Karlsruher Institut für Technologie

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

SuperLink

Development and Impacts of a Superconducting Power Cable in a 110kV Distribution Network

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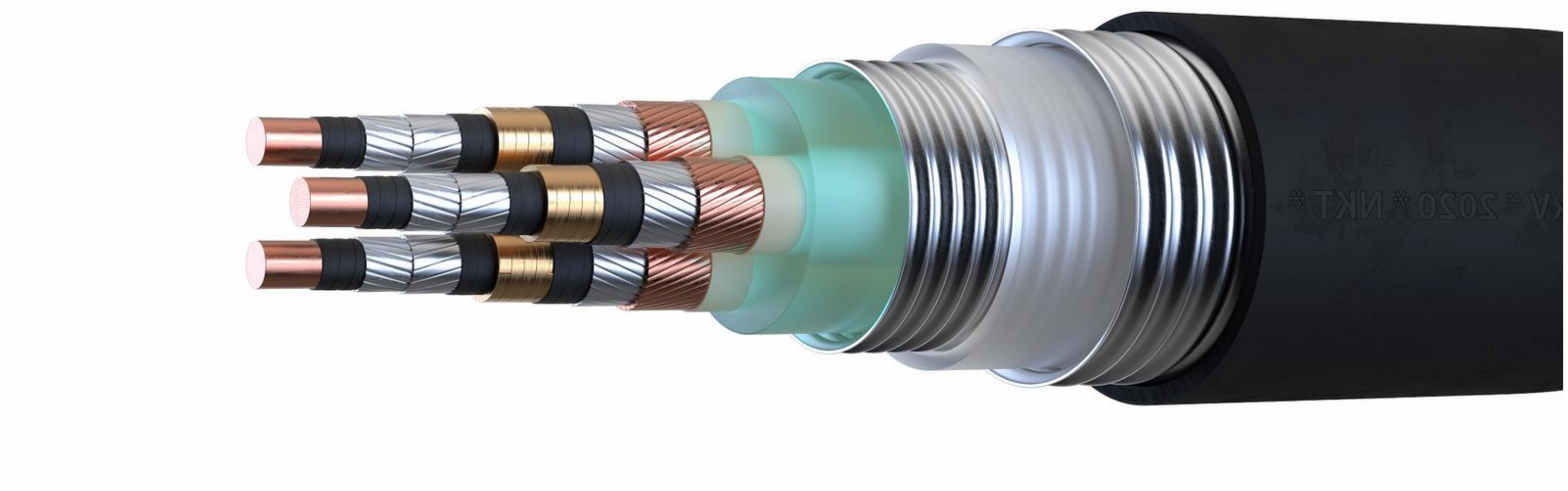


SuperLink - The longest HTS Cable in the World

Stromtransport: Das längste Hochspannungs-Supraleiterkabel der Welt

In München soll das längste Supraleiterkabel der Welt realisiert und wirtschaftlich eingesetzt werden. Das KIT ist an dem Projekt beteiligt.

Die Wissenschaftlerinnen und Wissenschaftler am KIT konzipieren mit den Projektpartnern effiziente und leistungsstarke supraleitende Dreileiterkabel (Abbildung: NKT Cables Group)

Im Stromnetz der Zukunft müssen große Mengen elektrischer Energie aus erneuerbaren Quellen in dicht bebaute städtische Lastzentren geleitet werden. Mit Supraleitern kann Strom ohne Widerstand und Verlust transportiert werden. „Die Leitung soll perspektivisch insgesamt zwölf Kilometer lang werden und kann eine bestehende 380 Kilovolt Leitung im regulären Betrieb ersetzen", sagt Mathias Noe, Direktor des Instituts für Technische Physik am KIT. „Wir nutzten ein Hochtemperatur-Supraleiterkabel, das sich durch extreme Kompaktheit und hohe Leistung auszeichnet."

Gemeinsam möchte das Konsortium innerhalb von zwei Jahren alle notwendigen technischen Voraussetzungen erfüllen und die wichtigsten Komponenten entwickeln; hierzu gehören ein 200 Meter langes Kabelteilstück, Endverschlüsse und die Kühlung. Nach erfolgreichem Abschluss des Projektes sollen dann die zwölf Kilometer angegangen werden. Die Forschungsarbeiten des KIT umfassen vor allem die komplexe Simulation des elektromagnetischen und thermischen Verhaltens des Kabels.

Die Forschungen sind Teil des vom Bundesministerium für Wirtschaft und Energie geförderten Projekts „SuperLink". Dem Projektkonsortium gehören neben dem KIT und der Fachhochschule Südwestfalen die Stadtwerke München sowie die Unternehmen THEVA, NKT Cables Group und Industriegase-Konzern Linde an.

