) Multilayer HTS cable b) Multistage MgB_2 cable

Keywaords: HTS power cable, MgB2 power cable, grid applications

SuperLink: 110 kV HTS Cable for Munich's Power Supply

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Abstract

As the energy transition advances, inner-city electricity demand increases rapidly due to electric mobility, CO_2-neutral heating and cooling, and AI data centers—posing immense challenges for urban distribution network operators. Limited space and high civil-engineering costs make the expansion of conventional 110 kV VPE-cable systems—each providing roughly 100 MVA—very difficult. To relieve urban networks, the "SWM SuperLink" project has for the first time developed a 110 kV high-temperature-superconductor (HTS) cable system with 500 MVA capacity that houses all three phases in a single, flexible cryostat. This design achieves high transmission performance in the city with comparatively little excavation and minimal space requirements.

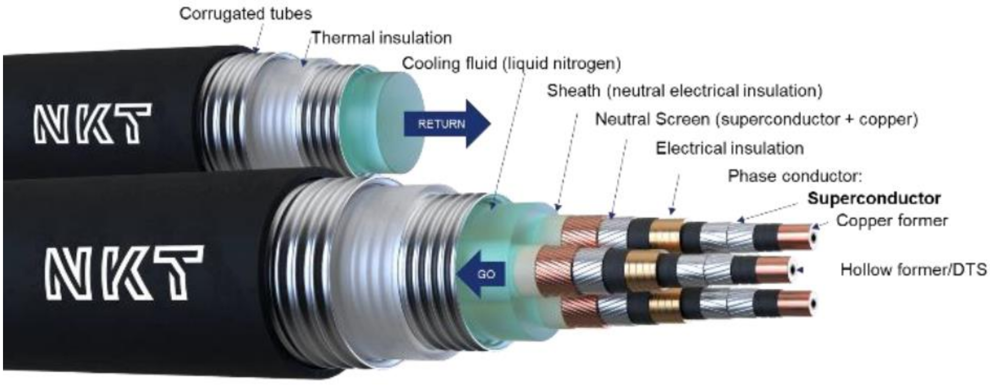

Figure 1 Schematic of the HTS cable design, showing all three phases plus neutral conductor in one flexible cryostat.

Funded by the German Federal Ministry for Economic Affairs and Energy (funding indicator 03EN2036), the project objectives were:

- To engineer a compact, short-circuit-tolerant 110 kV HTS cable system rated at 500 MVA over approximately 15 km.
- To develop and type-test all necessary components (cable, terminations, splitter box, joint assemblies, cryostat) and install a demo loop.
- To prove grid integration capability via detailed network calculations and simulations for Munich's 110 kV system.
- To demonstrate system longevity and economic viability (capex and opex) compared to

conventional solutions.
- To operate the HTS cable continuously up to full rating for at least six months under real network conditions.

The consortium comprised the network operator Stadtwerke München (SWM), HTS-wire producer THEVA, cable developer/manufacturer NKT Cables, cooling-system specialist Linde AG, and the universities South Westphalia University (FHSWF) and Karlsruhe Institute of Technology (KIT).

- KIT's network simulations showed that integrating a SuperLink cable relieves existing 110 kV routes without excessively increasing fault-current levels at substations. A transient thermal analysis confirmed that the SuperLink cable remains superconducting under fault currents and sustains stable operation without significant resistance rise.
- Material tests at FHSWF demonstrated that the cryogenic high-voltage insulation using "Cryoflex" tape achieves an exceptional breakdown strength of over 165 kV/mm, ensuring high electrical strength and strong partial-discharge resistance.
- THEVA optimized its production of $GdBa_2Cu_3O_7$ tapes—especially laser cutting and lamination—so that a 3 mm-wide tape over 200 m continuous length carries 163 A at 77 K.
- Linde's thermal–hydraulic simulations with NKT cable parameters showed that the full 15 km route can be cooled with just one intermediate refrigeration station, predicting a cooling power of 30 kW/km.
- NKT's short-circuit-tolerant cable design meets SWM's requirement of sustaining 40 kA for one second. An innovative use of radial core contraction fully compensates the 0.3 % thermal length shrinkage.

