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Karlsruhe Institute of Technology

SuperLink

Bundesministerium für Wirtschaft und Klimaschutz

SuperLink

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

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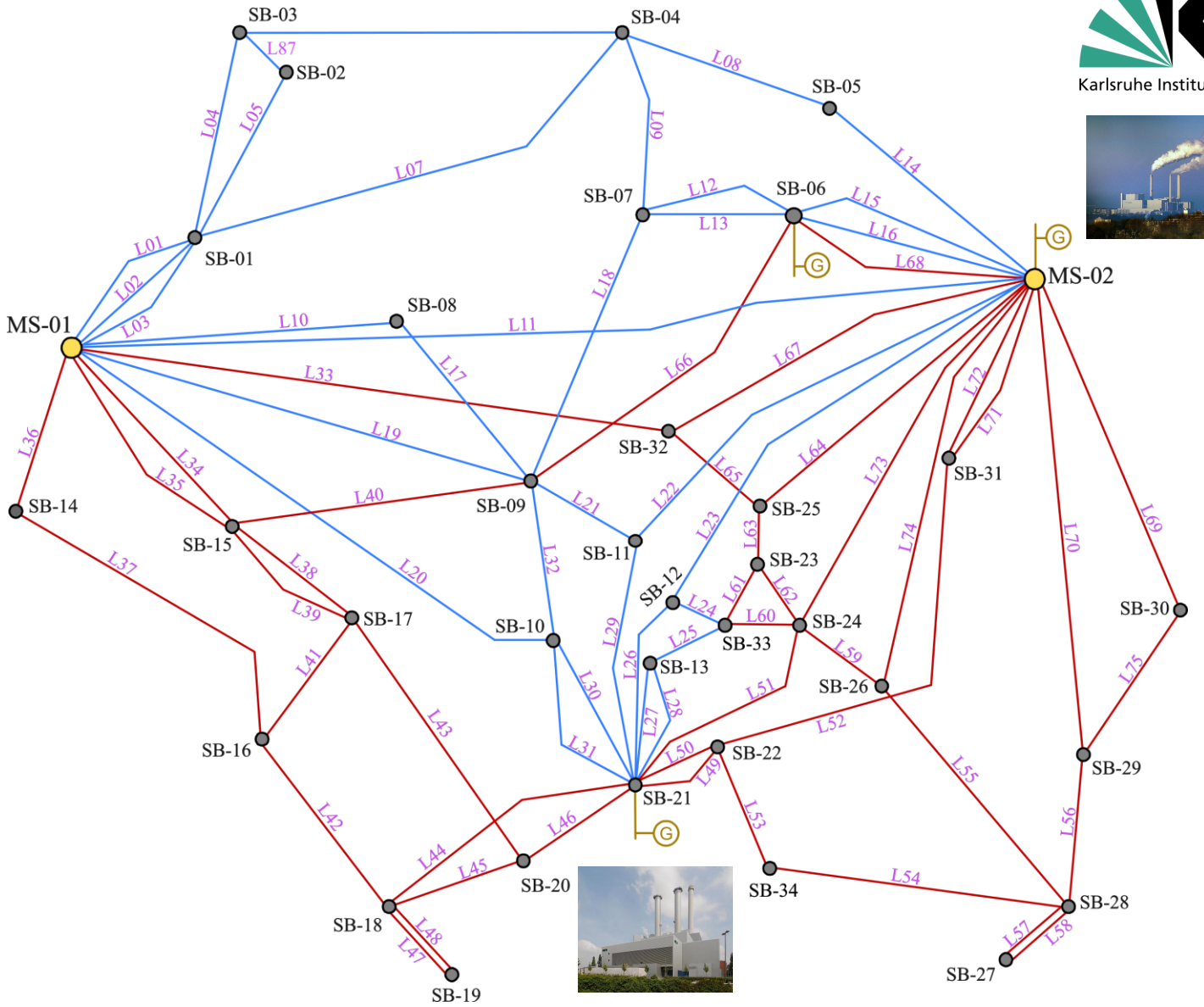
Background

- The conversion to electrical energy use, especially in the commercial, building and transport sector leads to a significant increase in the demand for electrical energy
  - Huge impact on distribution network
  - On its majority, old and no longer suitable for the upcoming load flow

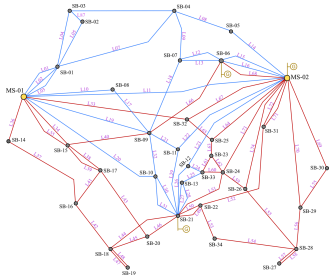
Munich 110 kV Network

SWM 110 kV-Network	
Cable Connections	87 Lines
Total Cable Length	383 km
Busbars	158

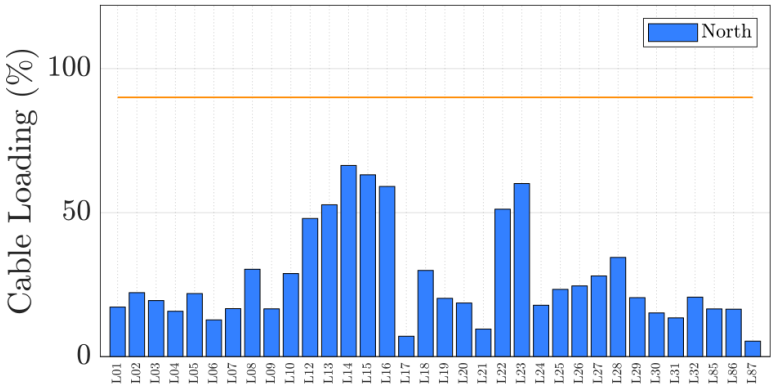
SWM 110 kV-Network Thermal Power Station	
SB-21	638 MVA
MS-02	276 MVA
SB-06	100 MVA

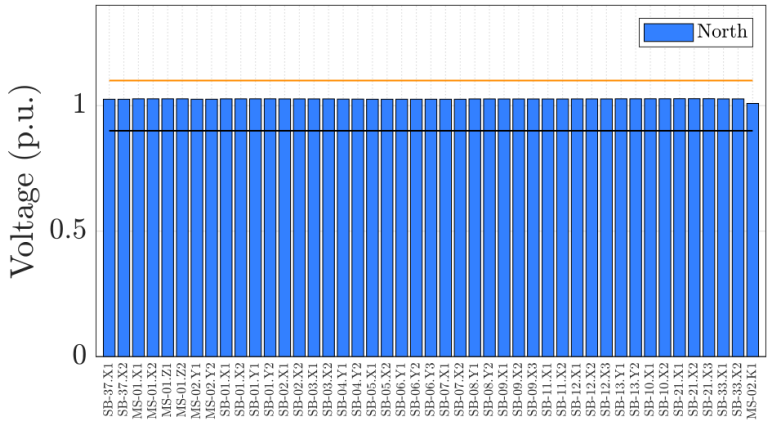


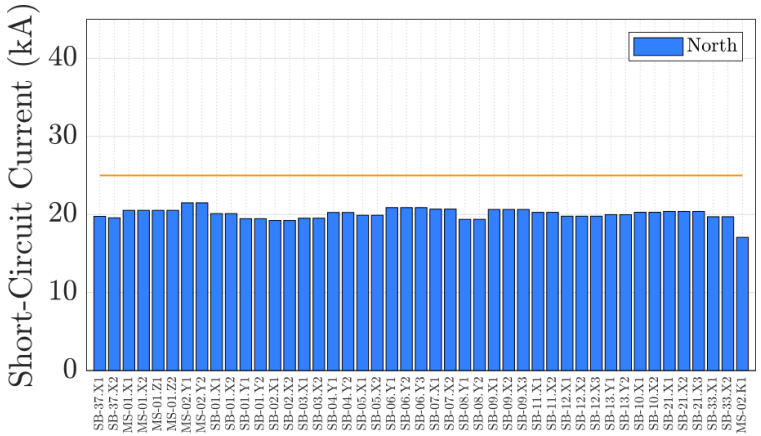
Munich 110 kV Network – Load Flow Analysis

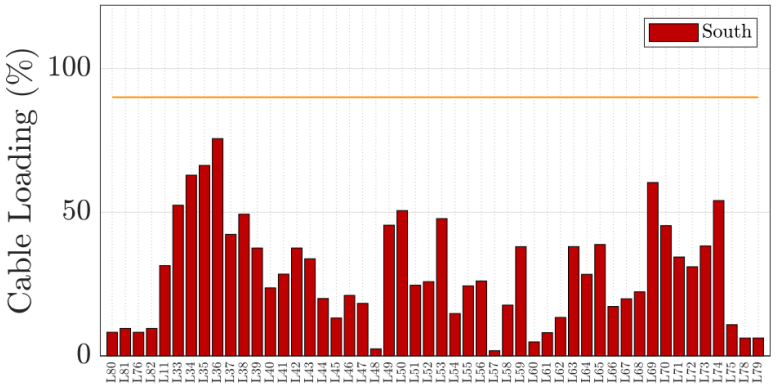


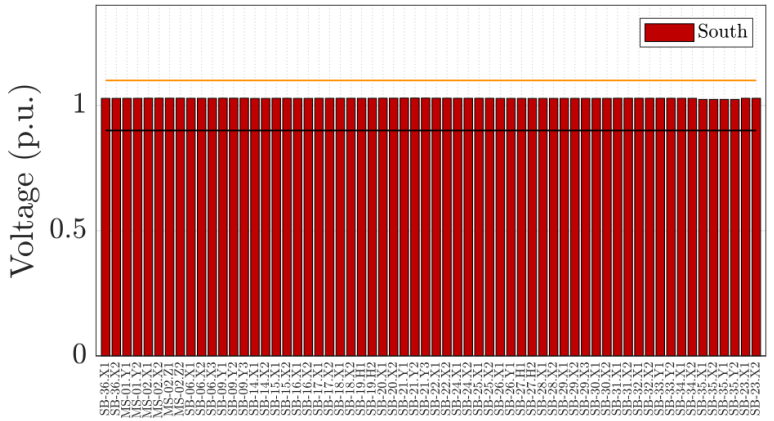
- 2019 – Peak Load = 1210 MVA
  - Network running fine