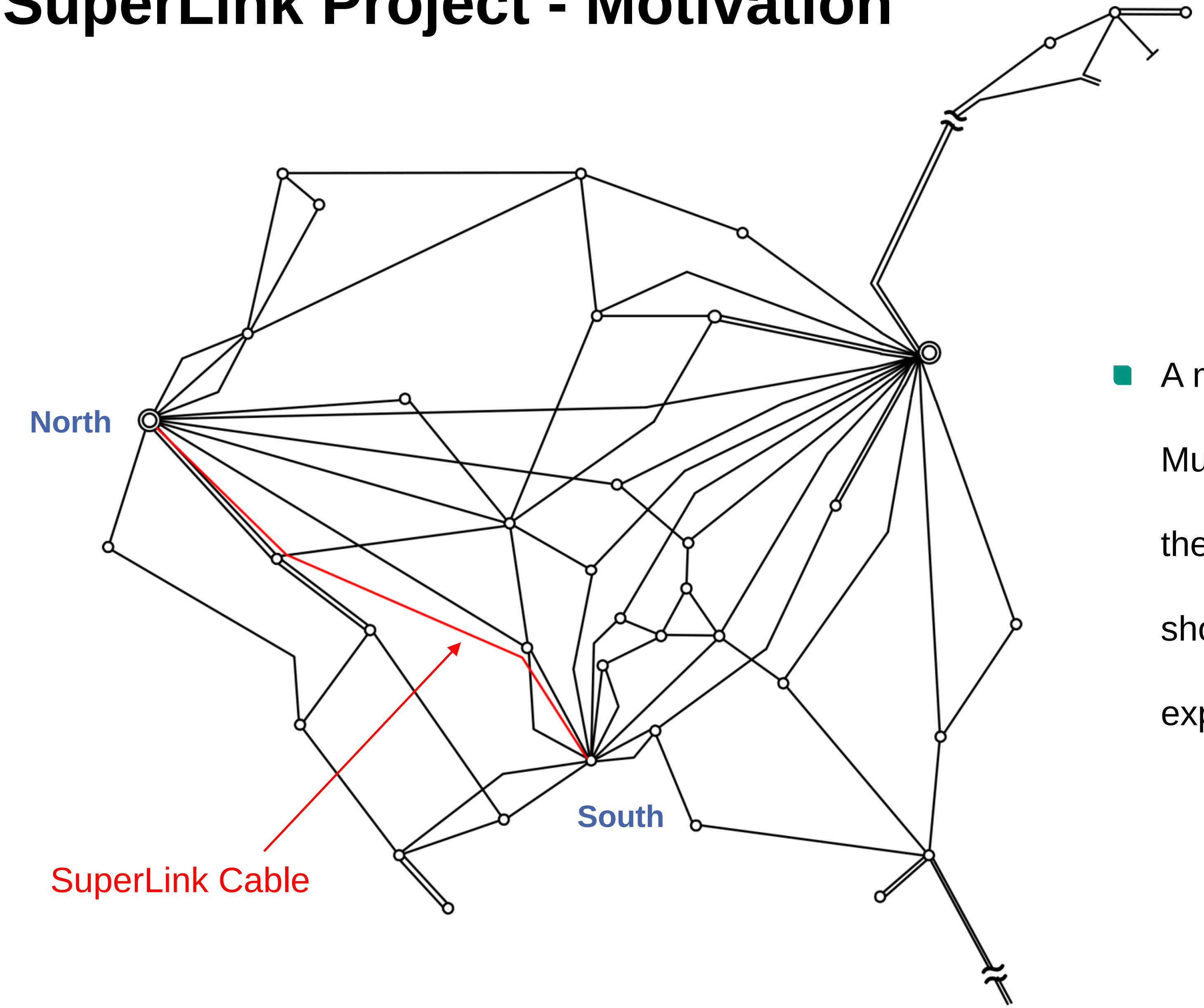
SuperLink Consortium

- SWM: City utility; Cable qualification & conduction of demo
- NKT: Development of cable & installation of democable
- THEVA: Development & production of HTS wire for democable
- Fachhochschule Südwestfalen (University of Applied Sciences): Analysis and selection of the insulating material
- Linde: Cryogenics
- KIT (Karlsruhe Institute of Technology): Grid simulations
- Gefördert durch: Bundesministerium für Wirtschaft und Klimaschutz: Financial support

SuperLink Project - Motivation

- The future is electric;
  - No burning of fossil fuel, energy consumption will double
- Strong renewal pressure;
  - Grid planning and cables installed before 1980
- Avoidance of new 400/110 kV main substation;
  - Saving space and cost
- Connect generation power station;
  - SWM needs a high power line between North and South with 500 MW and appr. 12 km

SuperLink Project - Motivation



- A major challenge nowdays of the 110 kV network in Munich is the off-peak times within the city, when the power generated at the southern substation should not only be available for Munich, but exported to external networks (South to North).

SuperLink Project - Possible Solutions

- **400 kV XLPE Cable System**
  - Would require the construction of tunnels

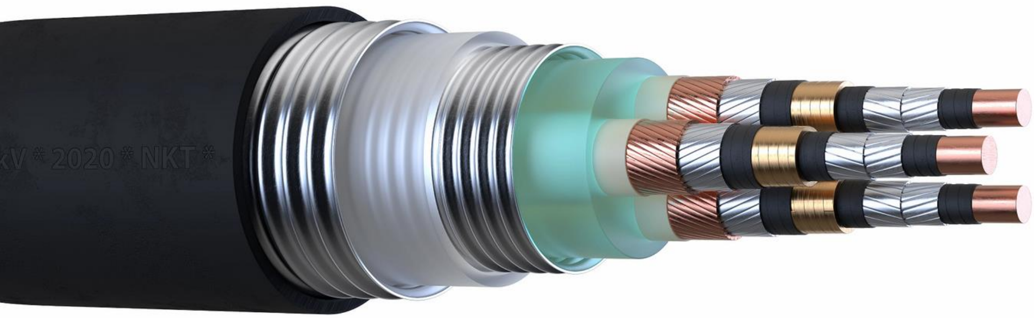
- **400 kV Overhead Line**
  - Not feasible in the city
  - Even in the city surroundings is almost unfeasible

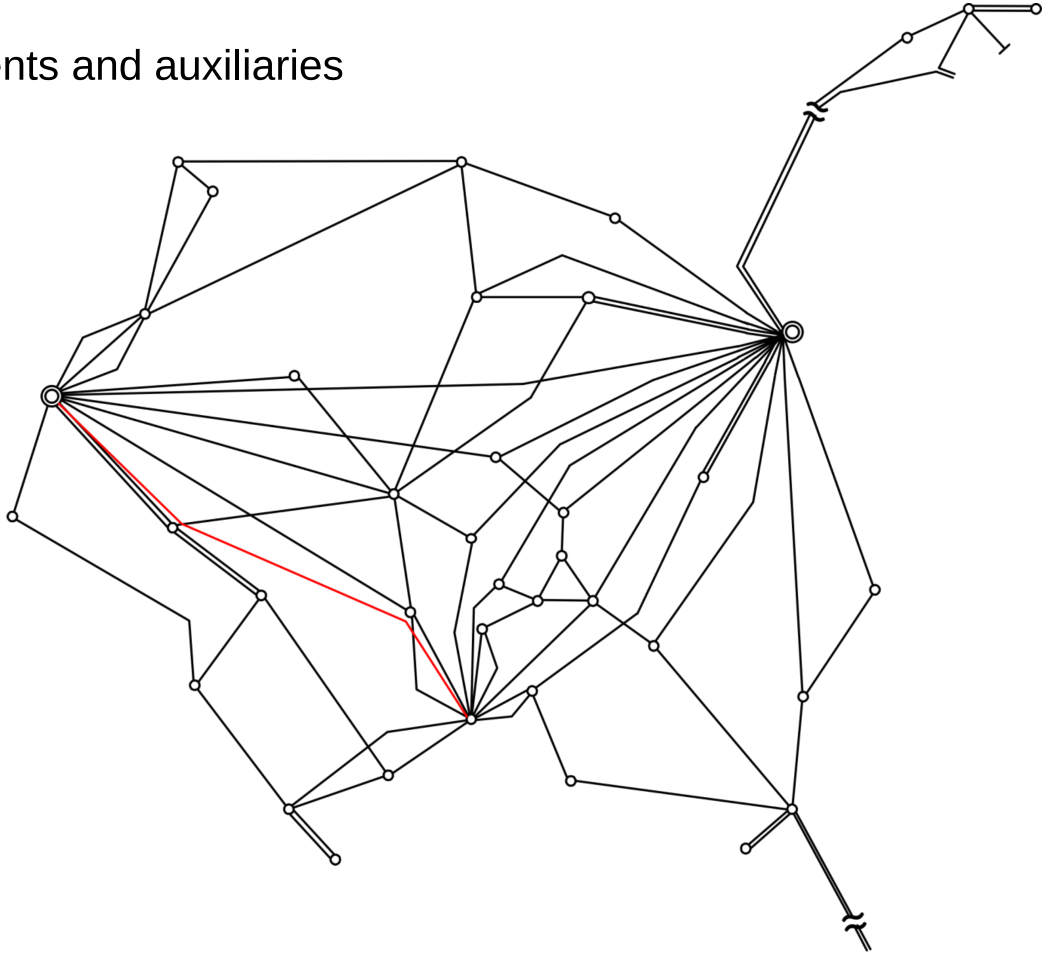
- **Multiple 110 kV XLPE Cables**
  - can only be used with limited cross-section (500 or 630 mm^2 Cu) due to bending radii.