After type-qualification at DTU Copenhagen, a 150 m test loop was installed in SWM's Menzing substation in 2024. Figure 2 shows the field layout.

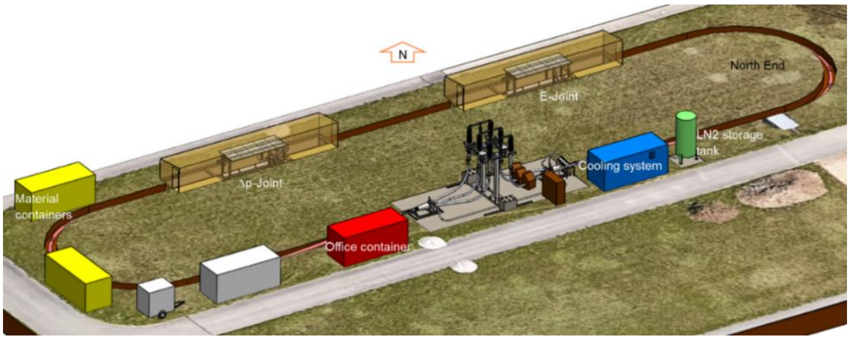

Figure 2 Layout plan of the test field at HUW Menzing.

Installation tests, high-voltage qualification, and DC/AC overload tests were completed, leading to the official commissioning of the test loop on 9 October 2024. Long-term operation ran until 1 July 2025, impressively demonstrating the HTS cable system's performance. Under various load scenarios and weather conditions, the cable system sustained continuous operation at its full 500 MVA rating, reliably conducting the specified 2 625 A in each of the three phases.

Keywords: HTS, high voltage cable, SuperLink

Environmental Perspective of HTS Cable System Refer to Singapore Power Grid

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Abstract

High Temperature Superconducting (HTS) Cable has merit as large capacity transmission with a compact cable. Some fast-growing cities need to install new transmission cables and to increase network capacity rapidly, but there is no underground space to bury the cable because other infrastructure equipment is already buried. Then HTS Cable can solve these urban grid issues.

Singapore's electricity demand is increasing as the economy grows. Moreover, the aging power transmission and distribution facilities are in need of renewal. For Singapore power grid, we considered the suitability of HTS Cable system based on some specifications and confirmed the benefits of introducing HTS Cable system to the electric distribution cable. In particular, HTS Cable systems including cooling system of a few lengths are designed.

In this presentation, some design results of HTS Cable system are introduced, these greenhouse gas emissions are described.

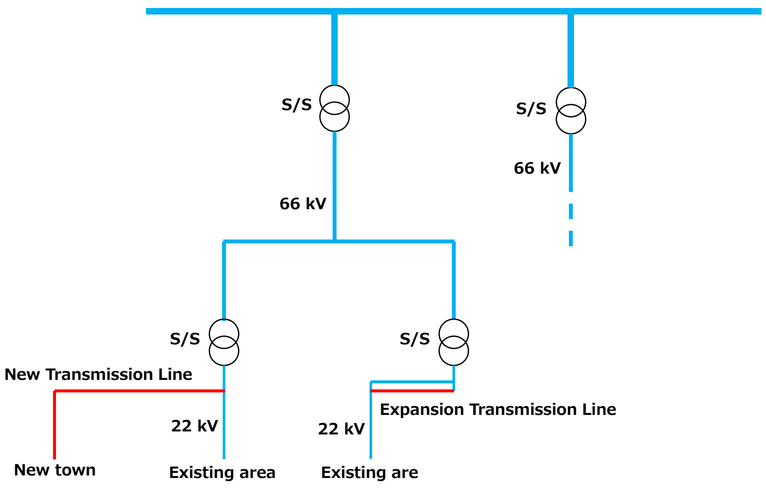

Figure 1 Example of HTS Cable installation image.

Keywaords: HTS Cable, Power grid, Refrigeration System, Greenhouse gas emissions