

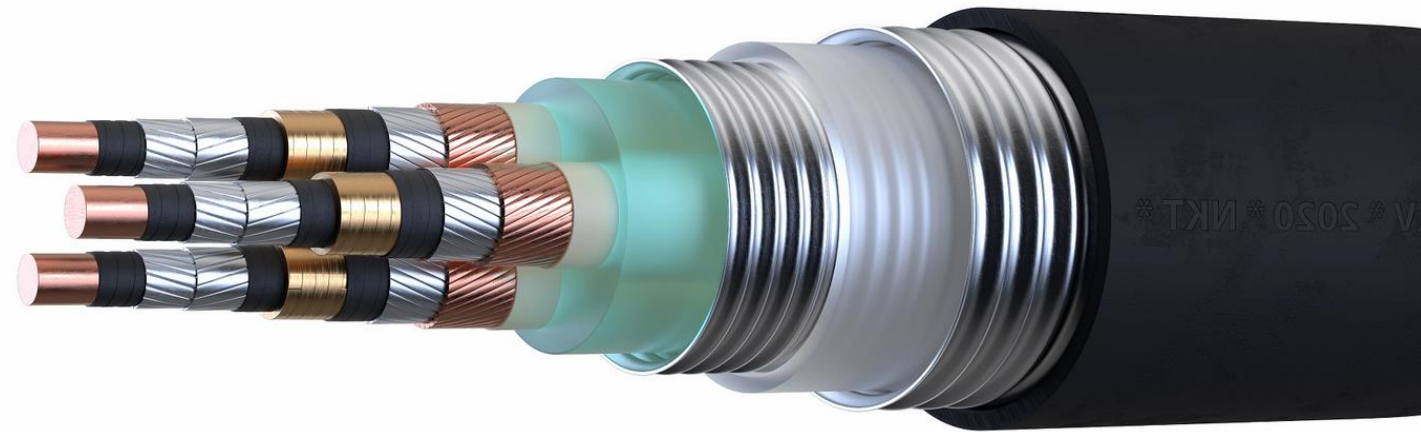
SuperLink

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)

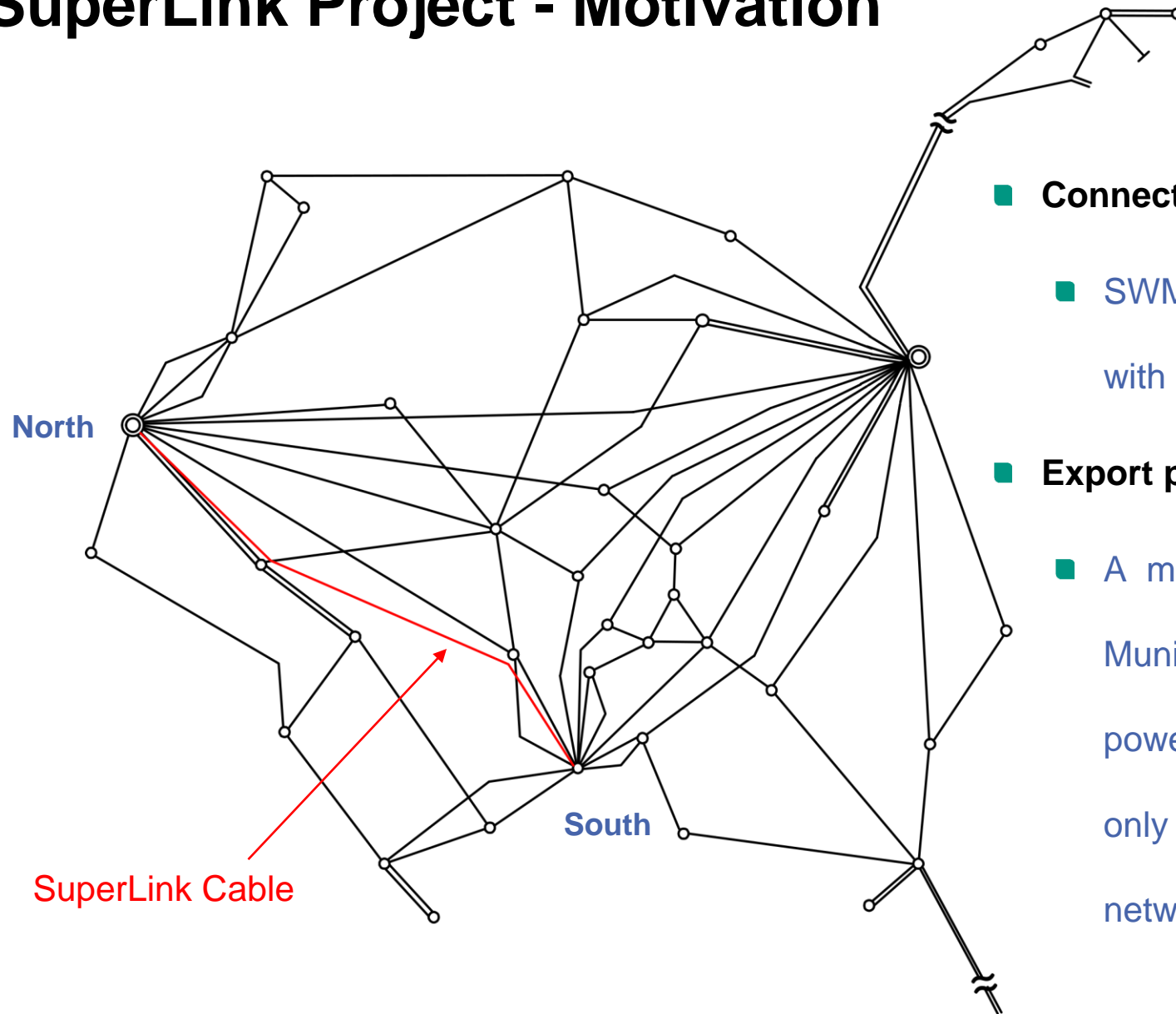
Im Stromnetz der Zukunft müssen große Mengen elektrischer Energie aus erneuerbaren Quellen in dicht bebaute städtische Lastzentren geleitet werden. Mit Supraleitern kann Strom ohne Widerstand und Verlust transportiert werden. „Die Leitung soll perspektivisch insgesamt zwölf Kilometer lang werden und kann eine bestehende 380 Kilovolt Leitung im regulären Betrieb ersetzen“, sagt Mathias Noe, Direktor des Instituts für Technische Physik am KIT. „Wir nutzen 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 Project - Motivation