- **110 kV HTS Cables**
  - Less Space required
  - HTS-Cable can easily transport more than 500 MVA
  - Low Losses

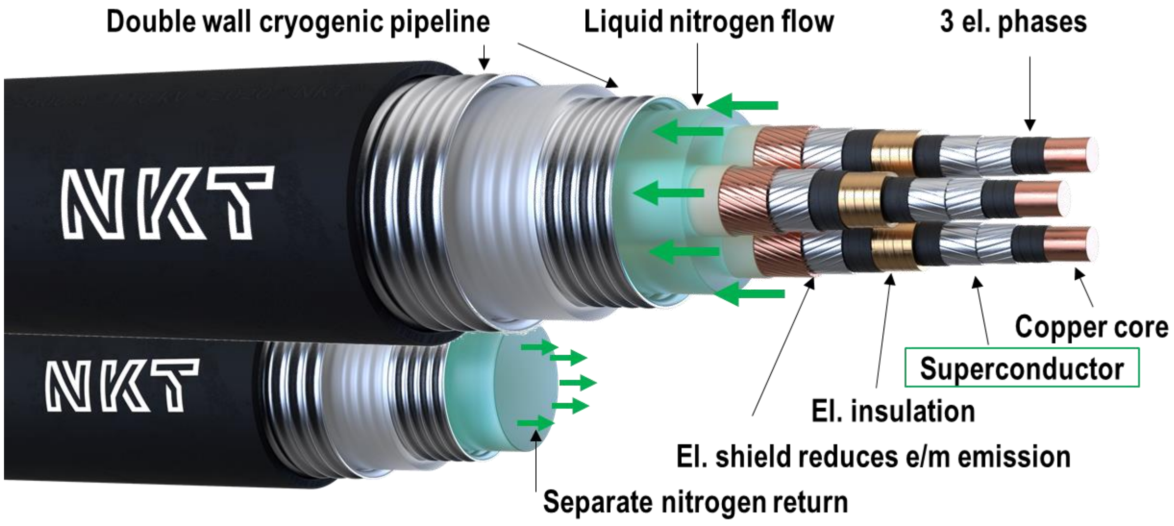
SuperLink Project - Goals

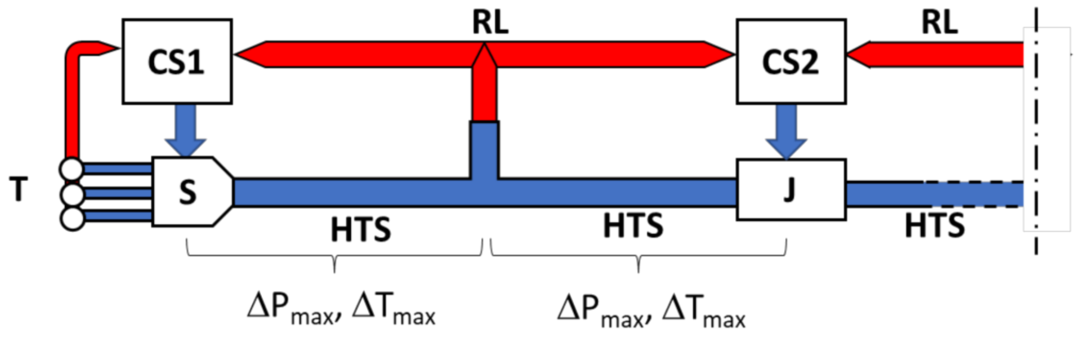
- Development of a commercial, long, high-power HTS cable
  - Design concept for a 12+ km long 110 kV cable line with all components and auxiliaries
  - Capacity 500 MVA in a compact single cable (three-in-one)
  - Closed cooling cycle & distributed cooling over 12+ km
  - Modeling HTS cable's impact on the surrounding grid





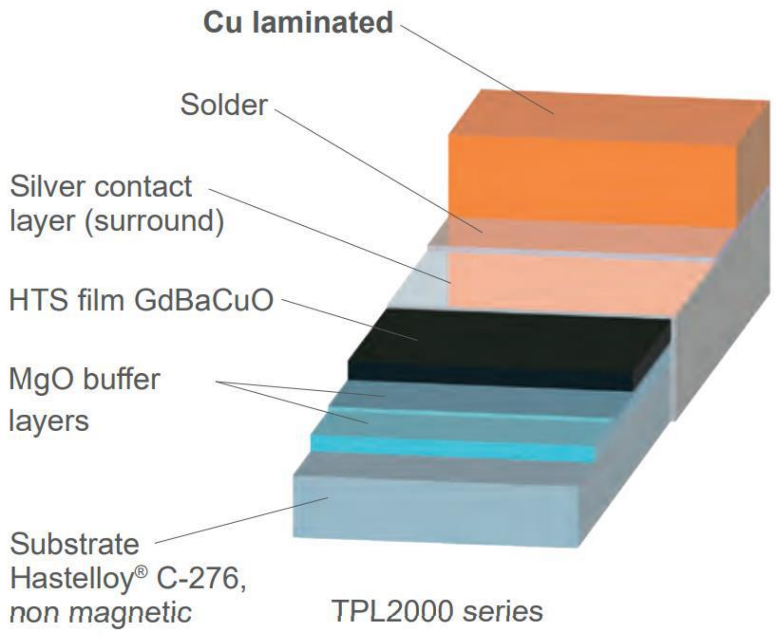
SuperLink Project – Cable Layout

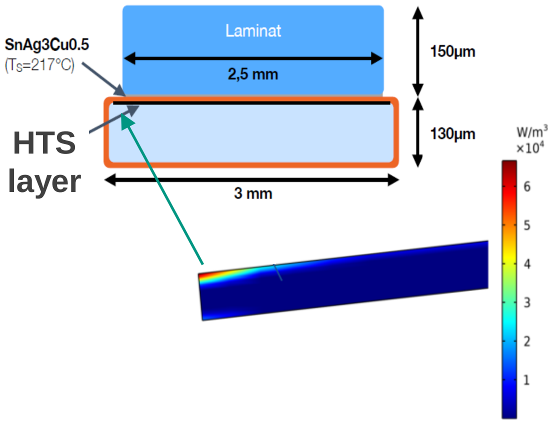




- **Cable Design**
  - 3 Phases in one Cryostat
  - Superconducting phases and screens
  - 110 kV, 500 MVA, 2.6 kA
  - Low AC- Losses (lower than 0.5 W/m per phase)
  - Fault Current Resilient
- **Closed cooling system (*friederike.boehm@kit.edu*)**
  - Separate LN_2 return pipe (single, one-way cable)
  - Low temperature and high pressure of LN_2 can be maintained in the main cryostat