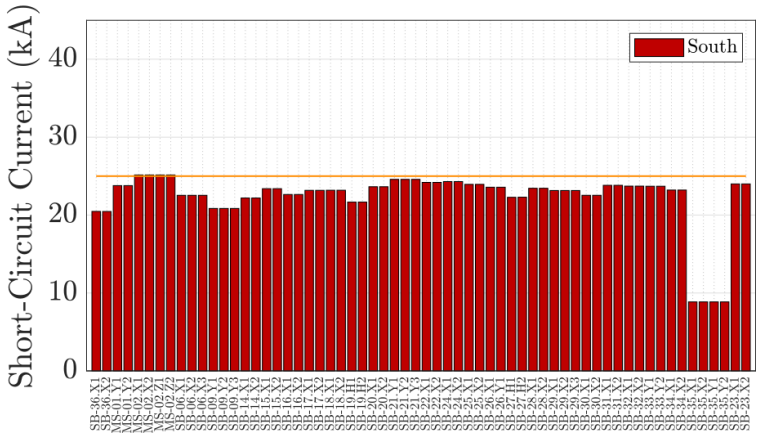












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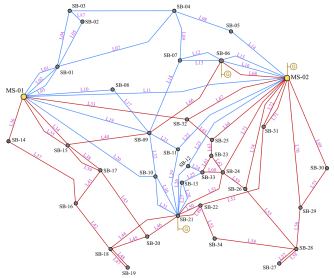
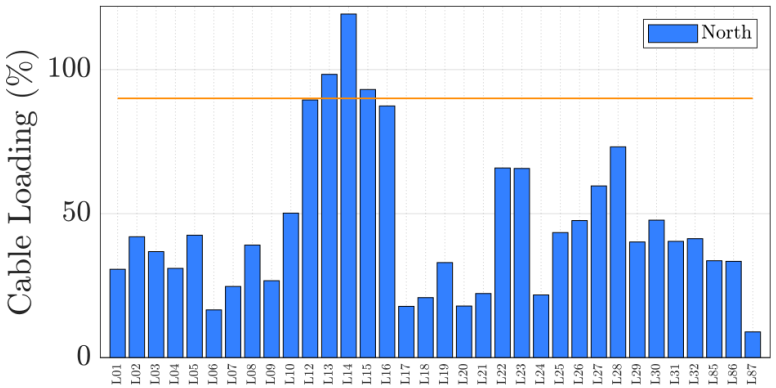
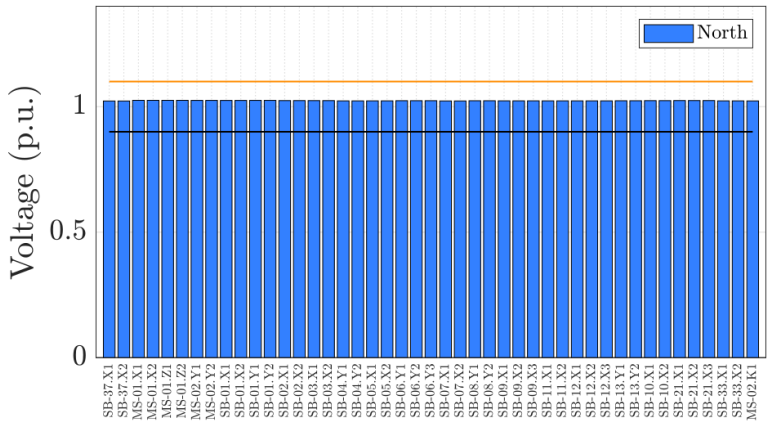
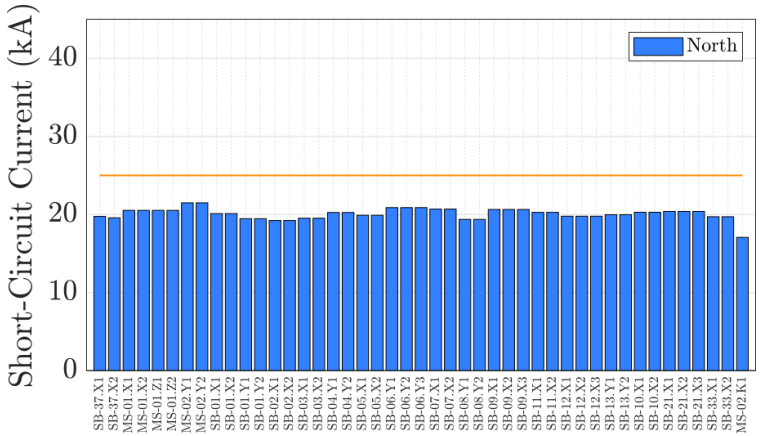
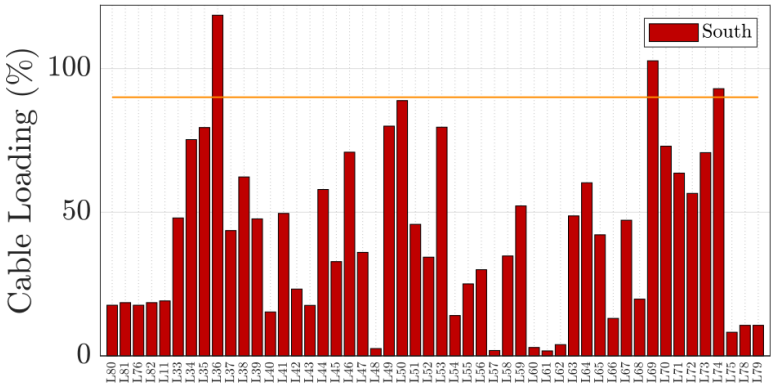


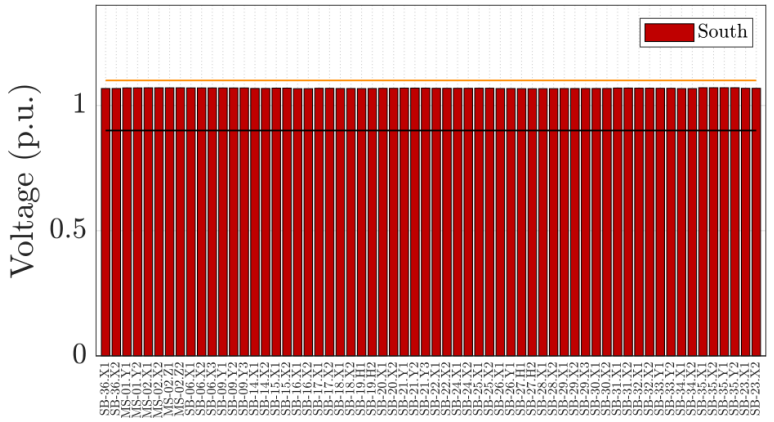
- Projection of the Peak Load for the next years ≈ 2500 MVA
  - Critical situation – not only overloaded cables, but also…..

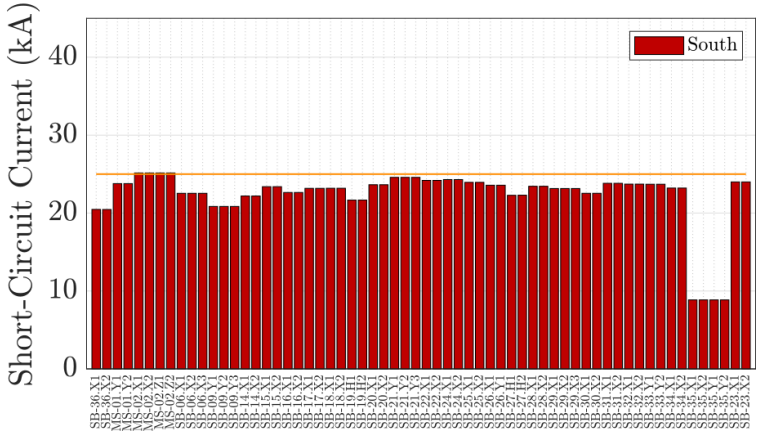






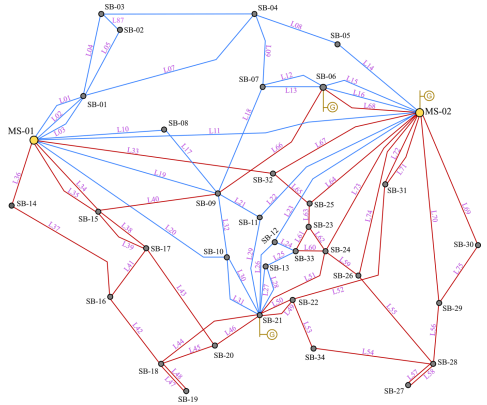






Munich 110 kV Network

- Projection of the Peak Load for the next years ≈ 2500 MVA
- Besides the overloading of cables…
  - To supply such a high load, all the thermal power stations must be dispached
    - Not good from the economical point of view…
    - Not good from the ecological point of view…
  - Network must be changed!



Munich 110 kV Network – Possible Solutions

- **400 kV XLPE Cables**
  - Requires construction of tunnels
  - High construction costs

- **400 kV Overhead Lines**
  - 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 Cable**
  - Less space
  - HTS-Cable can easily transport more than 500 MVA
  - Low Losses

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."

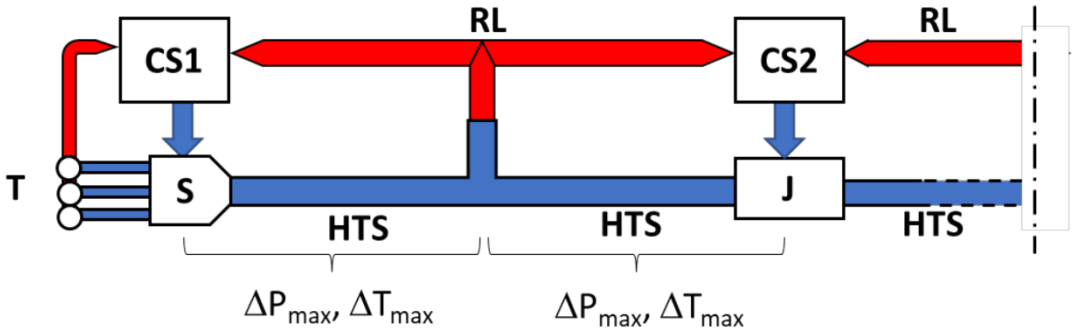
Gemeinsam möchte das Konsortium innerhalb von zwei Jahren alle notwendigen technischen Voraussetzungen erfüllen und die wichtigsten Komponenten entwickeln; hierzu gehören ein 200 Meter langes Kabelteilstück, Endverschlüsse und die Kühlung. Nach erfolgreichem Abschluss des Projektes sollen dann die zwölf 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 – Cable Layout