- **Connect generation power station;**
 - SWM needs a high power line between North and South with 500 MW and appr. 12 km
- **Export power;**
 - A major challenge nowadays 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

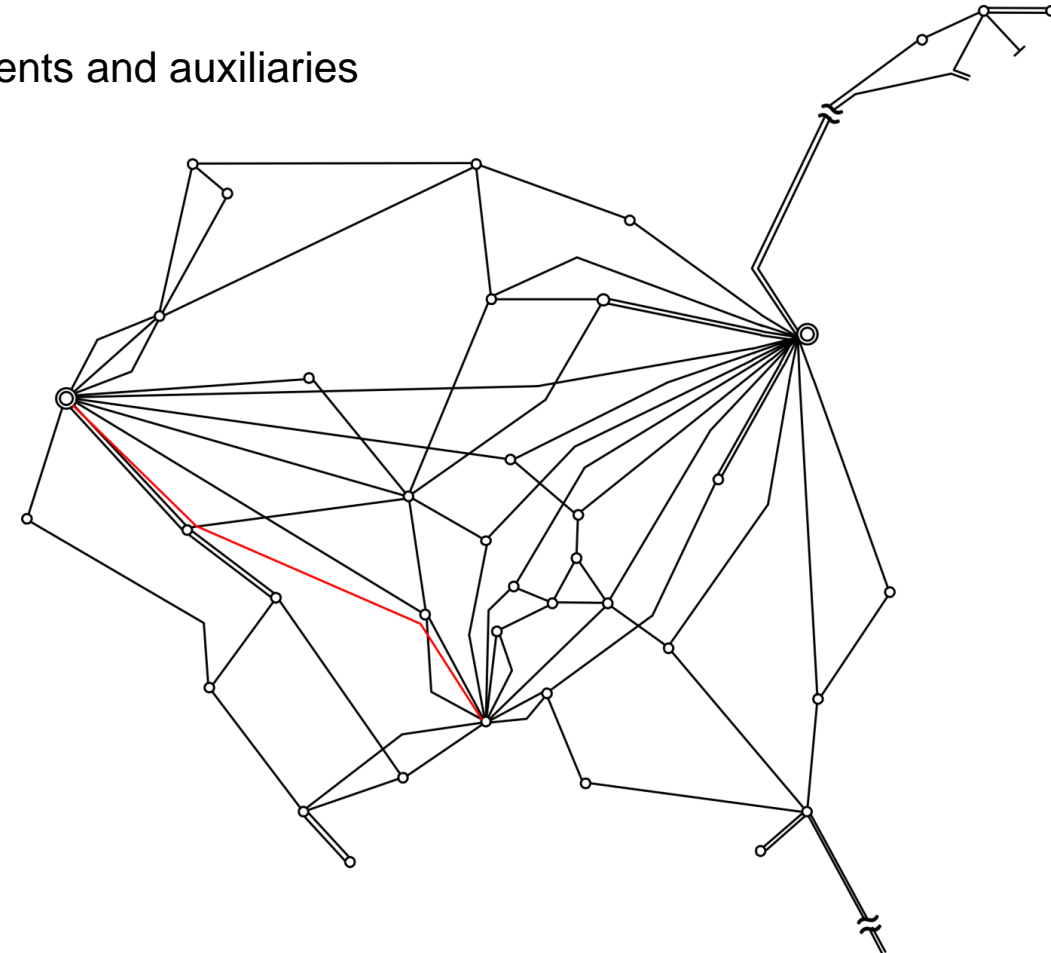
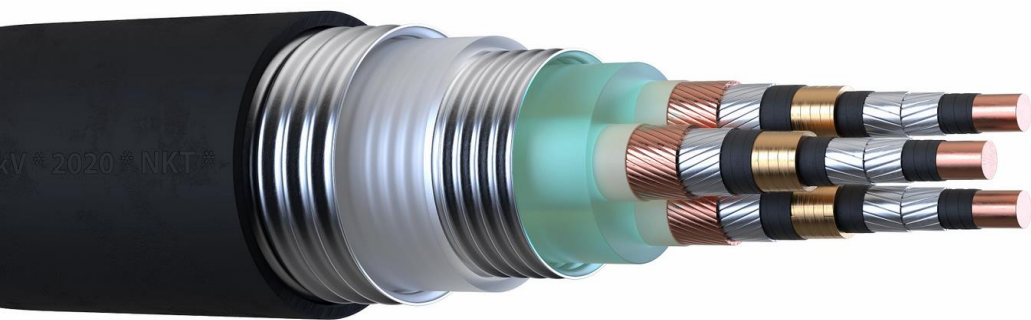
- can only be used with limited cross-section (500 or 630 mm² Cu) due to bending radii.