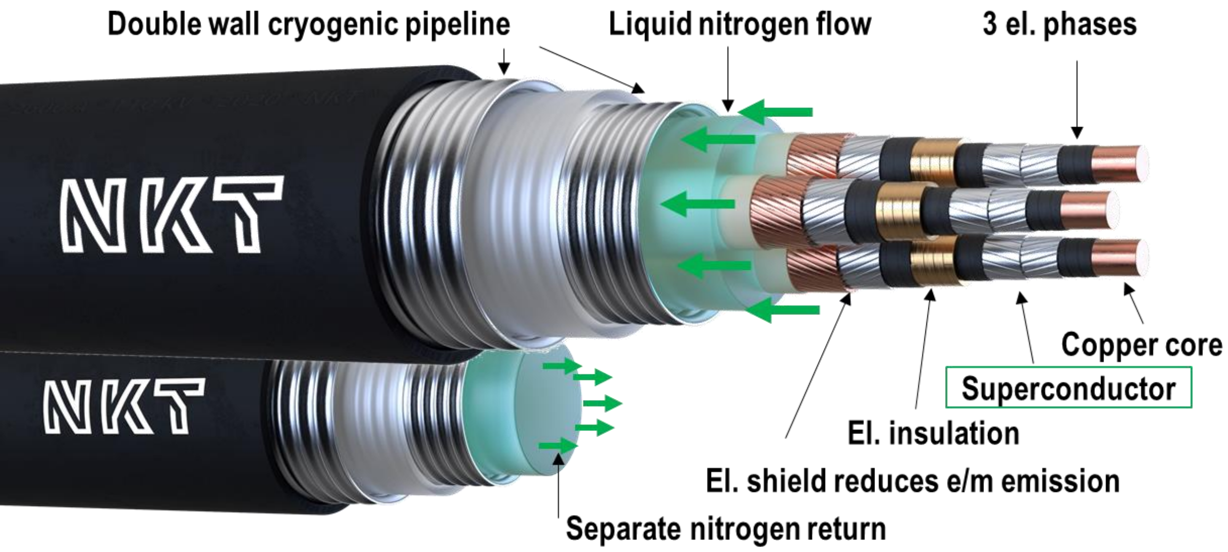
SuperLink Project – HTS Tapes





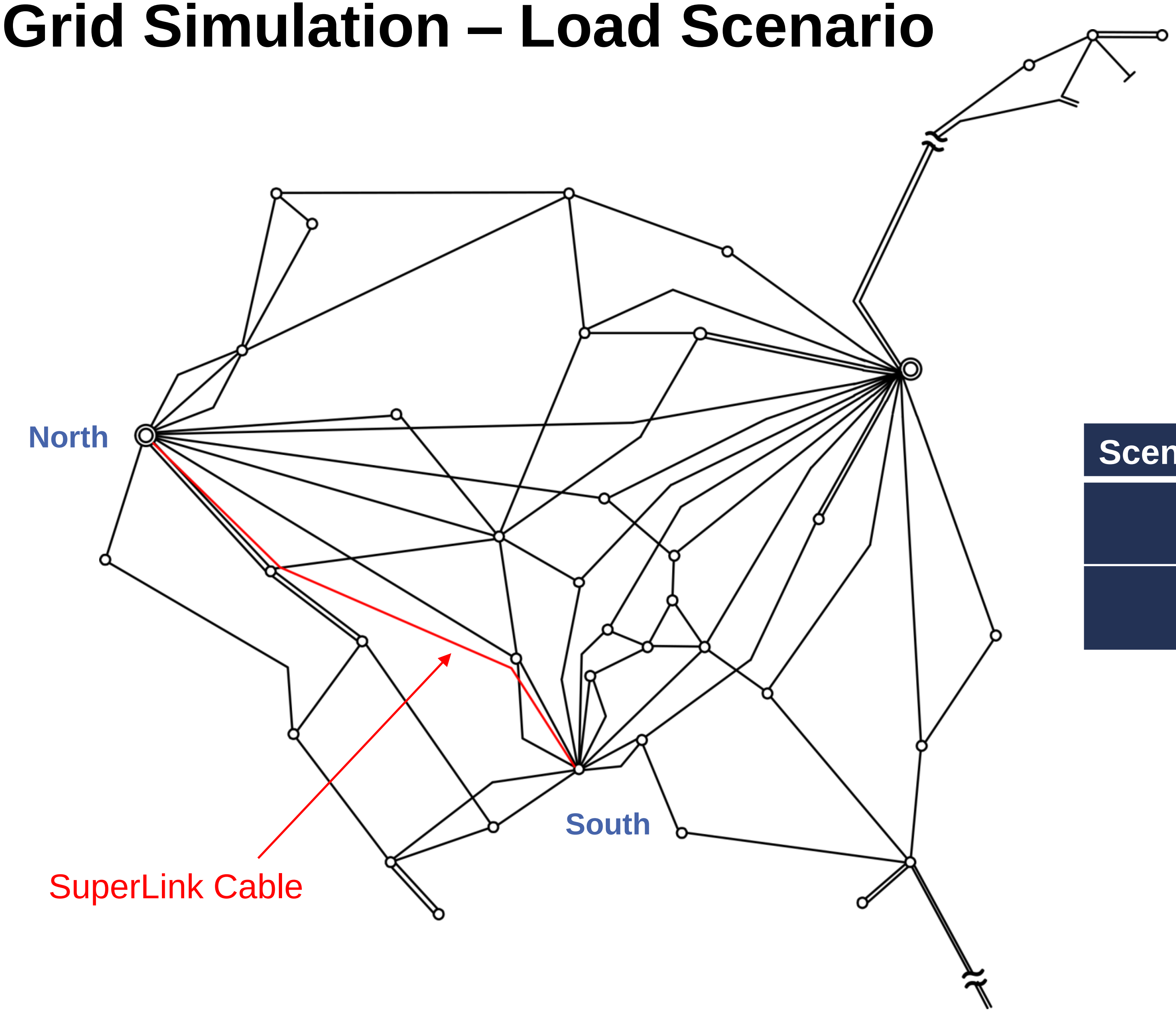
- HTS wire optimized for AC-cable manufacturing
- Robust, single-sided Cu-laminated
- Optimized for low AC-losses
  - 3 mm laser-slit wire, narrow tolerances
  - Trapezoidal shape to fit on round core and minimize gaps
- $I_{c,avg}$ (3mm, @77 K) = 163 A