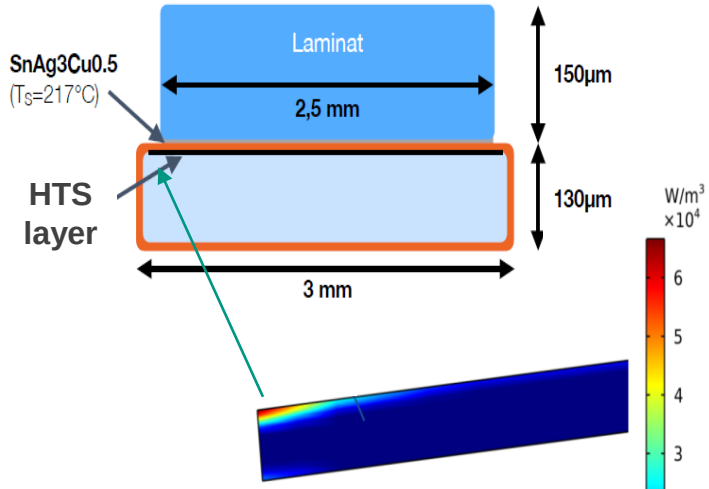
- **Cable Design**
  - 15 km long high-power HTS cable
  - 110 kV, 500 MVA, 2.6 kA
  - Superconducting phases and screens
  - Fault Current Resilient (40 kA, 1 s)
  - 3 Phases in one Cryostat
  - Low AC- Losses (lower than 0.5 W/m per phase)

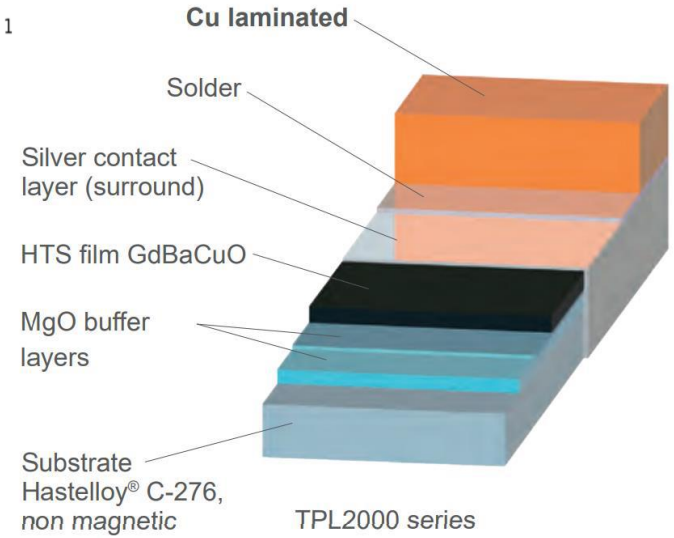
- **Closed cooling system**
  - Separate LN_2 return pipe (single, one-way cable)
  - Low temperature and high pressure of LN_2 can be maintained in the main cryostat



SuperLink – HTS Tapes

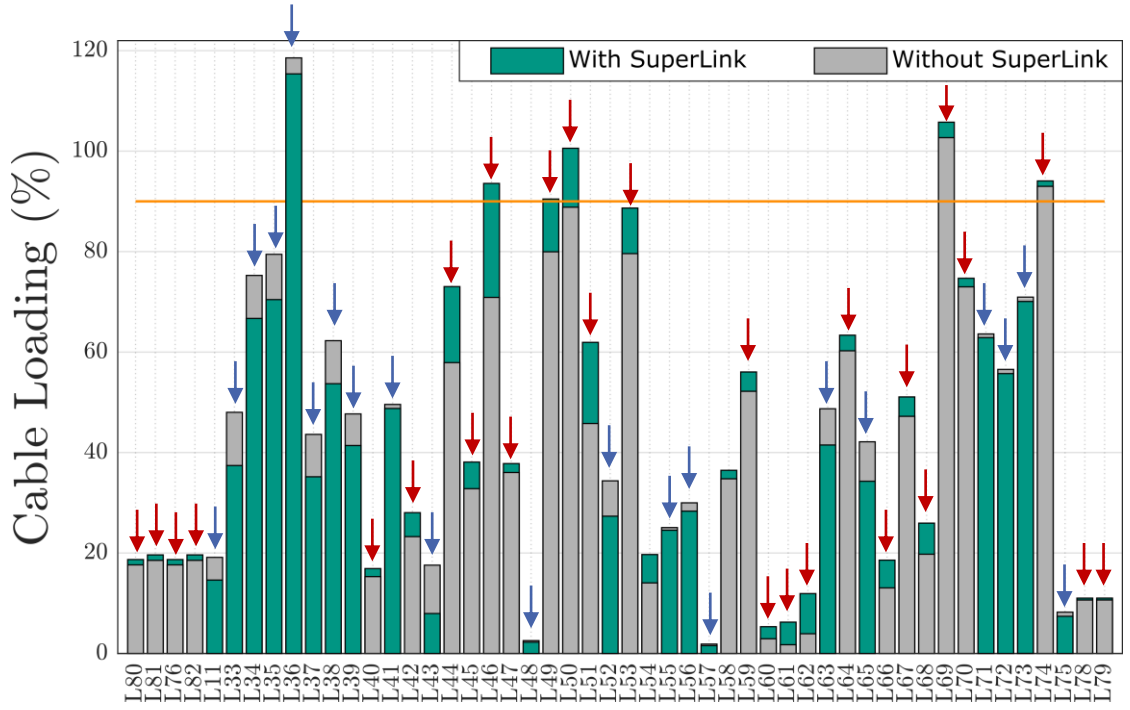
- HTS wire optimized for AC-cable manufacturing
- Robust, single-sided Cu-laminated
- Optimized for low AC-losses
- 3 mm laser-slit wire, narrow tolerances
- Trapezoidal shape to fit on round core and minimize gaps
- $I_{c,avg}$ (3mm, @77 K) = 163 A