■ 110 kV HTS Cables

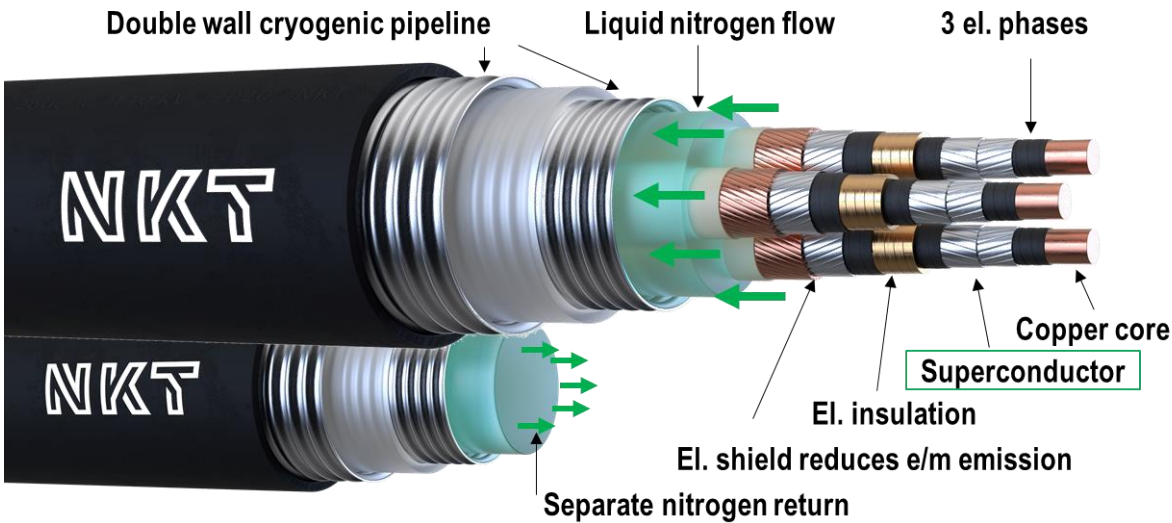
- Less Space required
- HTS-Cable can easily transport more than 500 MVA
- Low Losses

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

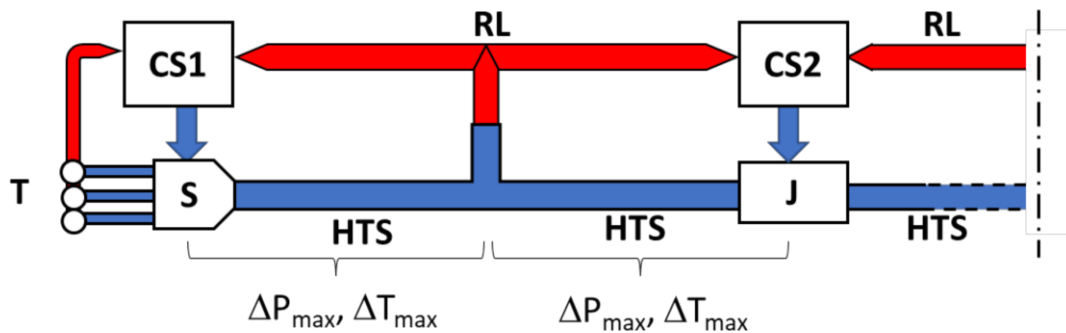


■ Cable Design

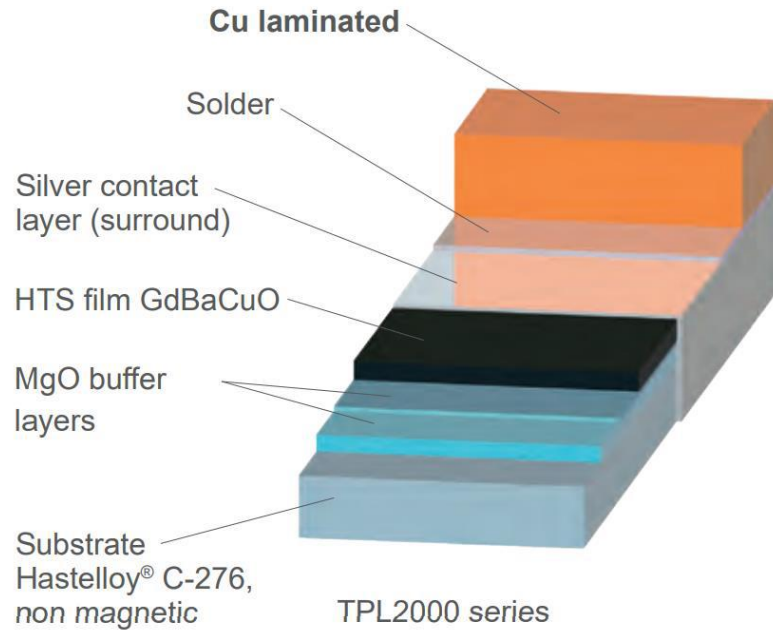
- 3 Phases in one Cryostat
- Superconducting phases and screens
- 110 kV, 500 MVA, 2.6 kA
- Low AC- Losses (lower than 0.5 W/m per phase)
- Fault Current Resilient (40 kA, 1 second)

■ Closed cooling system

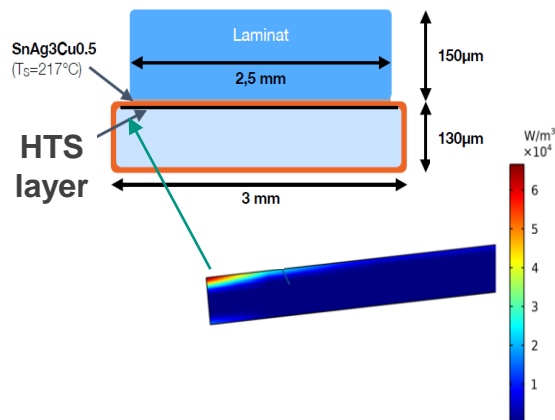
- Separate LN₂ return pipe (single, one-way cable)
- Low temperature and high pressure of LN₂ can be maintained in the main cryostat