Grid Simulation – Cable Properties



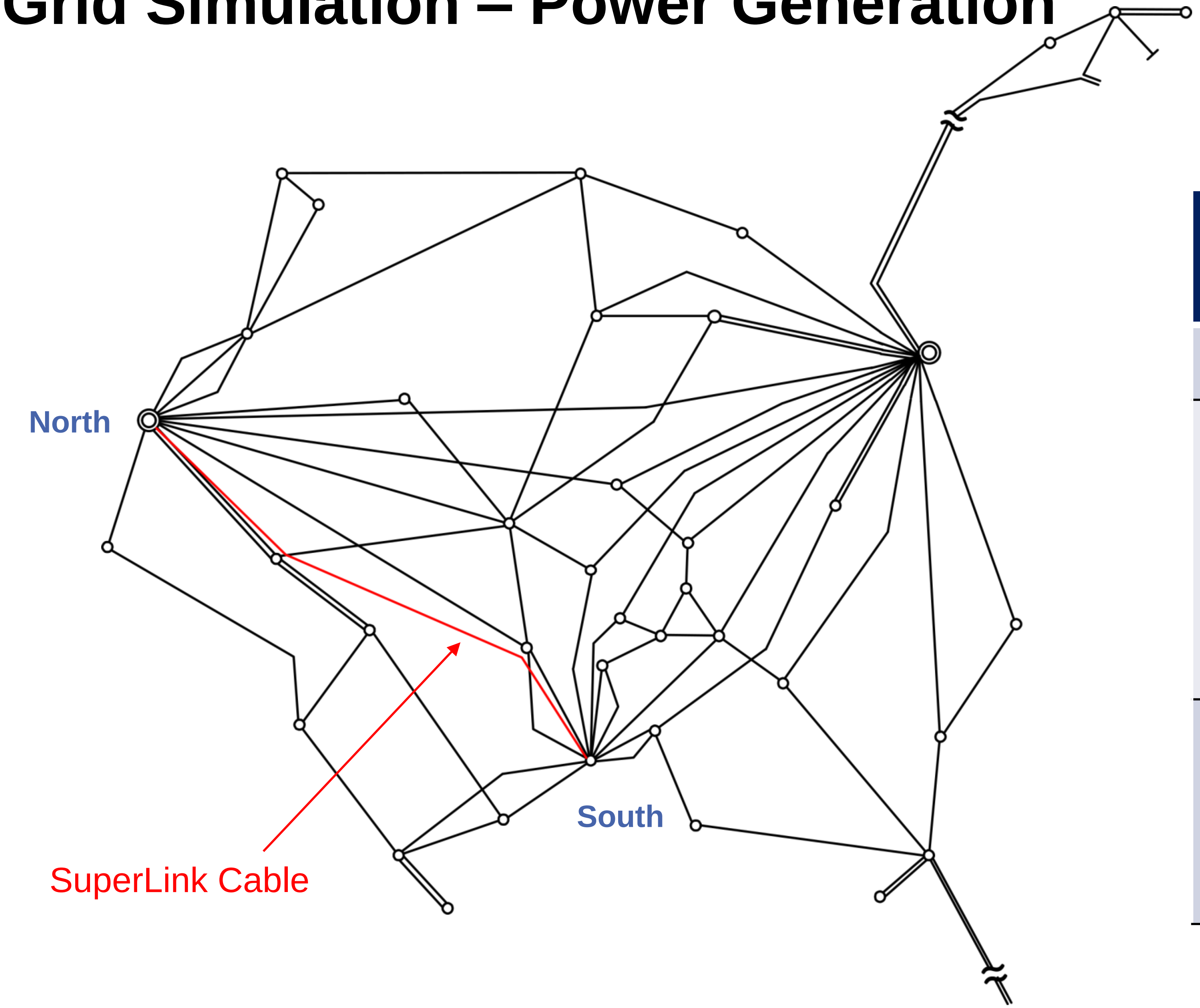
SuperLink Kabel	
R’	0.0 Ω/km
X´	29 mΩ/km
C´	0.327 µF/km
Cable length	12 km
Z (total)	0.35 Ω
Fault Current	40 kA (1s)

Grid Simulation – Load Scenario



Scenario	Description	Total Load
L2	Medium Load Scenario	**1728 MVA**
L3	Low Load Scenario	**456 MVA**

Grid Simulation – Power Generation



110 kV-Network Power - Generation		
E1	No generation	0 MVA
E2	PG01	871 MVA
	PG02	
	PG03	
	PG04	
E3	PG01	290 MVA
	PG03	
	PG04	

Grid Simulation – Analysis method

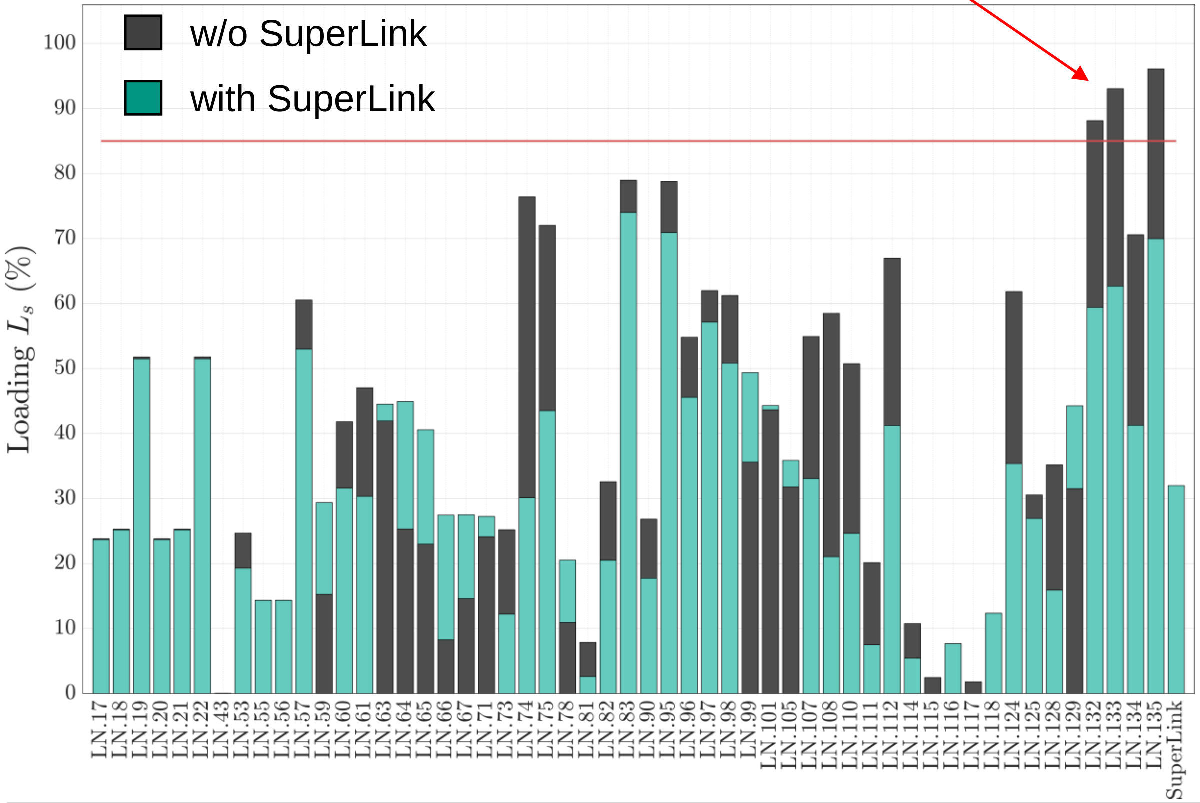
- **Load-Flow Calculations;**
  - Cable loading (percentage of current)
    - Cables with 85% of its capacity are considered “overloaded”
  - Maximum 3-phase short-circuit currents ("IK") on each 110 kV busbar of the network
    - Investigation on fault-current levels before and after the installation of SuperLink Cable
  - Voltage level (in p.u.) in each busbar.
    - Stability of the power system
  - Cable ohmic losses