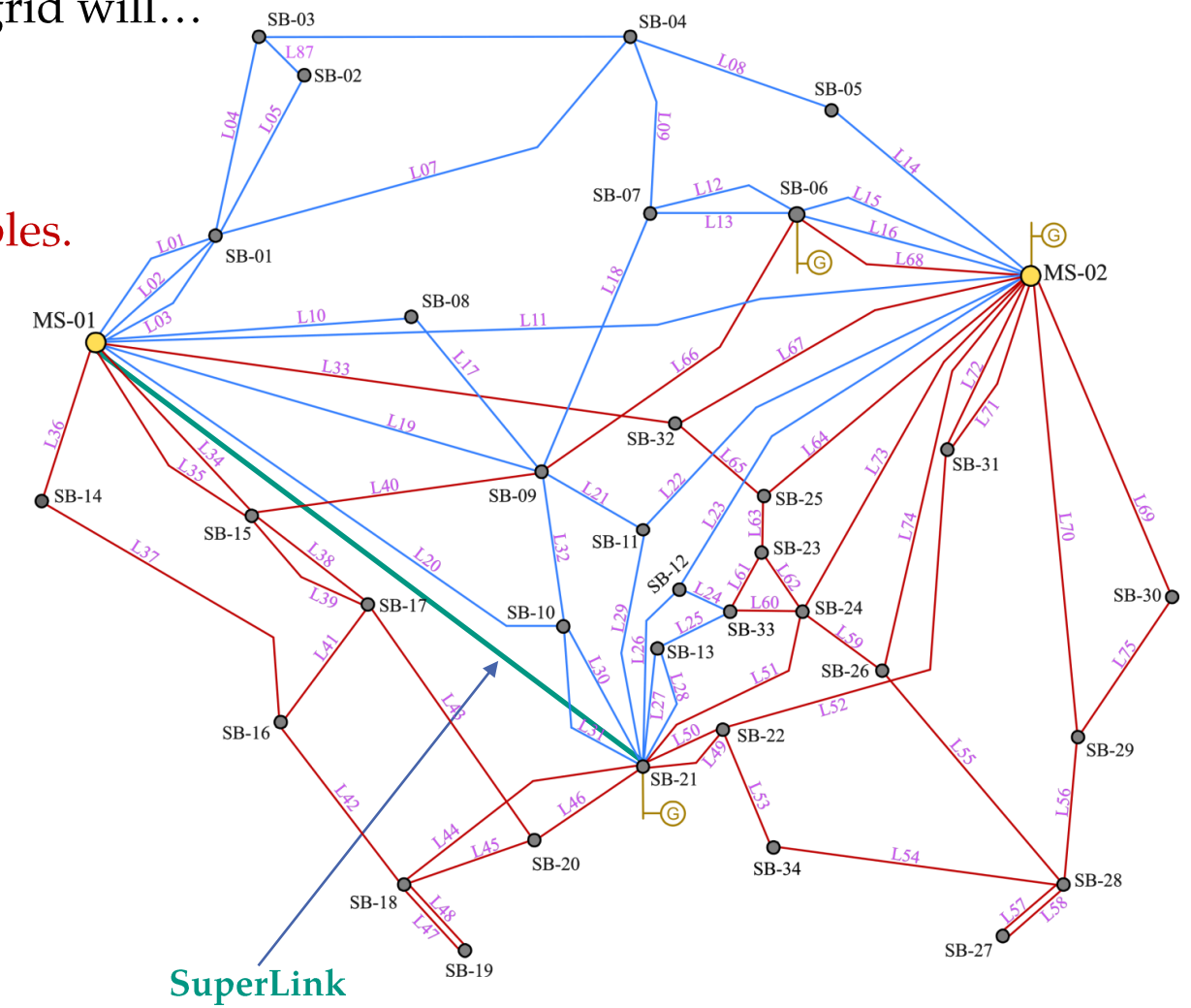




Munich 110 kV Network - Restructuring

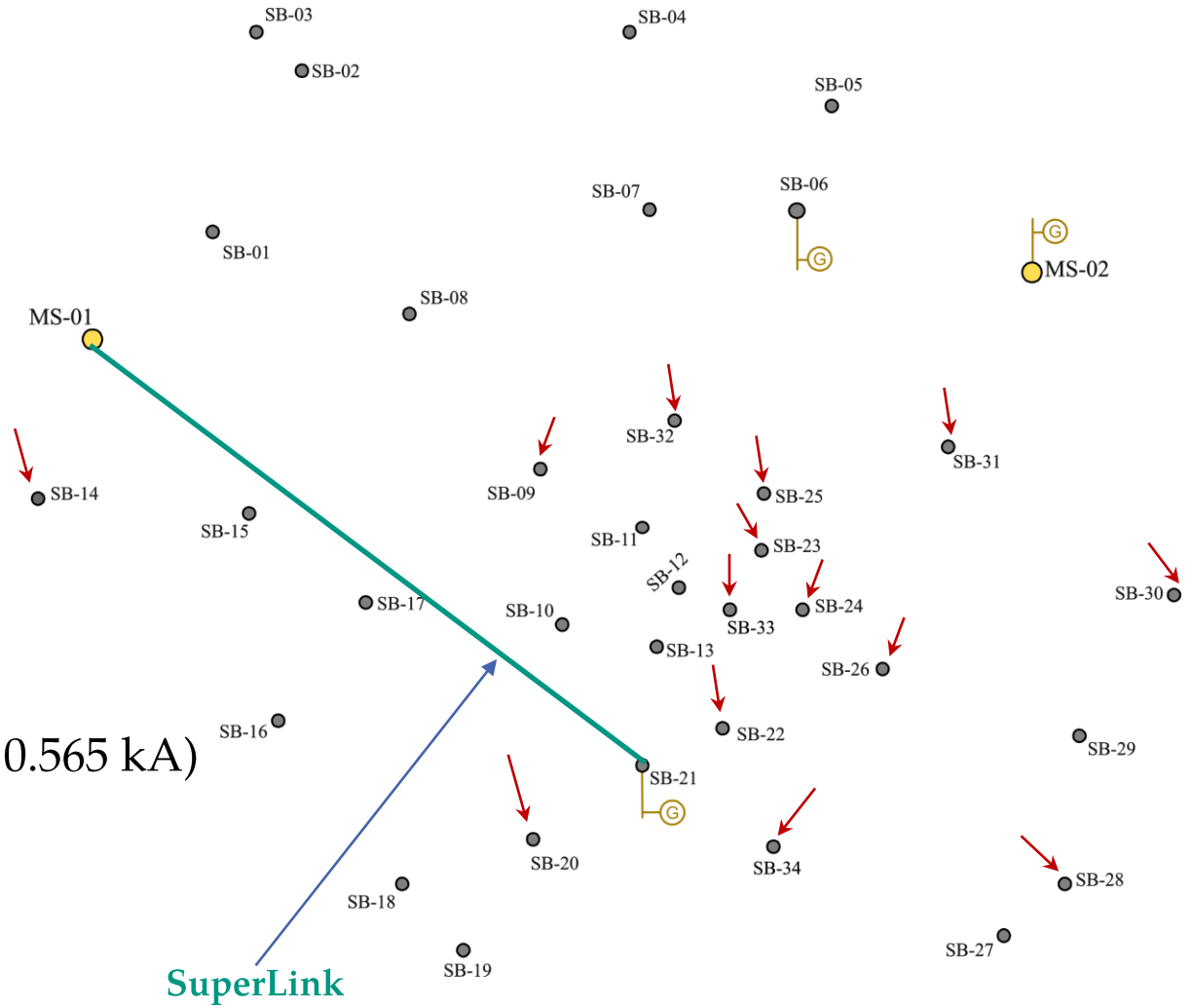
- Adding a superconducting cable to the high loaded grid will…
- result in the relief of some overloaded cables.
- But it will also result in the overloading of others cables.



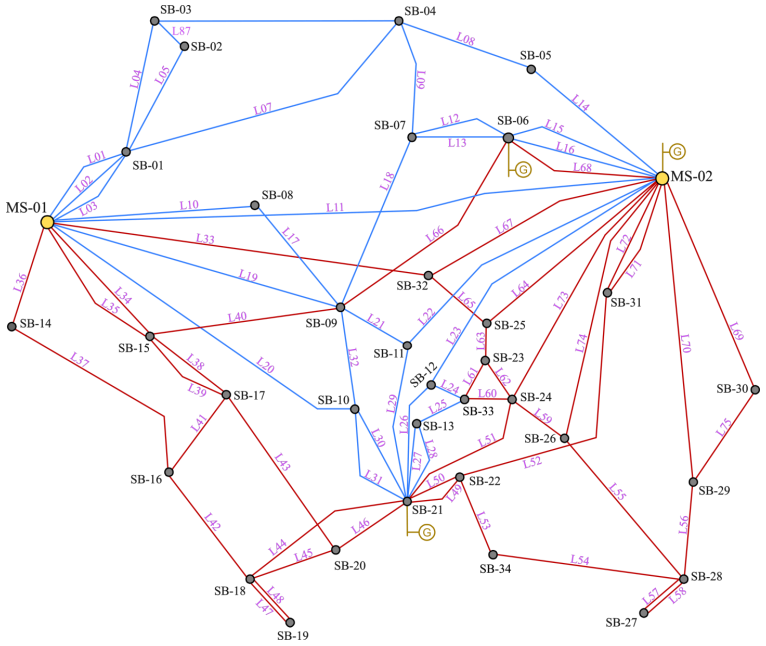


Munich 110 kV Network - Restructuring

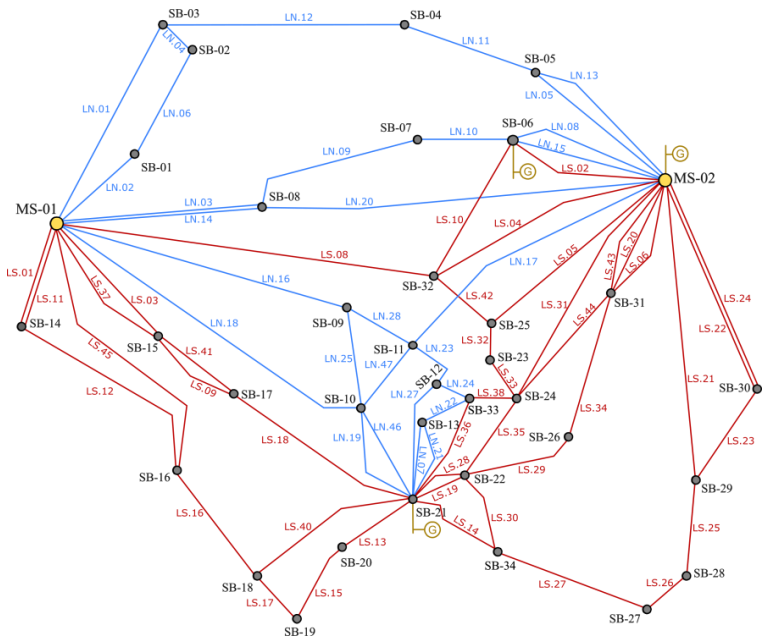
- Starting from scratch!
- Boundary Conditions:
  - Short-Circuit must remain < 25 kA
  - Minimize total lenght of cables
    - Try to use already available ducts
  - Cable cross section equal 500 mm² - (108 MVA, 0.565 kA)
  - Efficient power supply to dense loads (15 km)



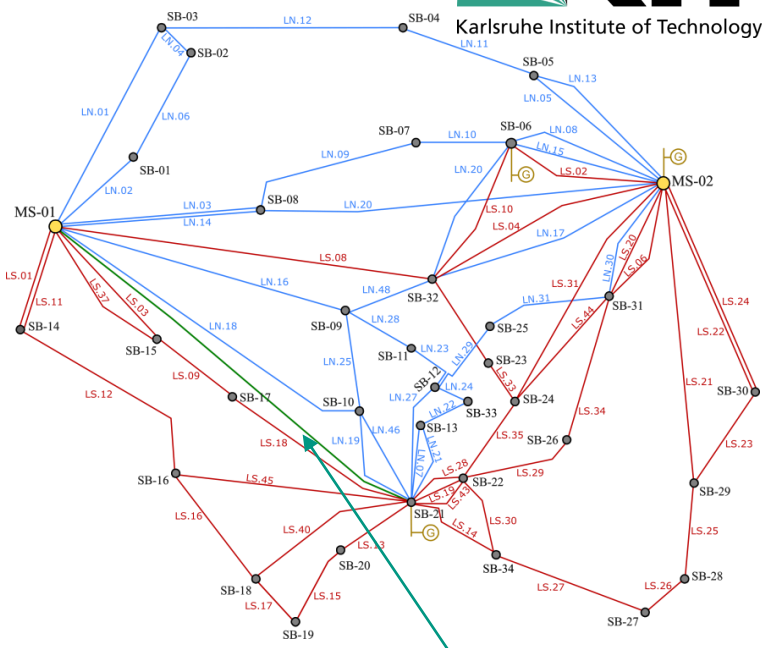
Munich 110 kV Network – Possible Designs



- **Net.00**
  - Current Network
  - 383 km
  - **No** HTS Cables



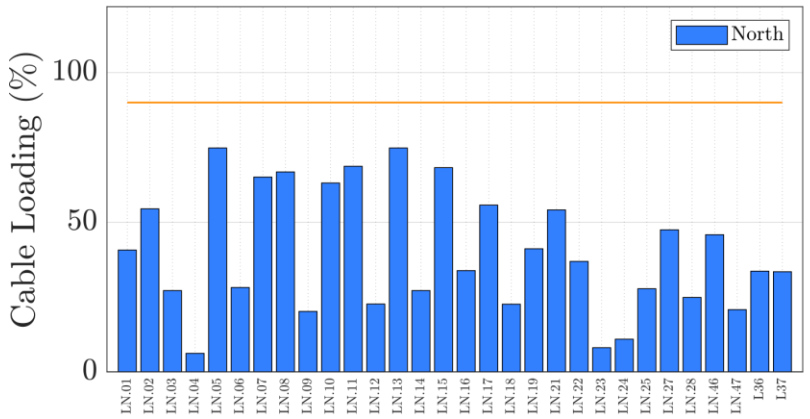
- **Net.01**
  - Optimized Grid
  - 339 km normal cables
  - **No** HTS