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



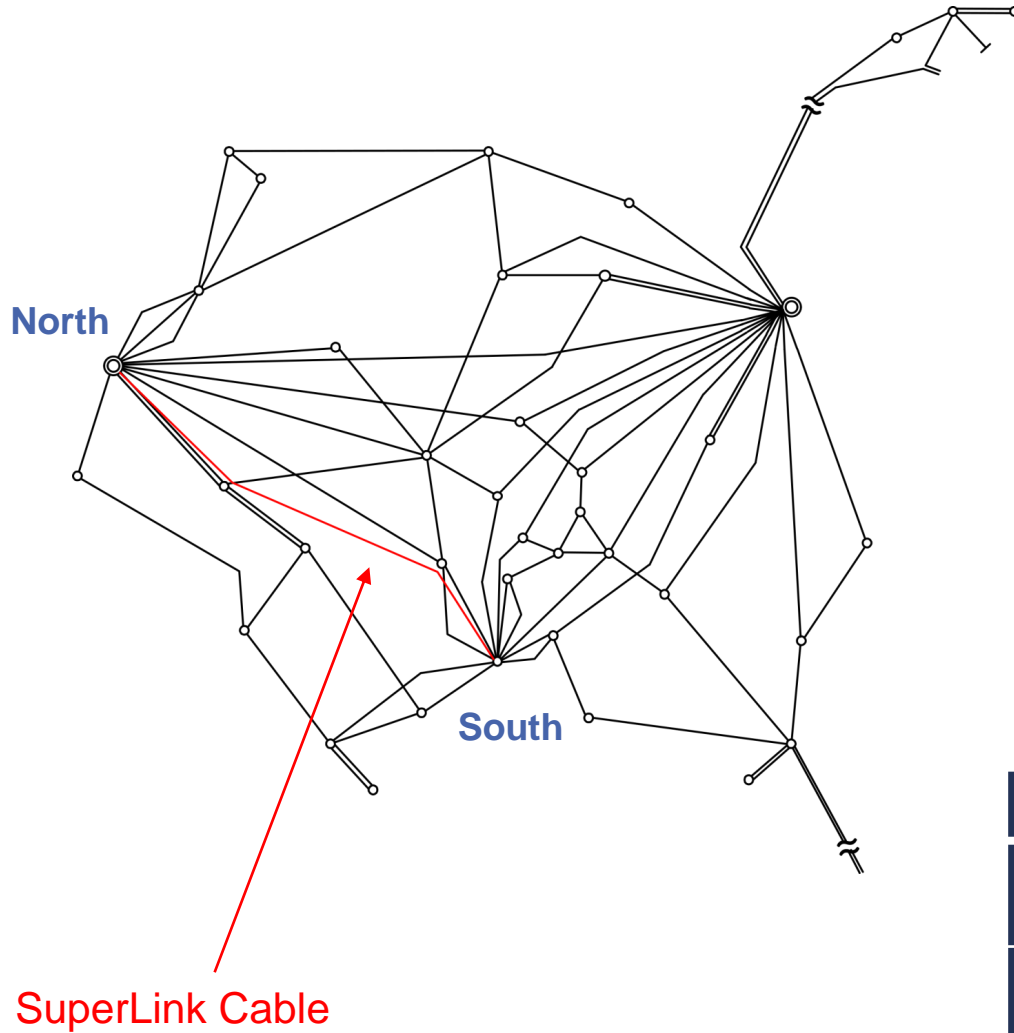
Further Questions?

Poster 3-MP-PR-02I - Development and testing of a 110 kV SuperLink system using HTS 2G wires

06/09/2023 – 11:30

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Grid Simulation – Load Scenario



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

| Scenario | Description | Total Load |
|----------|----------------------|------------|
| L2 | Medium Load Scenario | 1728 MVA |
| L3 | Low Load Scenario | 456 MVA |

Grid Simulation – Analysis method

▶ Load-Flow Calculations;