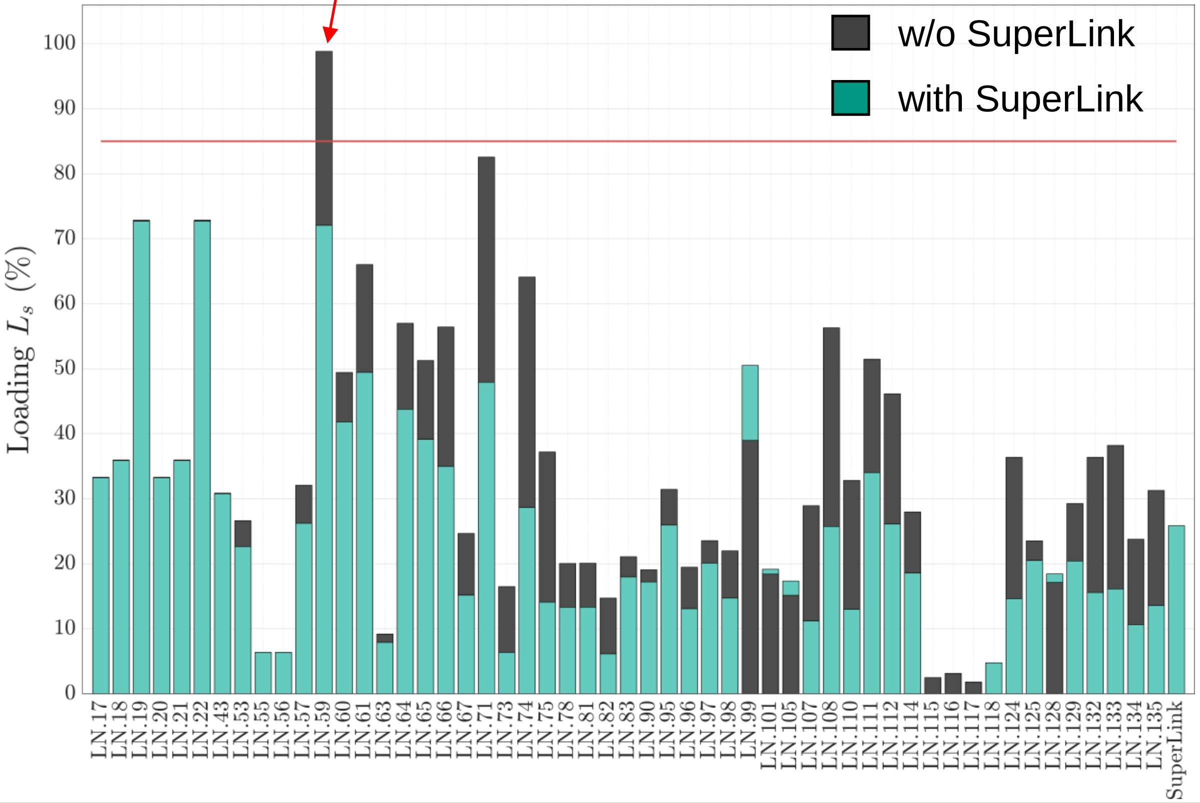
$$P_\Omega = \sum_{n=1}^{158} R_n \cdot I_n^2$$

  - Direction of load-flow
    - In the low load scenarioos, it is desirable that the power flows from South to North

Grid Simulation – Cable Loading and Losses

	L2 - (Medium Load Scenario)		L3 - (Low Load Scenario)	
	Overloaded Cables	Losses (MW)	Overloaded Cables	Losses (MW)
E1 (0 MVA)	3 / 0	2.73 / 1.84	0 / 0	0.22 / 0.14
E2 (871 MVA)	2 / 2	1.80 / 1.74	1 / 0	2.22 / 1.64
E3 (290 MVA)	0 / 0	2.14 / 1.74	0 / 0	0.42 / 0.35