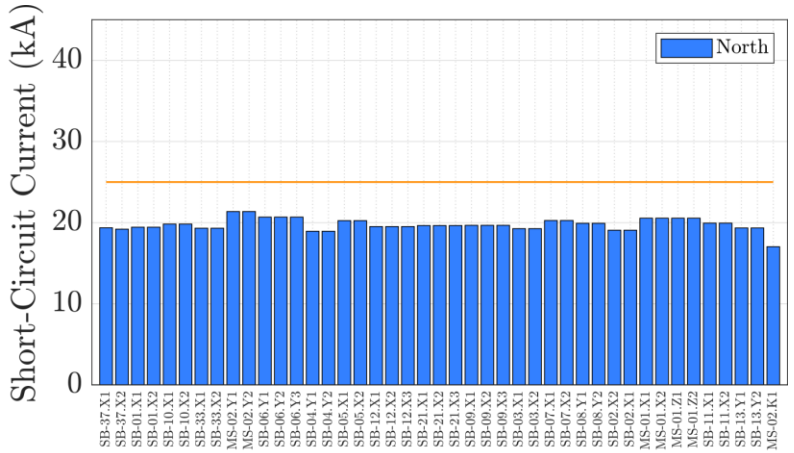


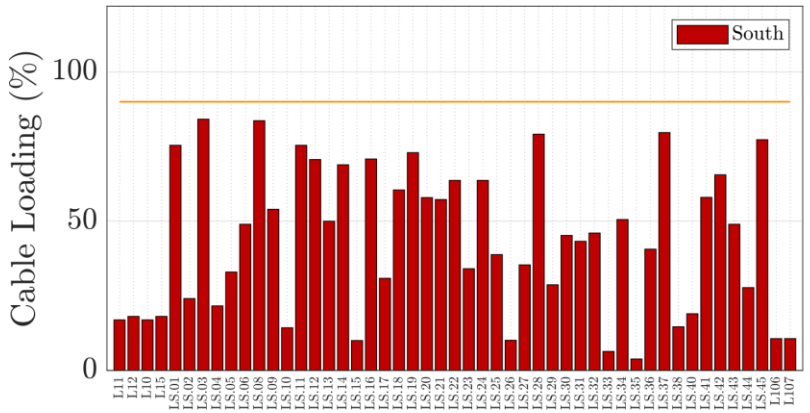
- **Net.02**
  - Optimized Grid with HTS
  - 316 km normal cables
  - 15 km HTS Cable (SuperLink)

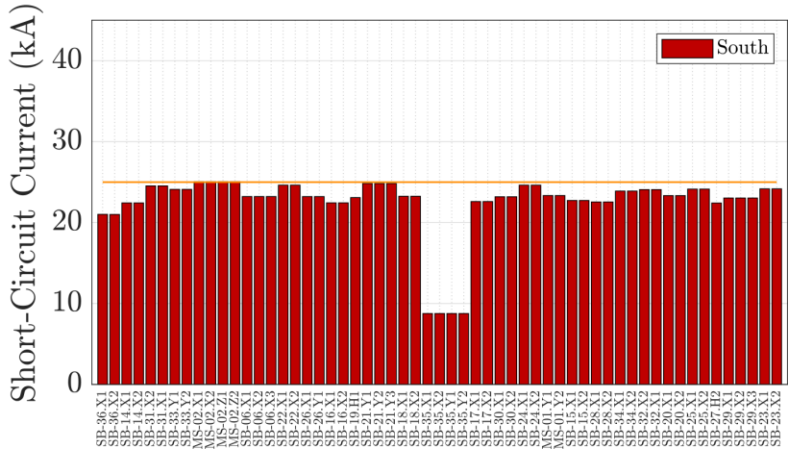
Munich 110 kV Network – Load Flow (2500 MVA)

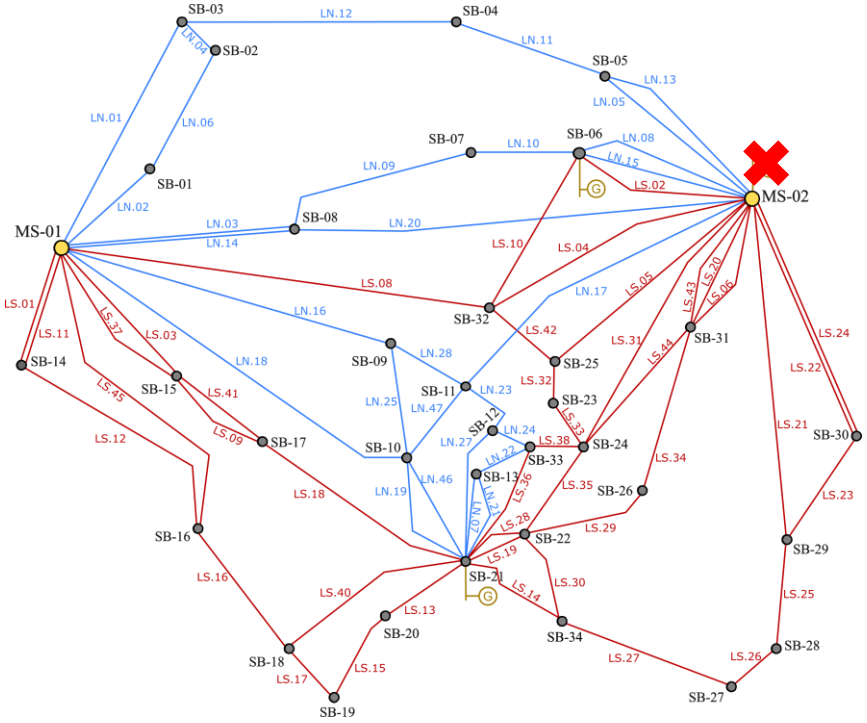
- **Net.01** – Optimized network without SuperLink (L_T = 339 km)







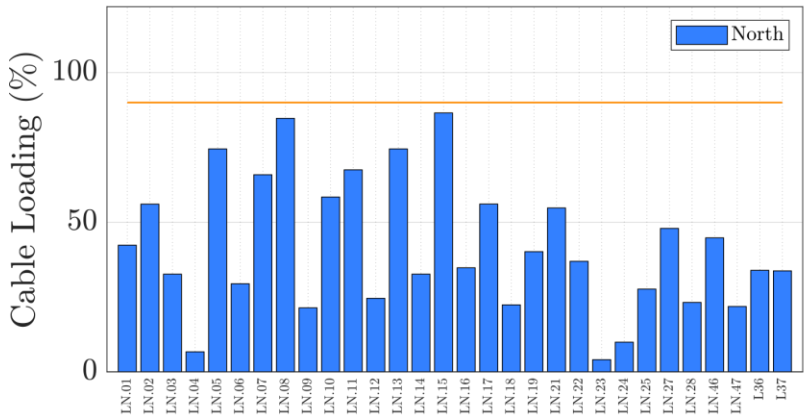


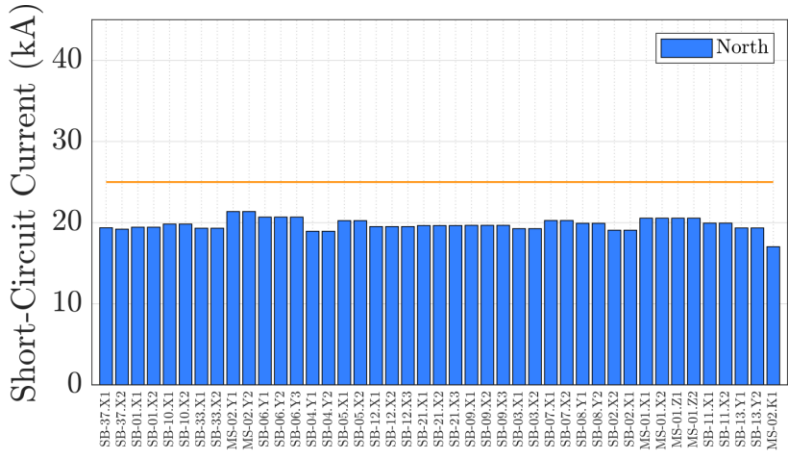


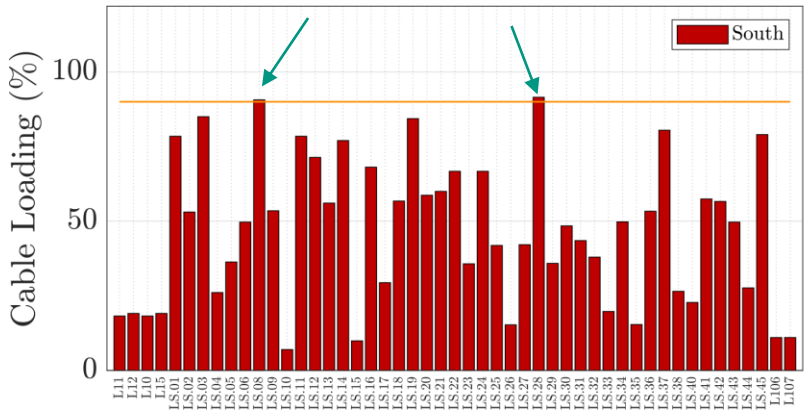
- Generators in MS-02 – offline
- Generators in SB-06 – online
- Generators in SB-21 - online

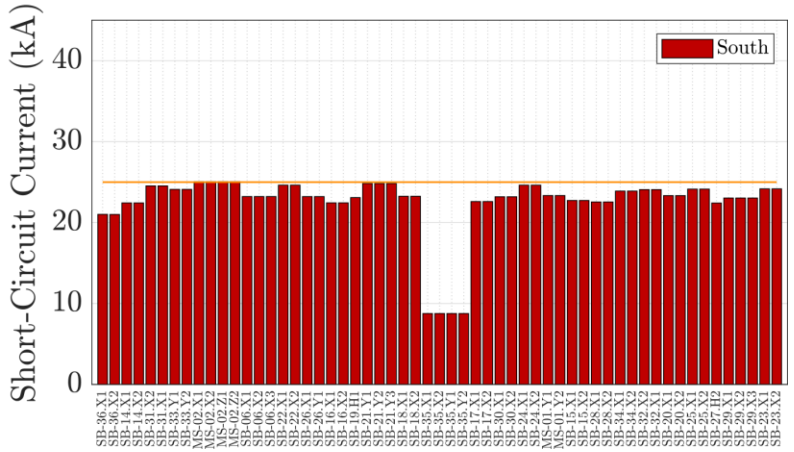
Munich 110 kV Network – Load Flow (2500 MVA)

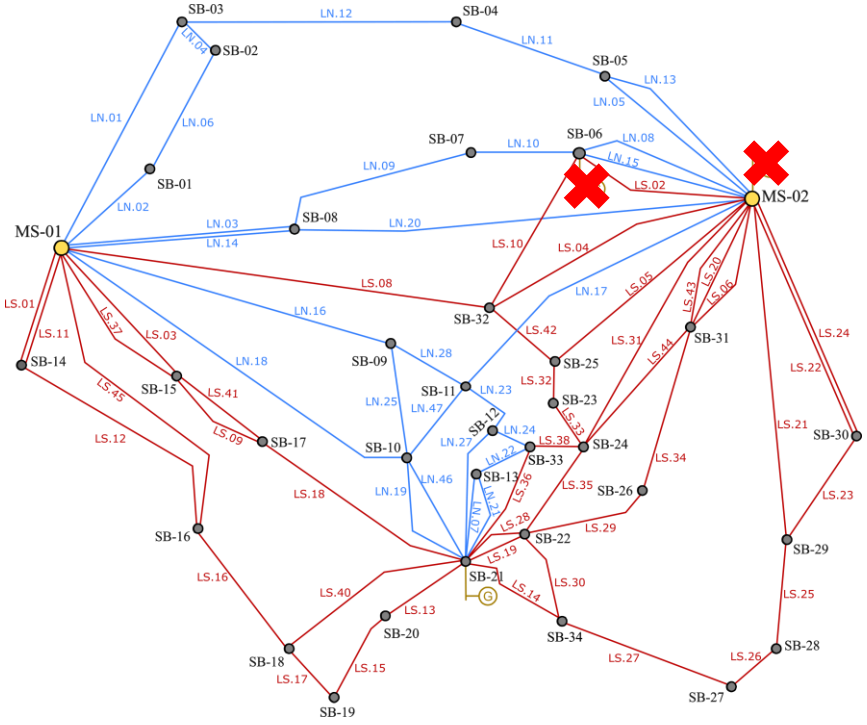
- **Net.01** – Optimized network without SuperLink (L_T = 339 km)