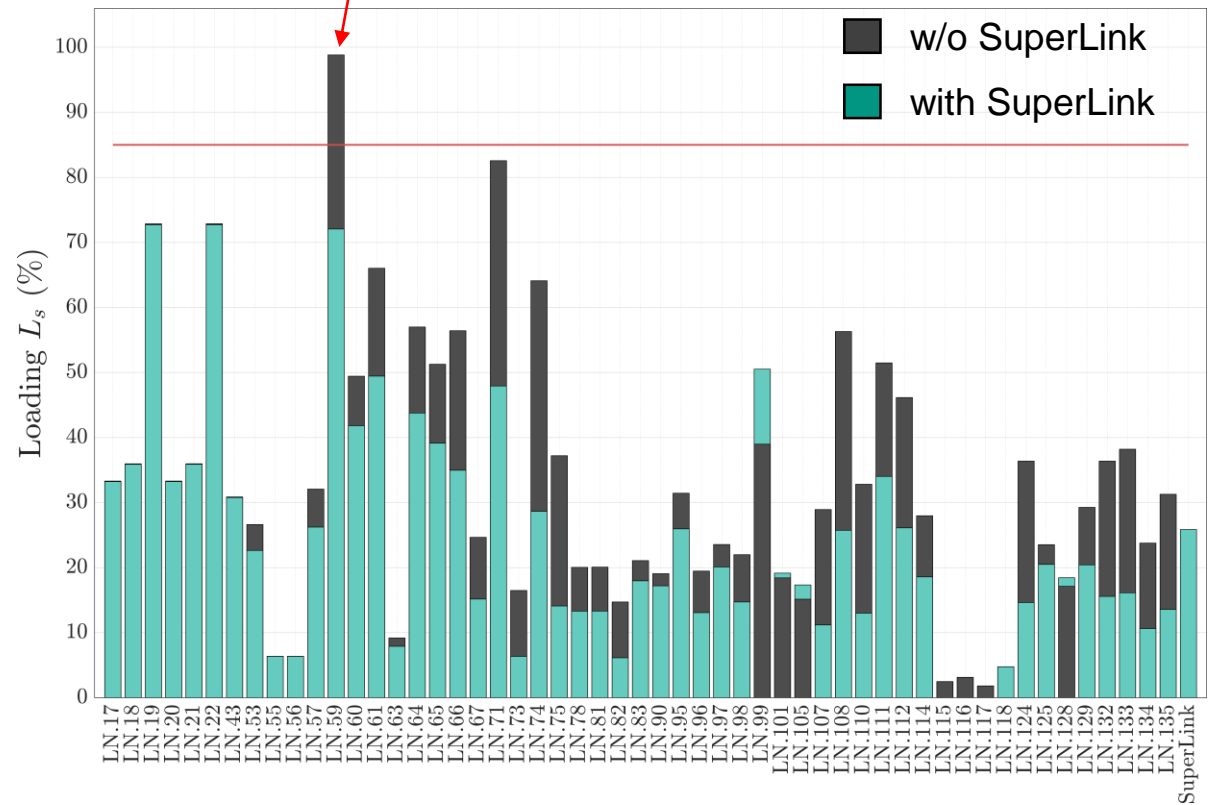
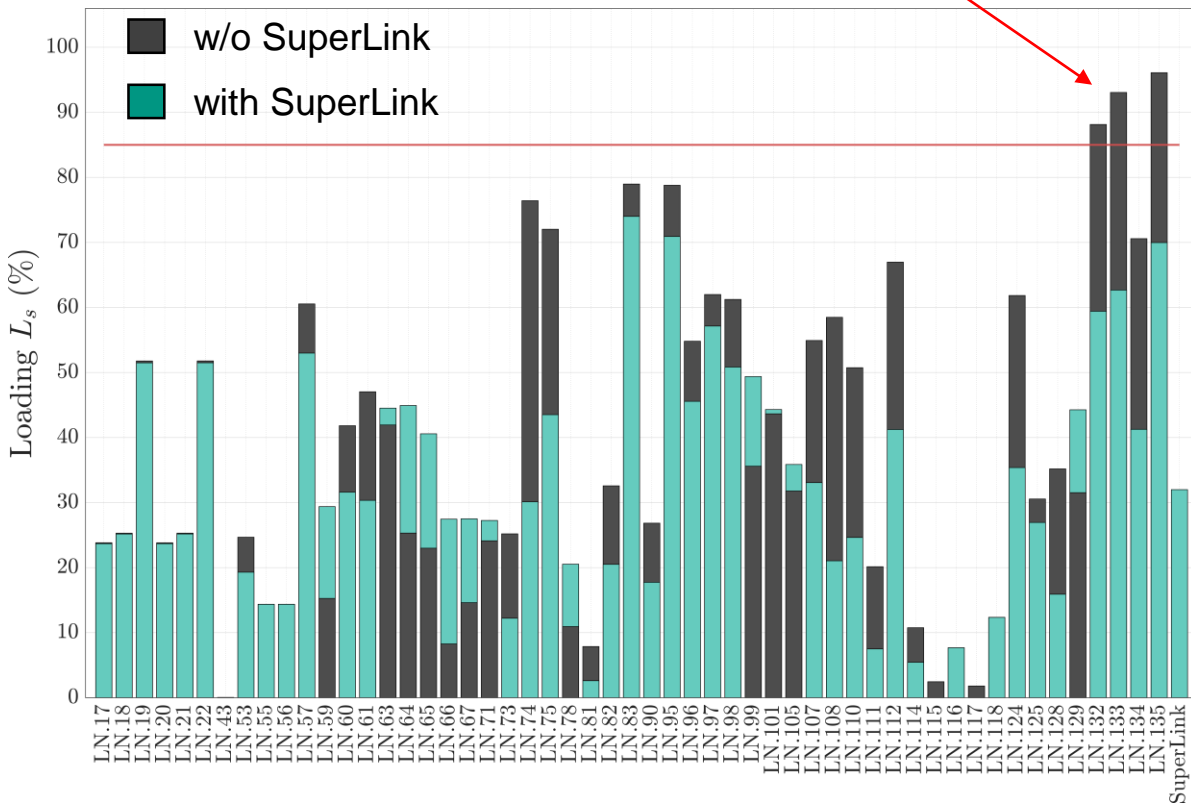
- ▶ Cable loading (percentage of current)
 - ▶ Cables with 85% of its capacity are considered “overloaded”
- ▶ Maximum 3-phase short-circuit currents ("IK") on each 110 kV busbar of the network
 - ▶ Investigation on fault-current levels before and after the installation of SuperLink Cable
- ▶ Voltage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