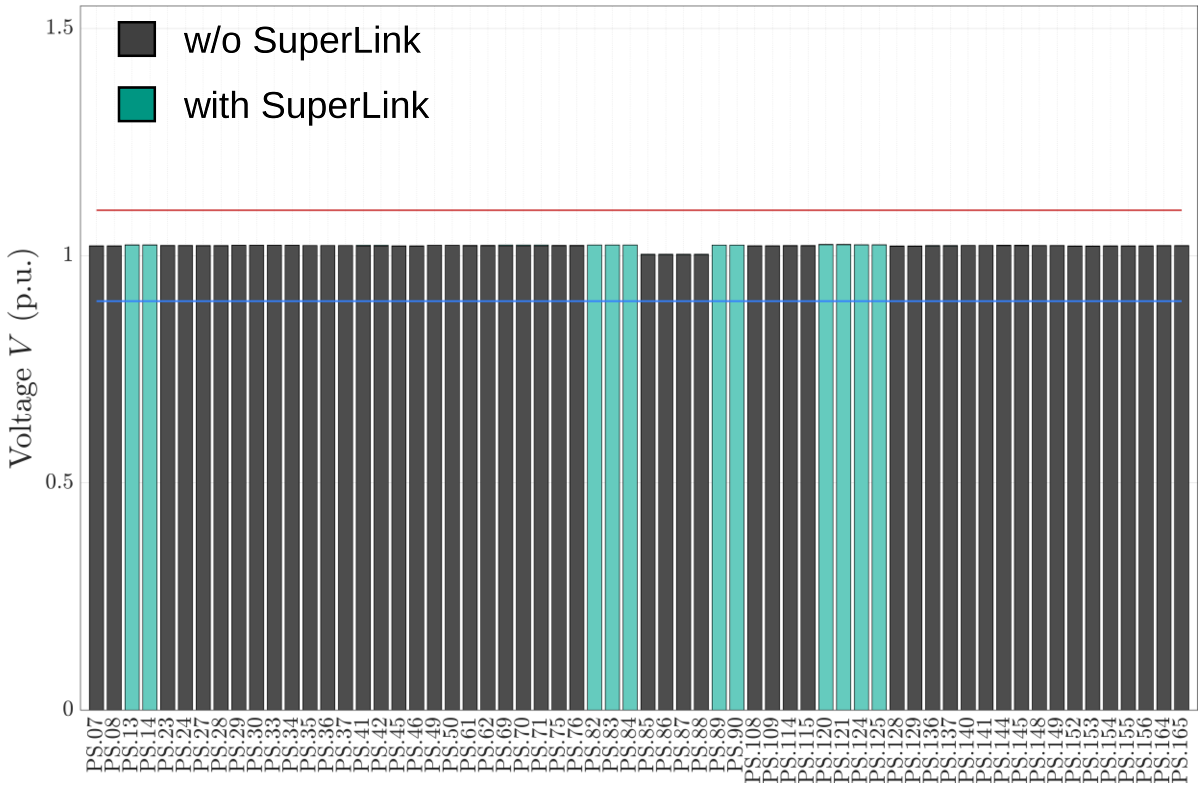


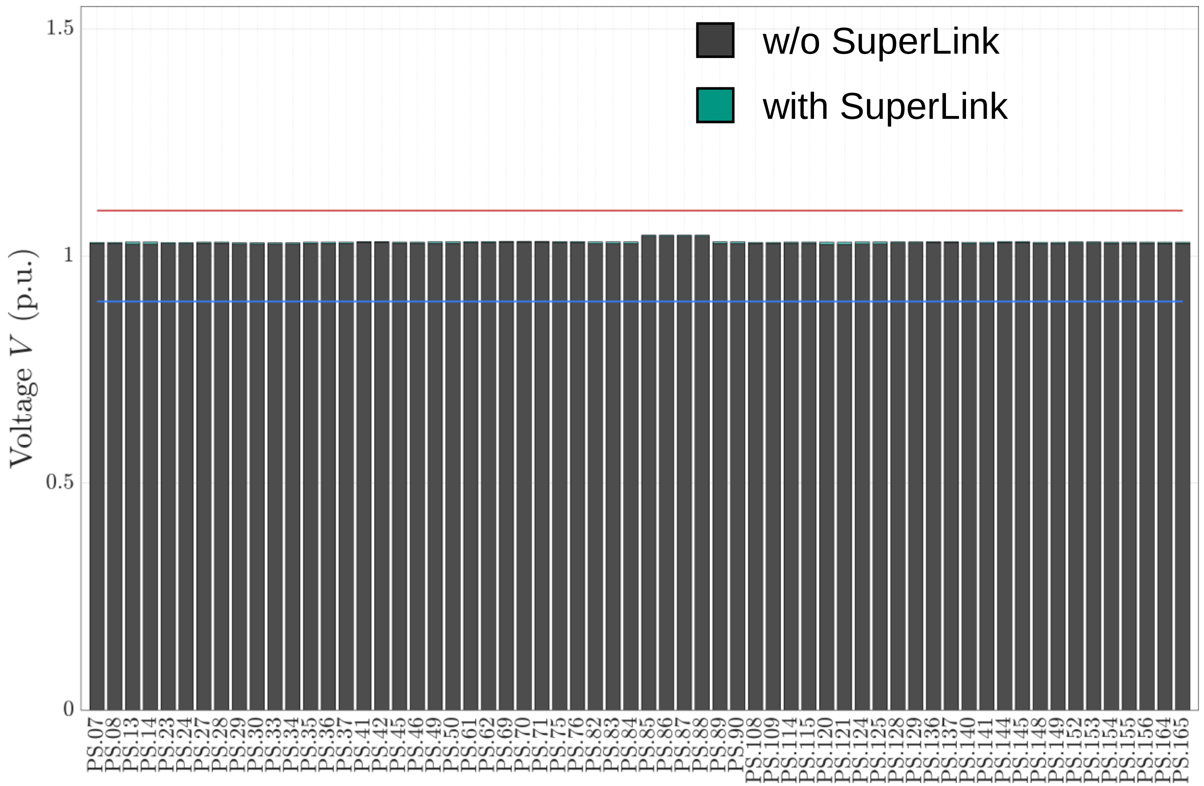


Grid Simulation – Voltage Levels

	L2 - (Medium Load Scenario)	L3 - (Low Load Scenario)
	Before / After	Before / After
E1 (0 MVA)	●/●	●/●
E2 (871 MVA)	●/●	●/●
E3 (290 MVA)	●/●	●/●

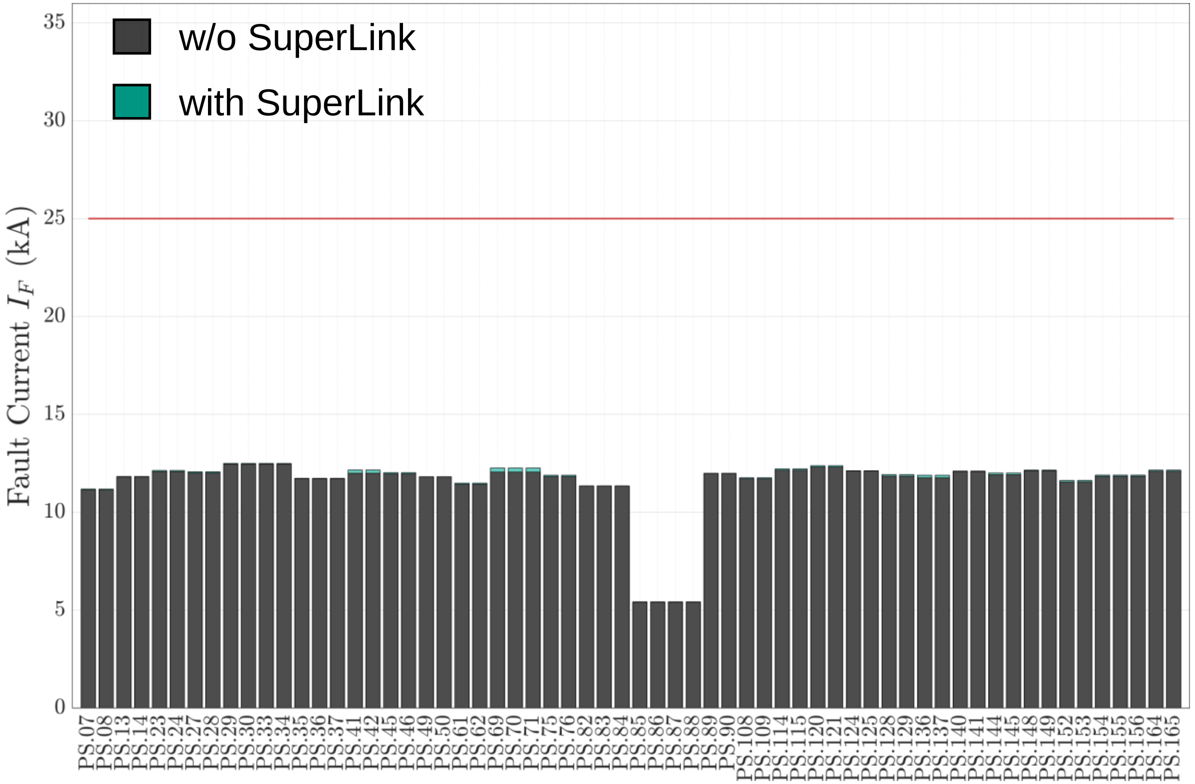
- ● Voltage level ≥ 1.1 p.u
- ● Voltage level = 1.0 p.u
- ● Voltage level ≤ 0.9 p.u