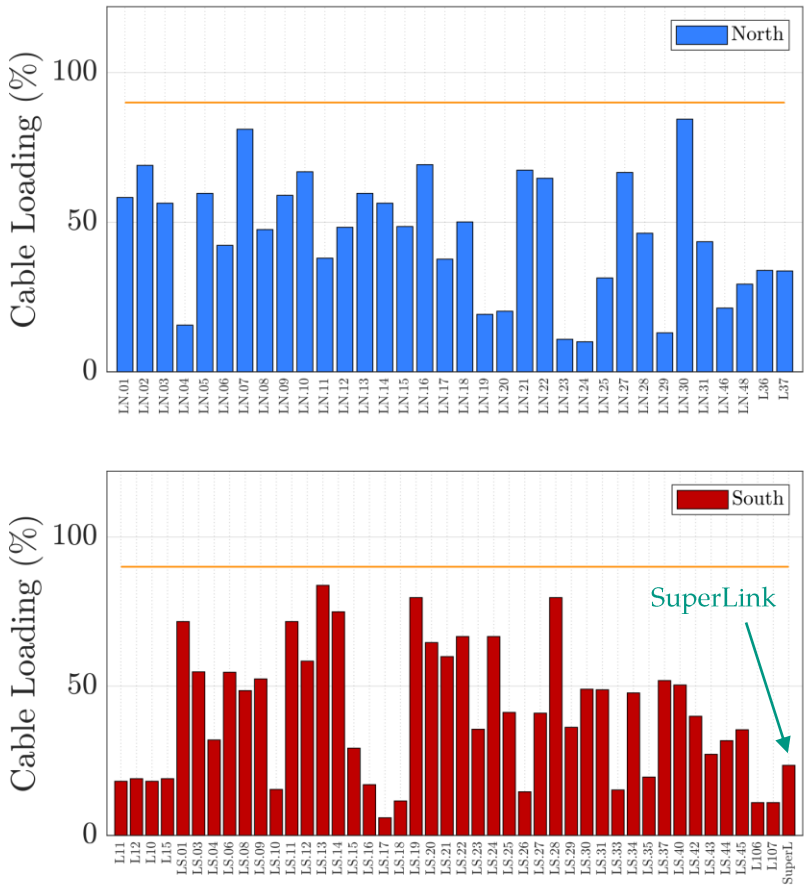


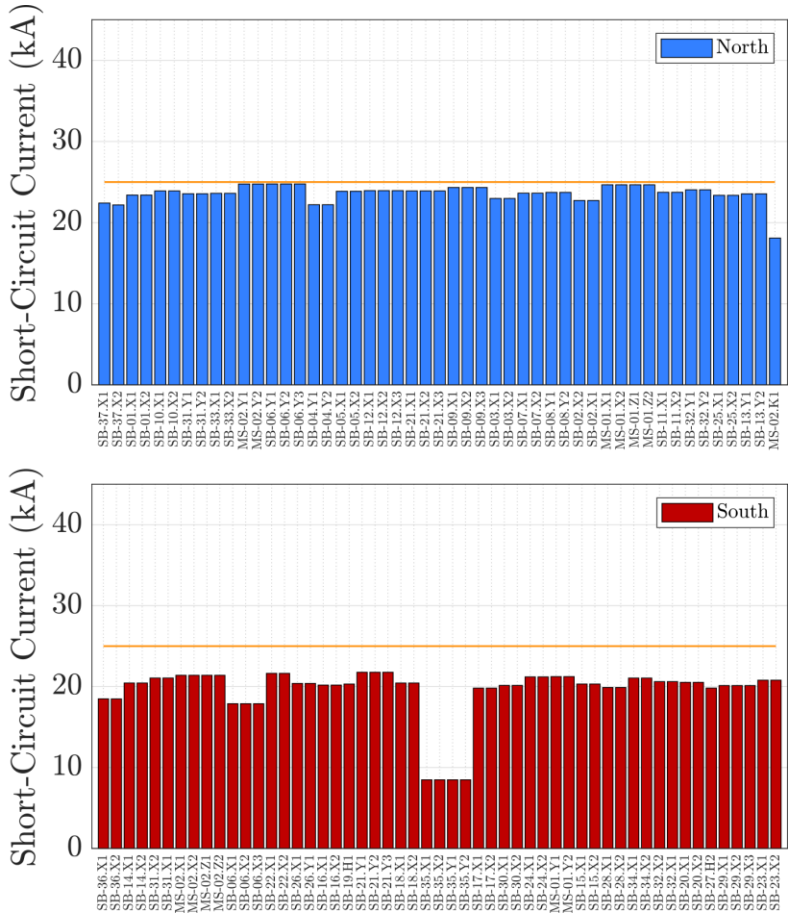


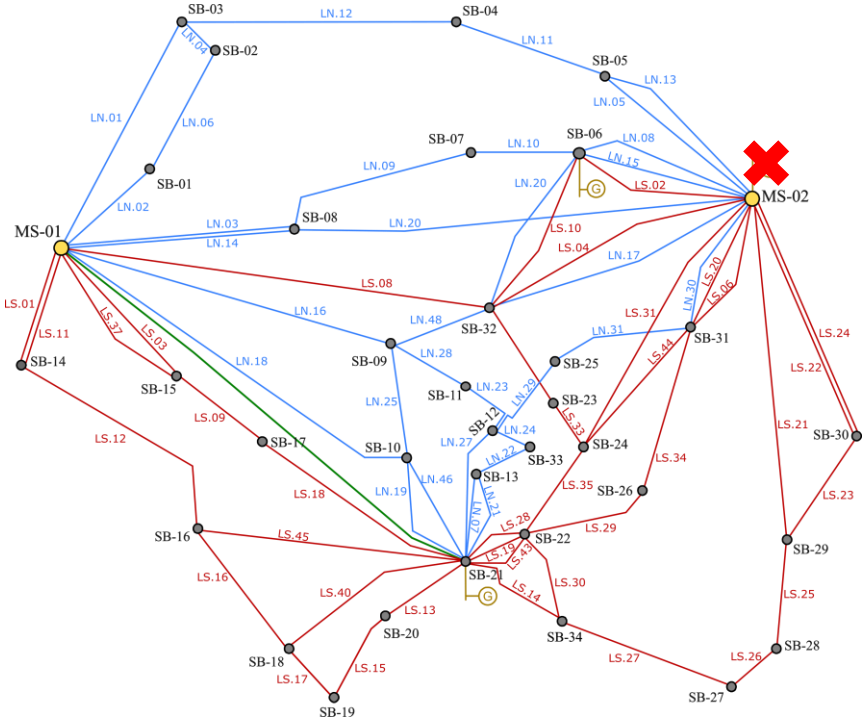
- Generators in MS-02 – offline
- Generators in SB-06 – offline
- Generators in SB-21 - online

Munich 110 kV Network – Load Flow (2500 MVA)

- **Net.02** – Optimized network **with** SuperLink (L_T = 331 km)