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

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

Grid Simulation – Cable Loading and Losses

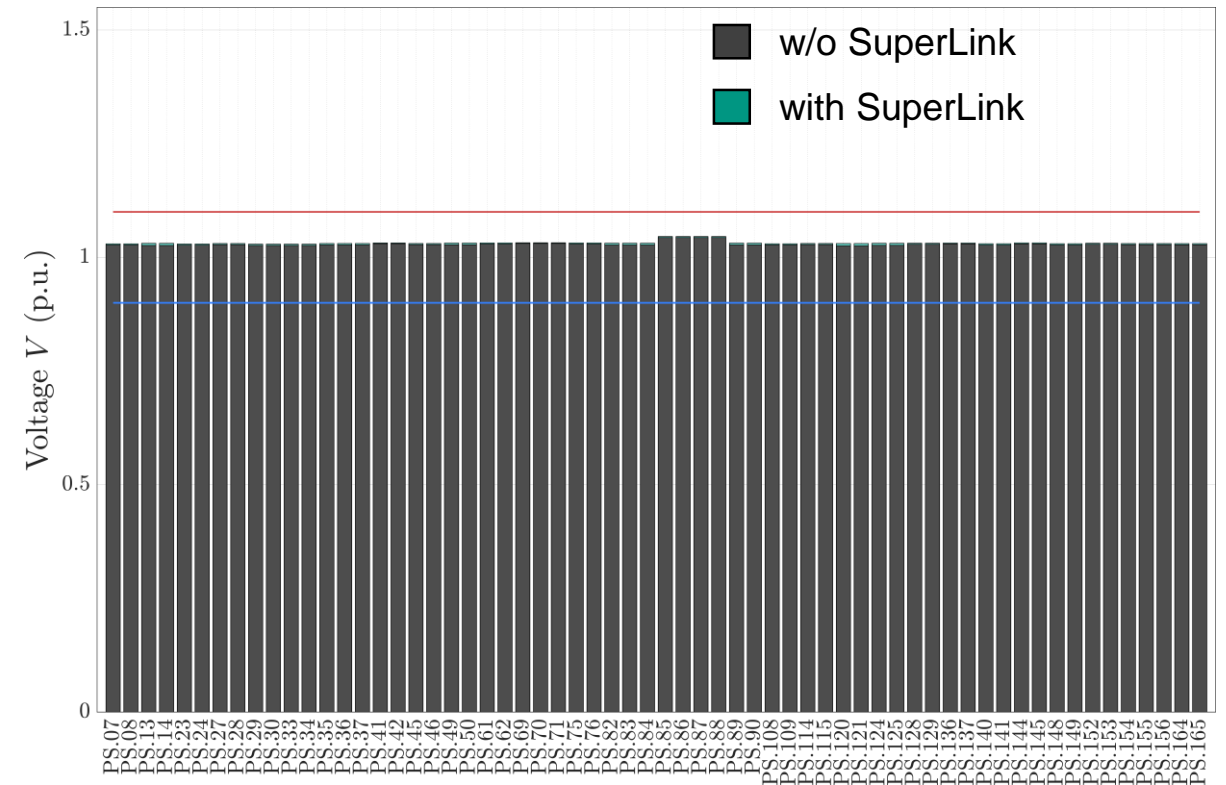
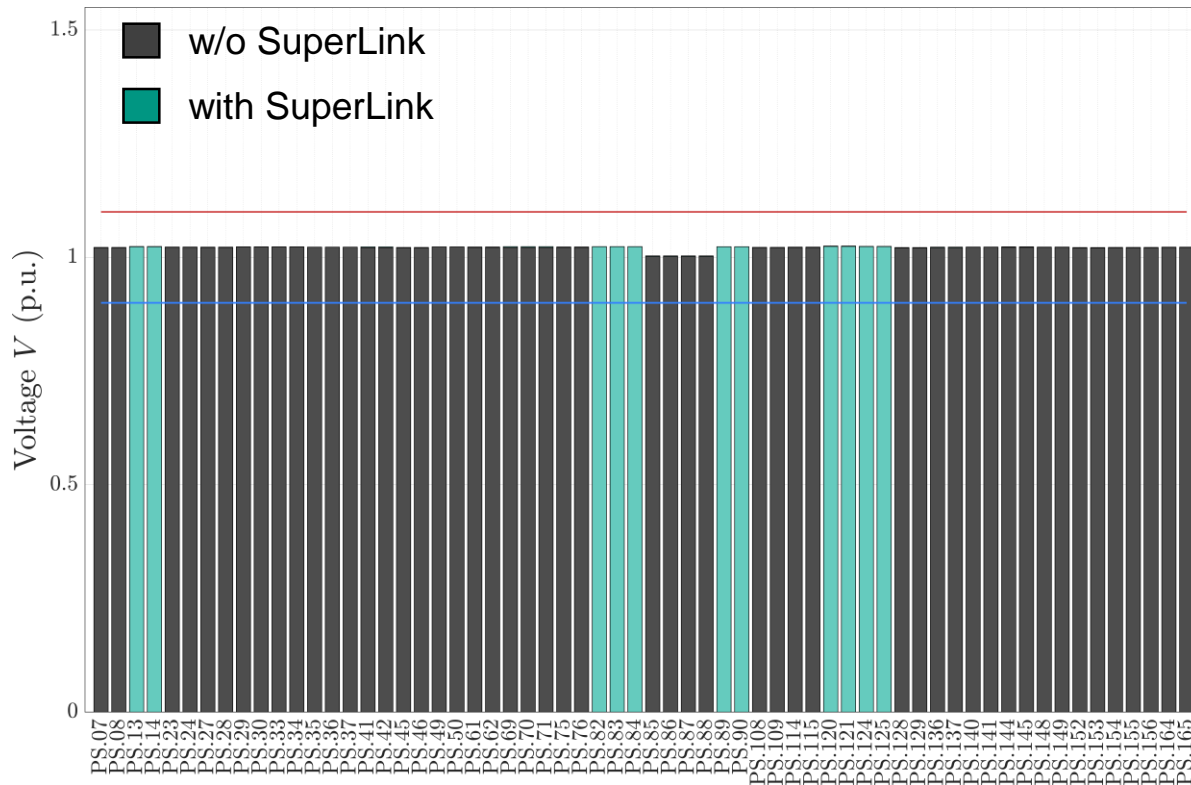
| | L2 - (Medium Load Scenario) | | L3 - (Low Load Scenario) | |
|--------------|-----------------------------|-------------|--------------------------|-------------|
| | Overloaded Cables | Losses (MW) | Overloaded Cables | Losses (MW) |
| E1 (0 MVA) | 3 / 0 | 2.73 / 1.84 | 0 / 0 | 0.22 / 0.14 |
| E2 (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

