

Benefits

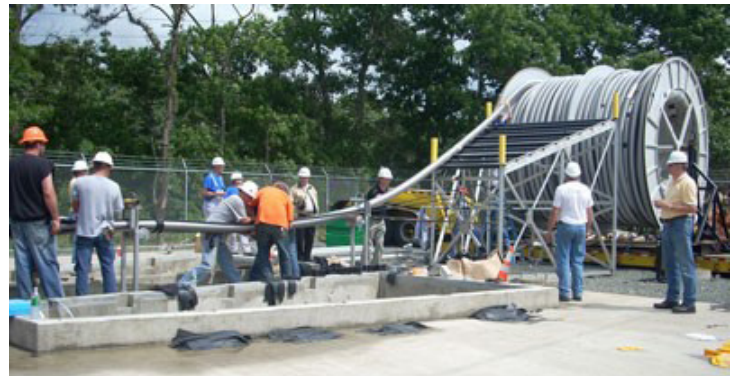
Superconductor cable systems can be used to improve T&D substation reliability, serve new load without requiring new substations, achieve lower costs in underground cable construction, and complete any project where minimizing the impact on the environment is important. HTS systems enable:

- Transmission of up to 10 times more power than conventional cables with the same cross section, or can carry equivalent power at much lower voltages
- Reduced right-of-way for transmission and distribution corridors
- Elimination of need for soils engineering and construction for thermal management
- Optimal environmental friendliness due to a lack of external electric or magnetic fields
- Fault current management capability, creating a more interconnected, resilient and reliable grid

Background

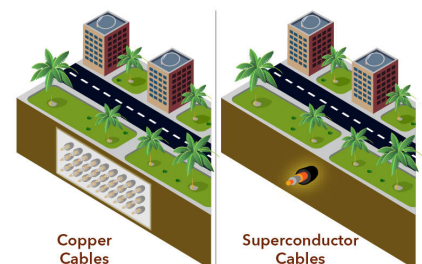
Electric transmission and distribution cables are a critical component for connecting generation to load. High temperature superconducting (HTS) cables replace the copper or aluminum wires in conventional underground cables with wires made from superconductors. HTS cables may be used in utility power networks or in commercial and industrial applications such as data centers – in both direct current (DC) and alternating current (AC) systems. Cable system components include the cable as well as splices/joints, terminations and the cryogenic cooling system to maintain proper operating conditions. The thermal insulation around the cable is generally a vacuum-jacketed pipe called a cryostat.

HTS cables are produced in the same manner as conventional copper or aluminum core cables, using the same or slightly modified manufacturing machines and in the same factories. HTS cables are



HTS cable being installed. Courtesy Nexans.

To achieve superconducting operation, cryogenic cooling plants operating at -200°C are connected to the cable to circulate pressurized liquid nitrogen (LN) through the cable. LN is environmentally friendly, non-flammable, and relatively inexpensive. The earth's atmosphere is approximately 78% nitrogen gas. This gas is simply distilled from the atmosphere and condensed into liquid form. A 100-year old "cold" industry supplies LN and other industrial gases, which are used in many businesses including healthcare, food preparation/storage, semiconductors, steel and others. Multiple vendors supply customer-owned commercial refrigerators, cryostats, and bulk LN transportation systems to serve this market.



One HTS cable has the same power throughput as 27 conventional copper cables



About the IEA HTS TCP

The International Energy Agency's High Temperature Superconductivity Technology Collaborative Program (IEA HTS TCP) aims to analyze superconductivity technology, monitor developments in industry standards, and assess the benefits and existing barriers to deployment. It brings together manufacturers, cryogenics research, laboratories and trade organizations to enable significant improvements in the generation, transmission, distribution and use of electric power.

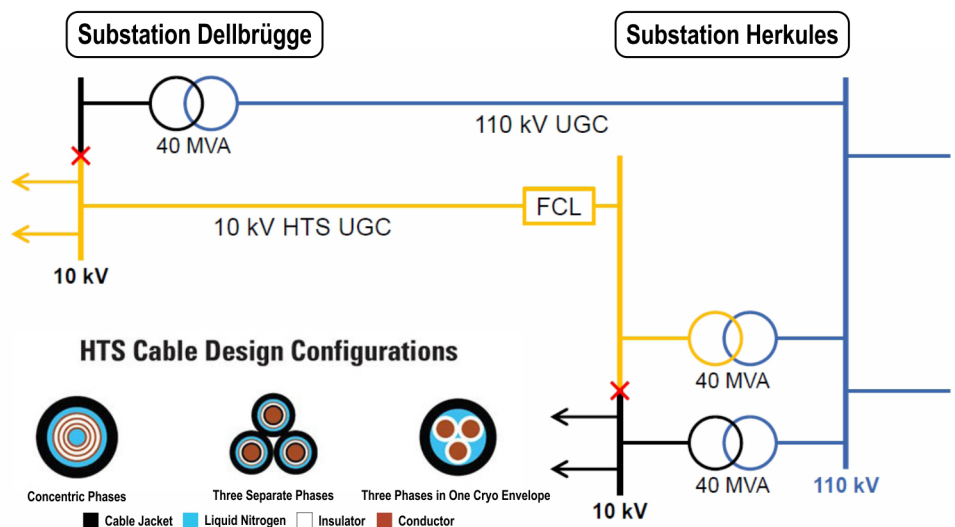
www.ieahts.org

Cable Status

The table below highlights several HTS cable projects around the world.

Lead Company	Country /Year	Operating Characteristics
LS Cable	Seoul Korea, 2017	22.9 kV, 50MVA, 1000m
Nexans	Essen, Germany, 2014	10 kV, 2.4 kA, 1000m
Sumitomo	Yokohama, Japan, 2013	66 kV, 1.8 kA, 240m
LS Cable	Incheon, Korea, 2011	22.9 kV, 3.0 kA, 100m
Nexans	Long Island, US, 2008	138 kV, 2.4 kA, 600m

The graphic below shows how the HTS cable (shown in yellow) in Essen Germany was installed between two substations. The project started out as a demonstration project and is now officially part of the local utility grid. A transformer and a high voltage cable can be replaced by a medium voltage HTS cable in combination with a fault current limiter.



There are three configurations used in HTS cable design, see above. Courtesy of Superconductor Technologies.



The graphic above shows a right of way comparison to transmit 5 GW for 1,000 miles with overhead AC lines and DC superconductor cables.