- Generators in MS-02 – offline
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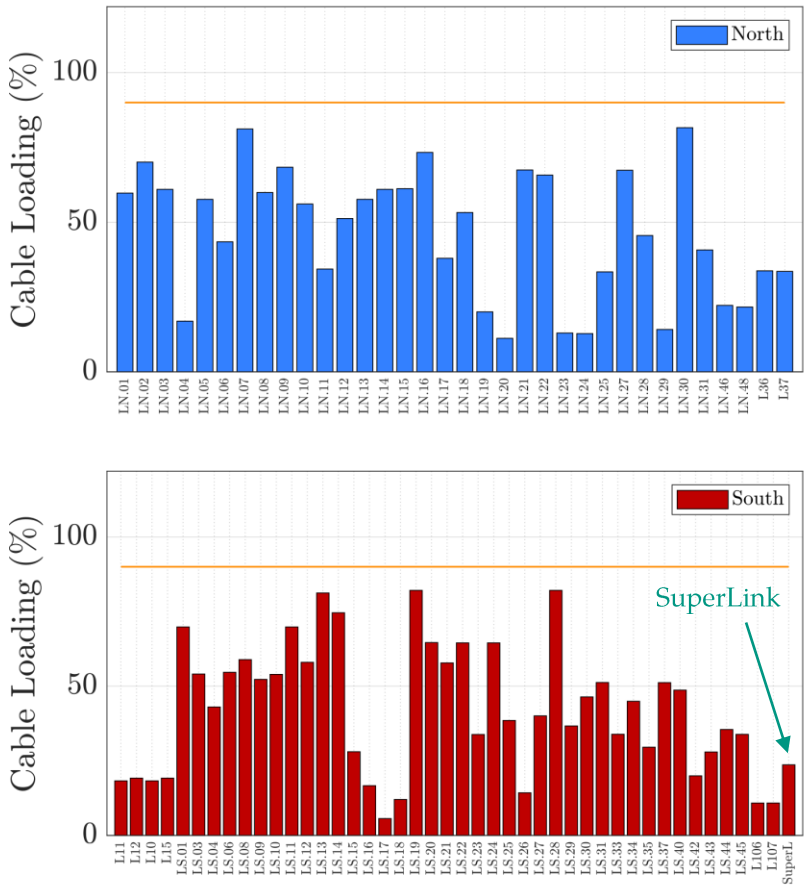
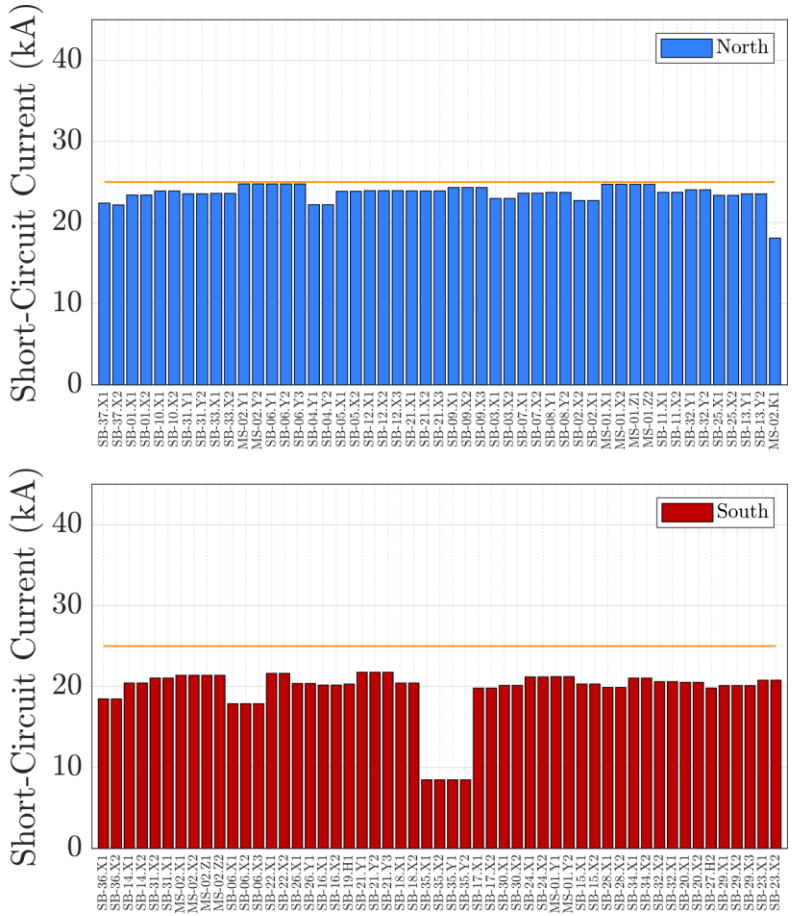
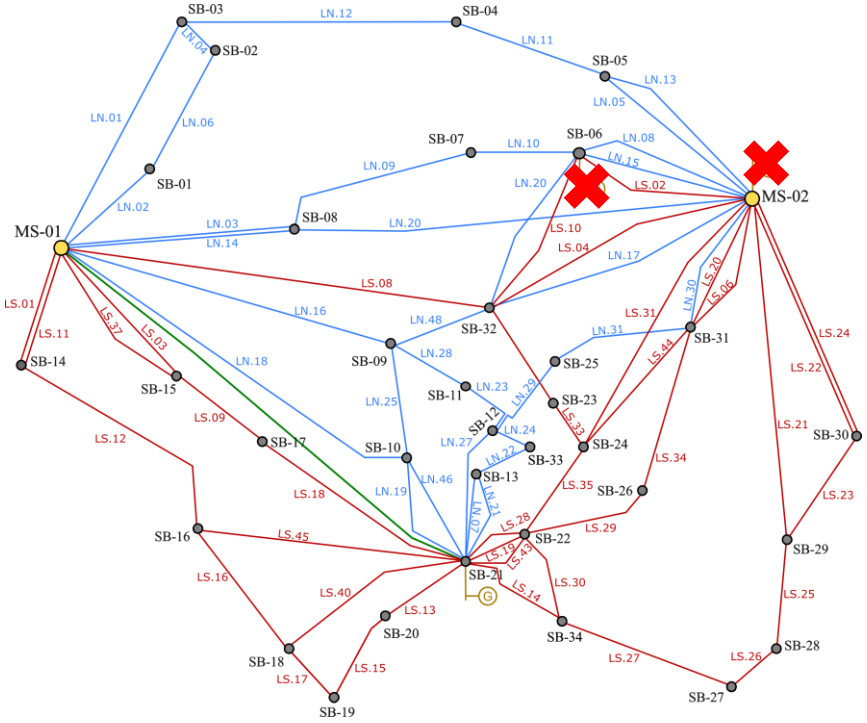
Munich 110 kV Network – Load Flow (2500 MVA)

- **Net.02** – Optimized network **with** SuperLink (L_T = 331 km)



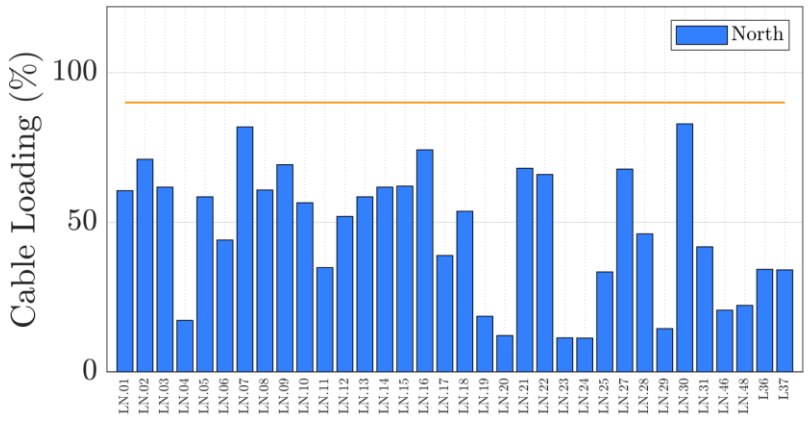


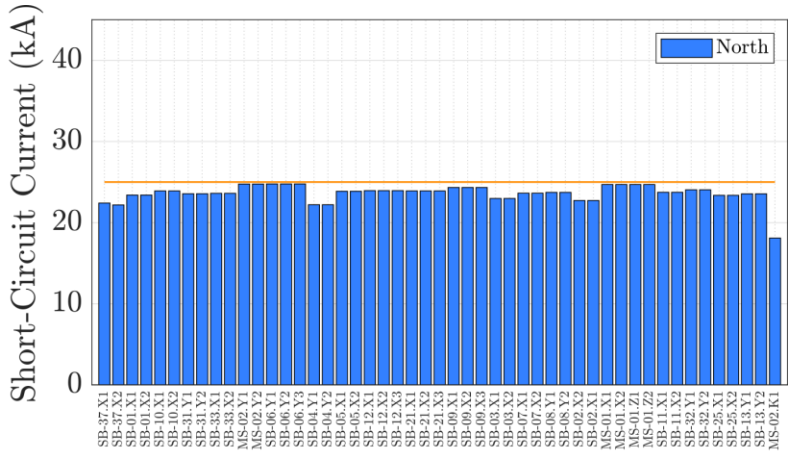


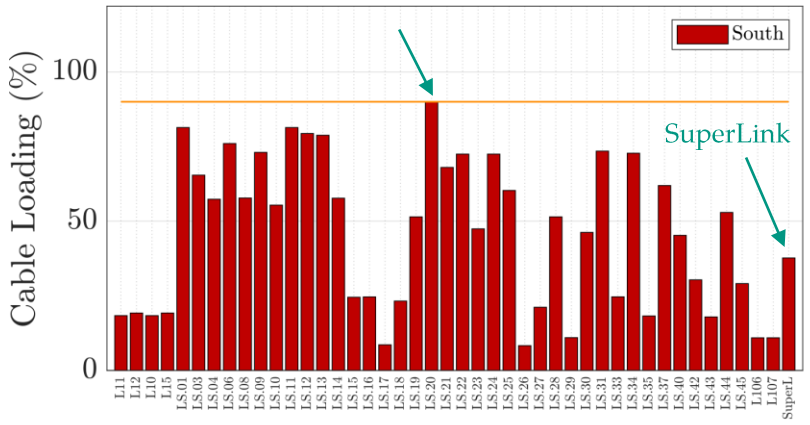
- Generators in MS-02 – offline
- Generators in SB-06 – offline
- Generators in SB-21 - online

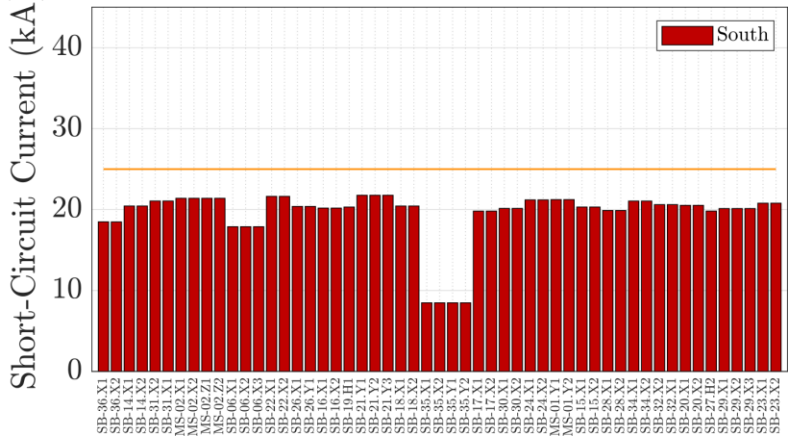
Munich 110 kV Network – Load Flow (2500 MVA)

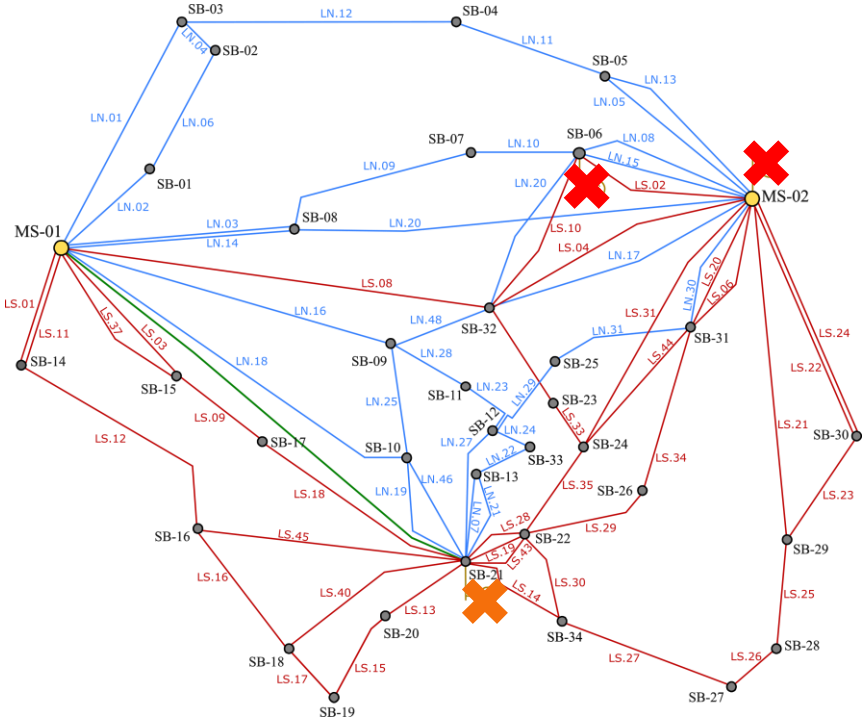
- **Net.02** – Optimized network **with** SuperLink (L_T = 331 km)