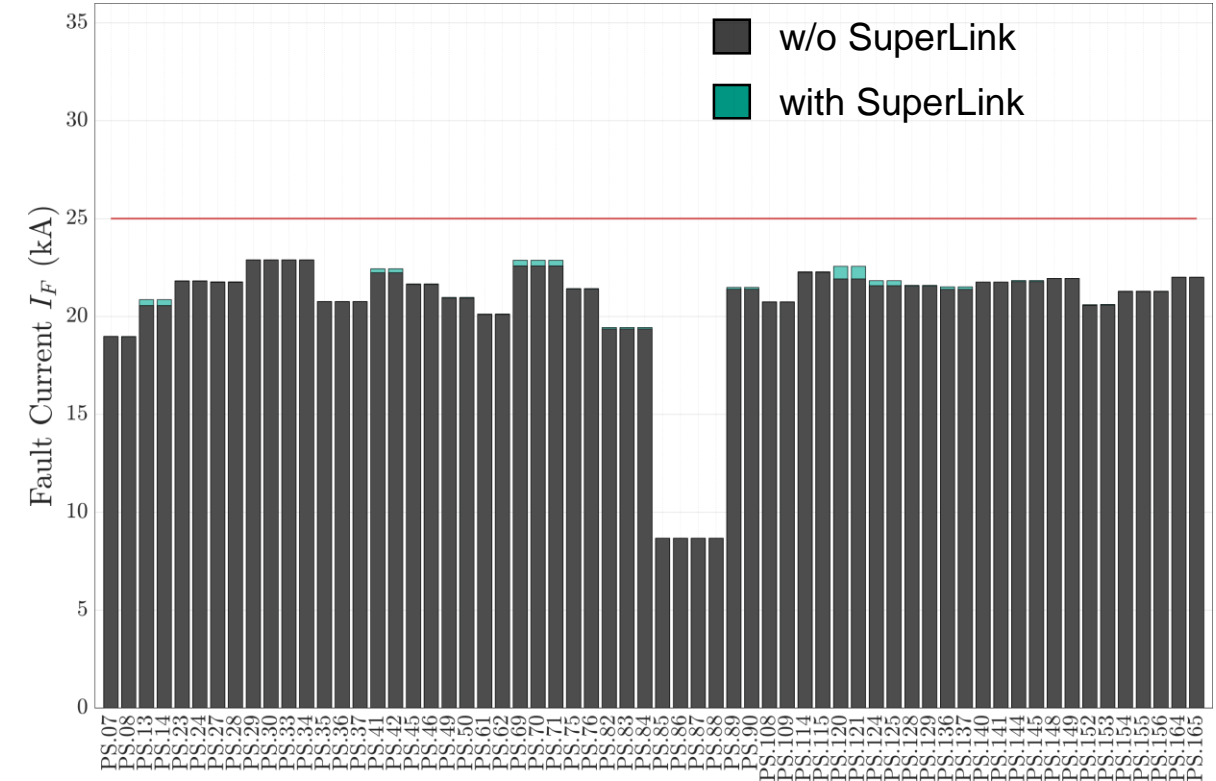
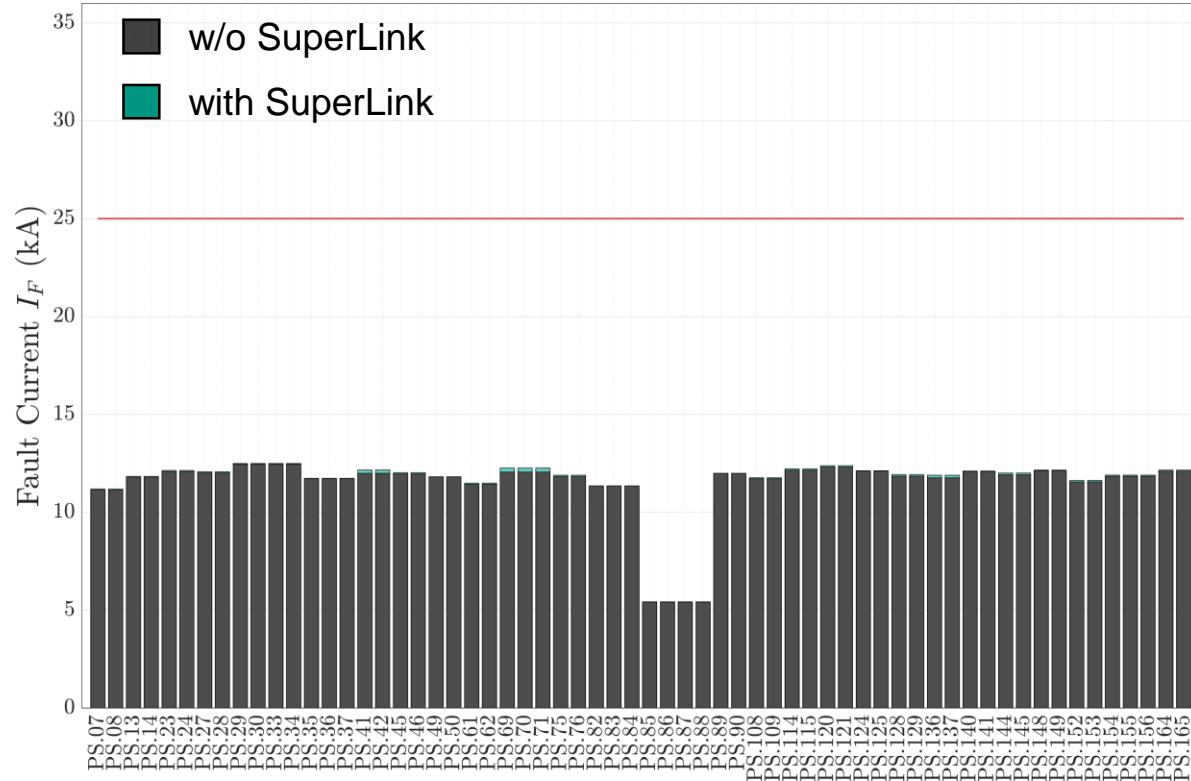
| | L2 - (Medium Load Scenario) | L3 - (Low Load Scenario) |
|--------------|-----------------------------|--------------------------|
| | Before / After | Before / After |
| E1 (0 MVA) | ./. | ./. |
| E2 (871 MVA) | ./. | ./. |
| E3 (290 MVA) | ./. | ./. |