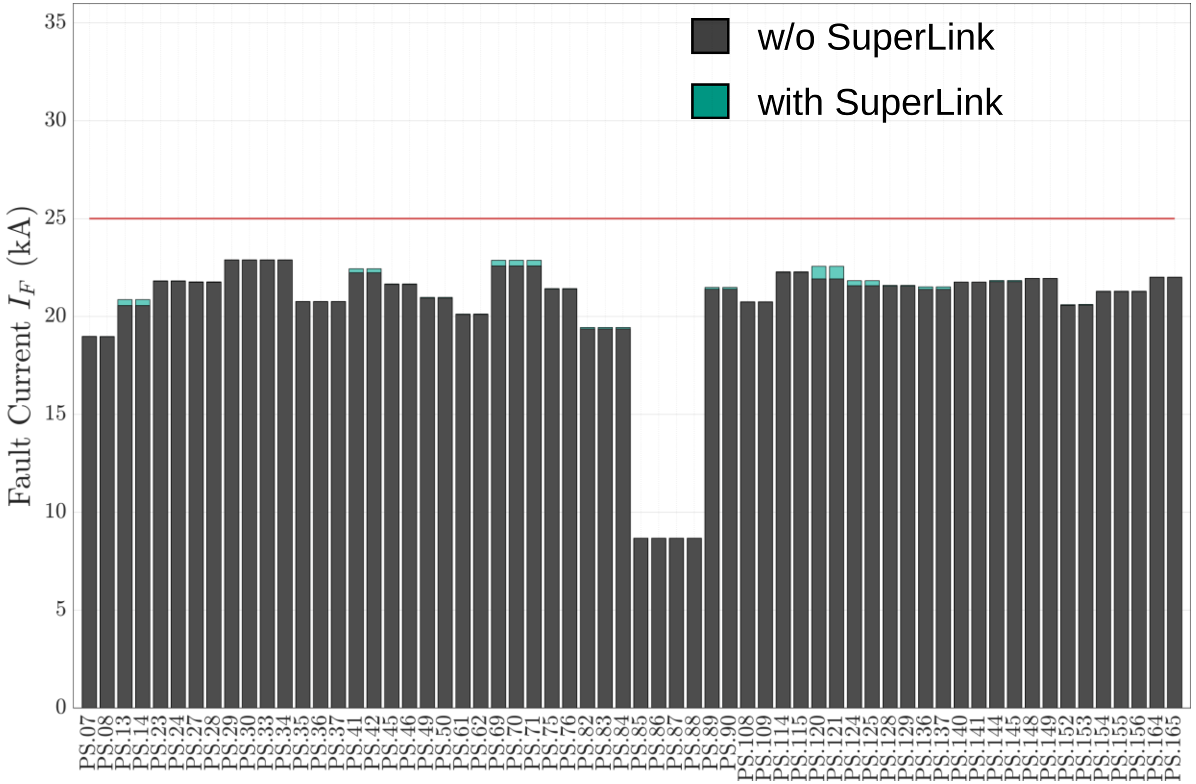




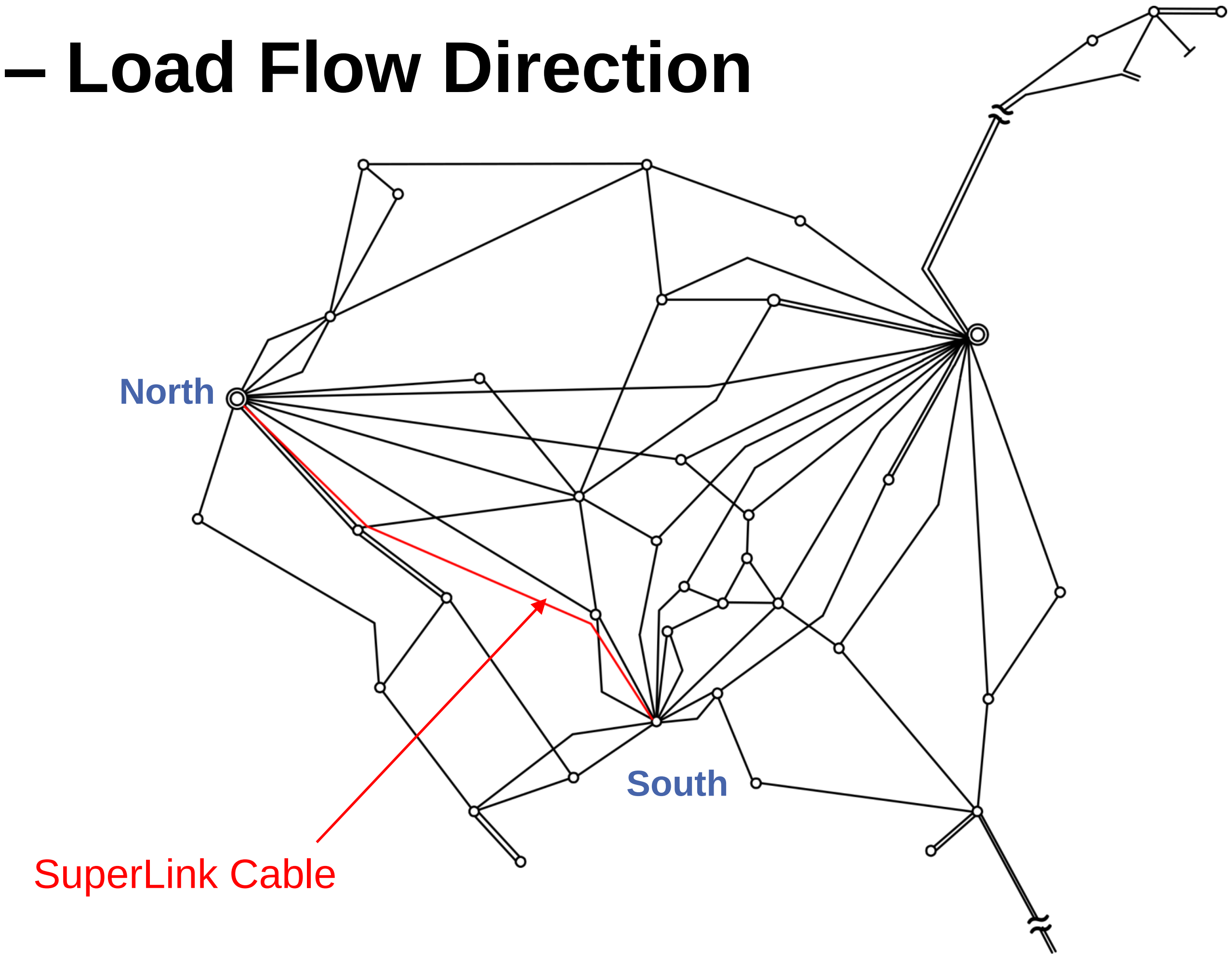
Grid Simulation – Fault Currents

	L2 - (Medium Load Scenario)	L3 - (Low Load Scenario)
	Before / After	Before / After
E1 (0 MVA)	≤ 25 kA / ≤ 25 kA	≤ 25 kA / ≤ 25 kA
E2 (871 MVA)	≤ 25 kA / ≤ 25 kA	≤ 25 kA / ≤ 25 kA
E3 (290 MVA)	≤ 25 kA / ≤ 25 kA	≤ 25 kA / ≤ 25 kA





Grid Simulation – Load Flow Direction



	L2 - (Medium Load Scenario)	L3 - (Low Load Scenario)
E1 (0 MVA)	from North to South	from North to South
E2 (871 MVA)	from North to South	from South to North
E3 (290 MVA)	from North to South	from South to North

Summary

- Several cables will benefit from the connection of the SuperLink cable in the 110 kV grid
- Overall Network losses are reduced
- In low-load scenarios, the power is transported from South to North
  - Project requirement fulfilled!
- Network remains stable
  - No changes on the busbars voltage levels
  - No increase on fault current levels

Danke!

Thank you very much for your attention!

Questions?

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