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

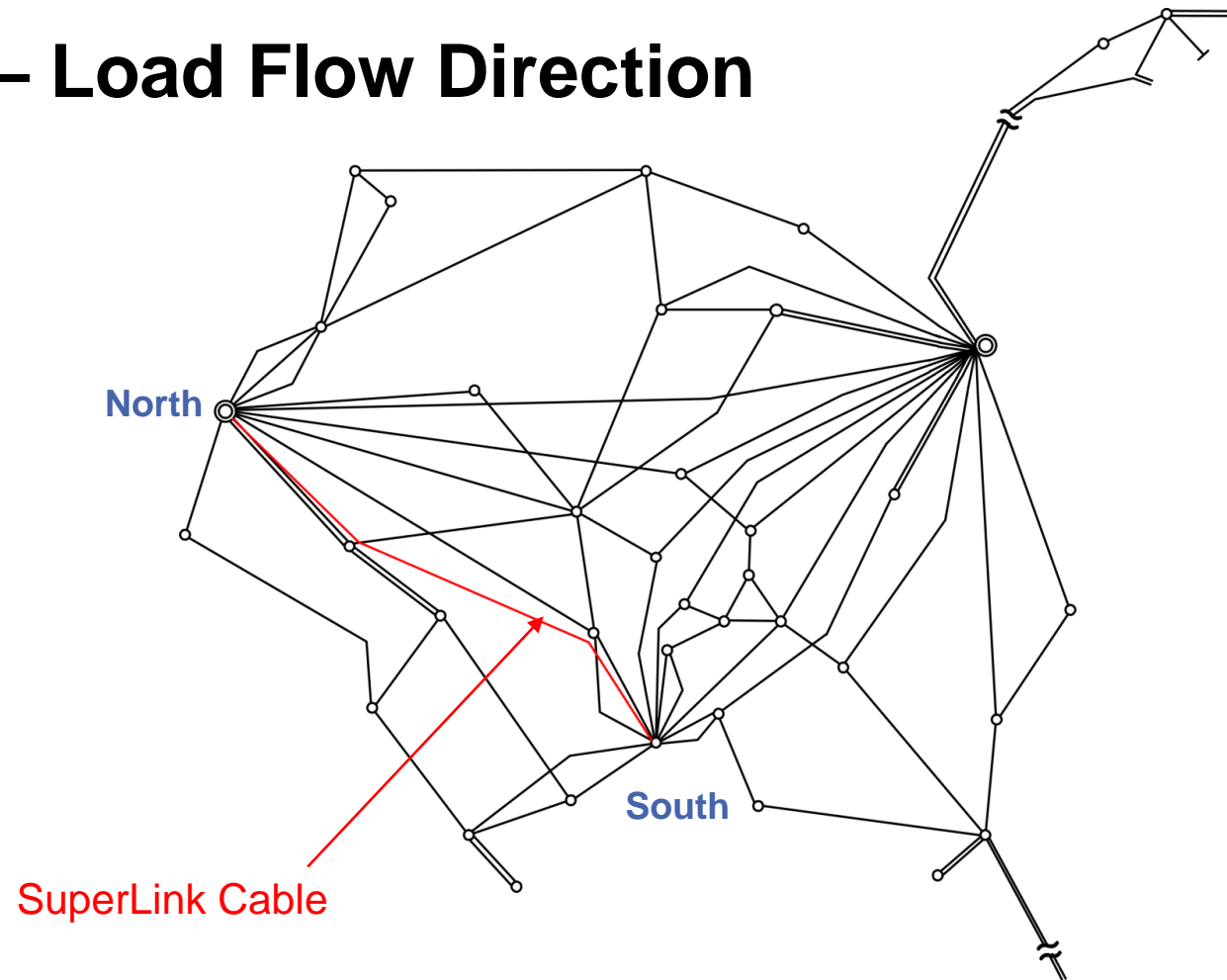


Grid Simulation – Fault Currents

| | 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 |

- 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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