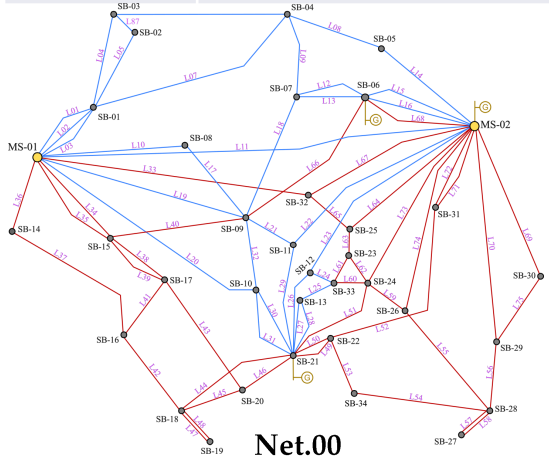


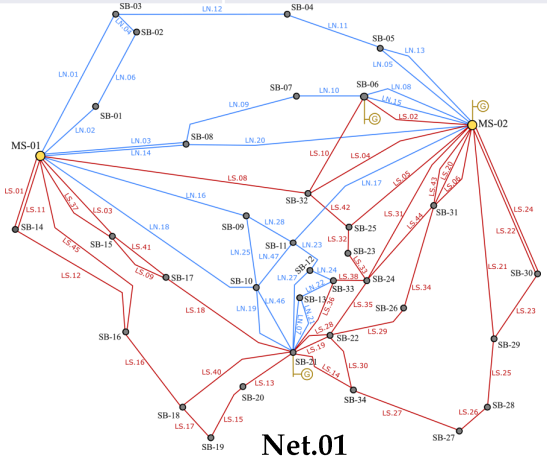
- Generators in MS-02 – offline
- Generators in SB-06 – offline
- Generators in SB-21 – at 65 %

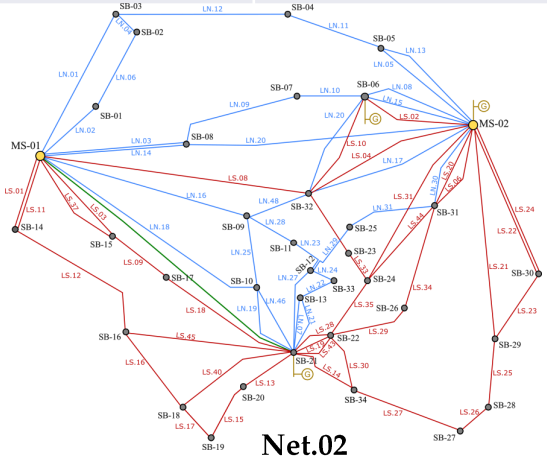
Munich 110 kV Network – Load Flow Outcome

- Main Outcomes for the load scenario 2500 MVA

Grid	Description	Out of service			L_N	L_{HTS}	L_T
		MS-02	SB-06	SB-21 at 65%			
Net.00	Current 110 KV Network	☹	☹	☹	373 km	0 km	373 km
Net.01	Optimized grid without SuperLink	☺	☹	☹	339 km	0 km	339 km
Net.02	Optimized grid with SuperLink	☺	☺	☺	316 km	15 km	331 km

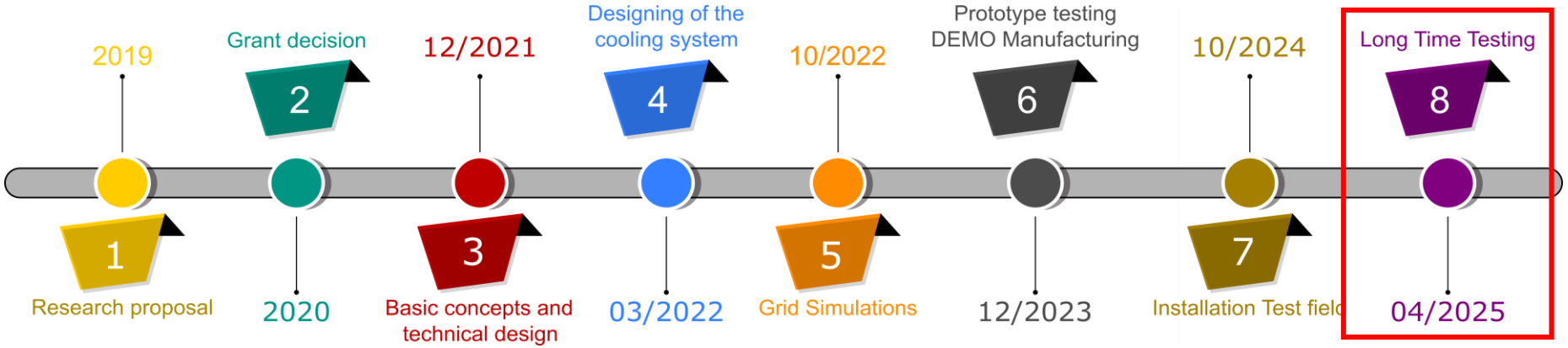




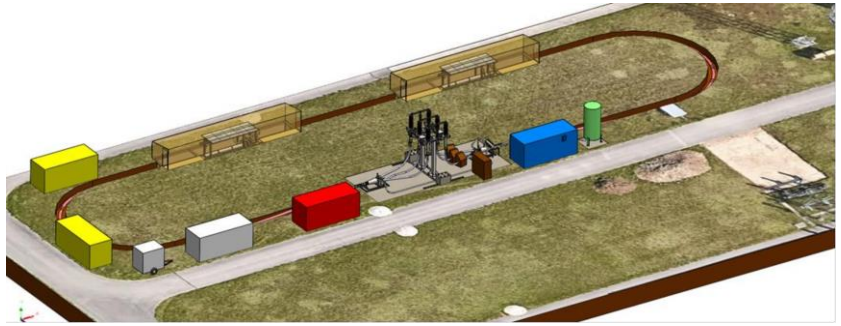


- L_N = length of normal cables
- L_{HTS} = length of the HTS cable
- L_T = Total length

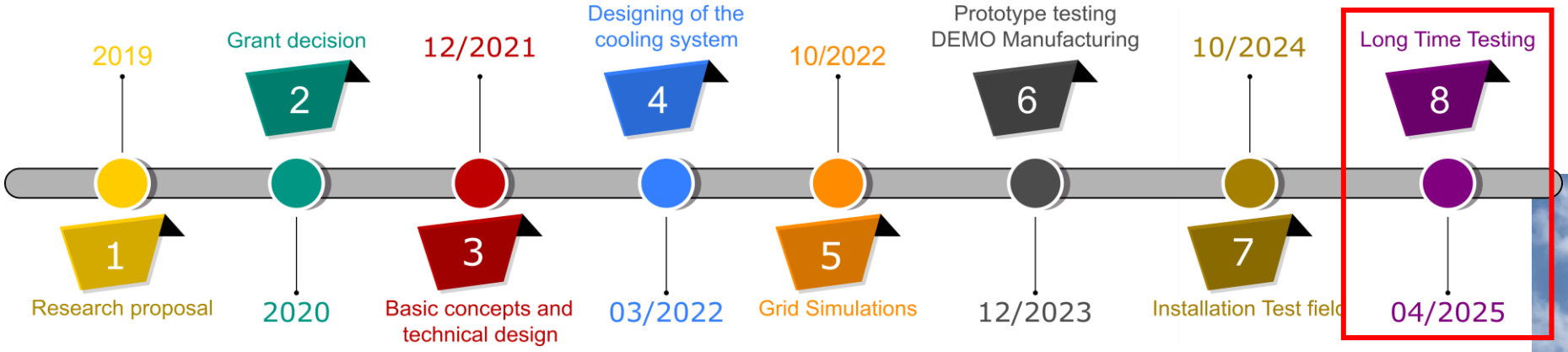
SuperLink Project – Current Status



- **Launch: 09.10.2024**



SuperLink Project – Current Status



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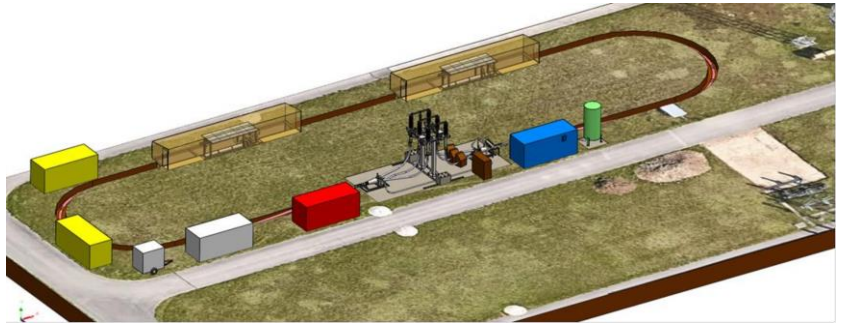
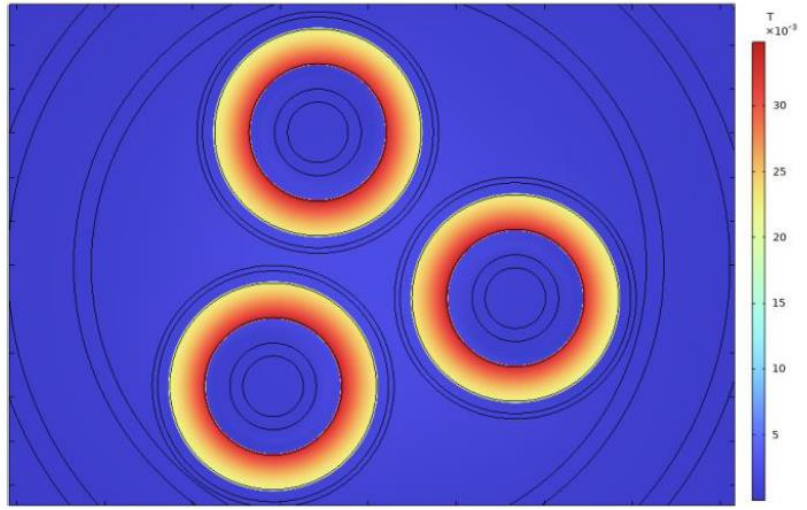
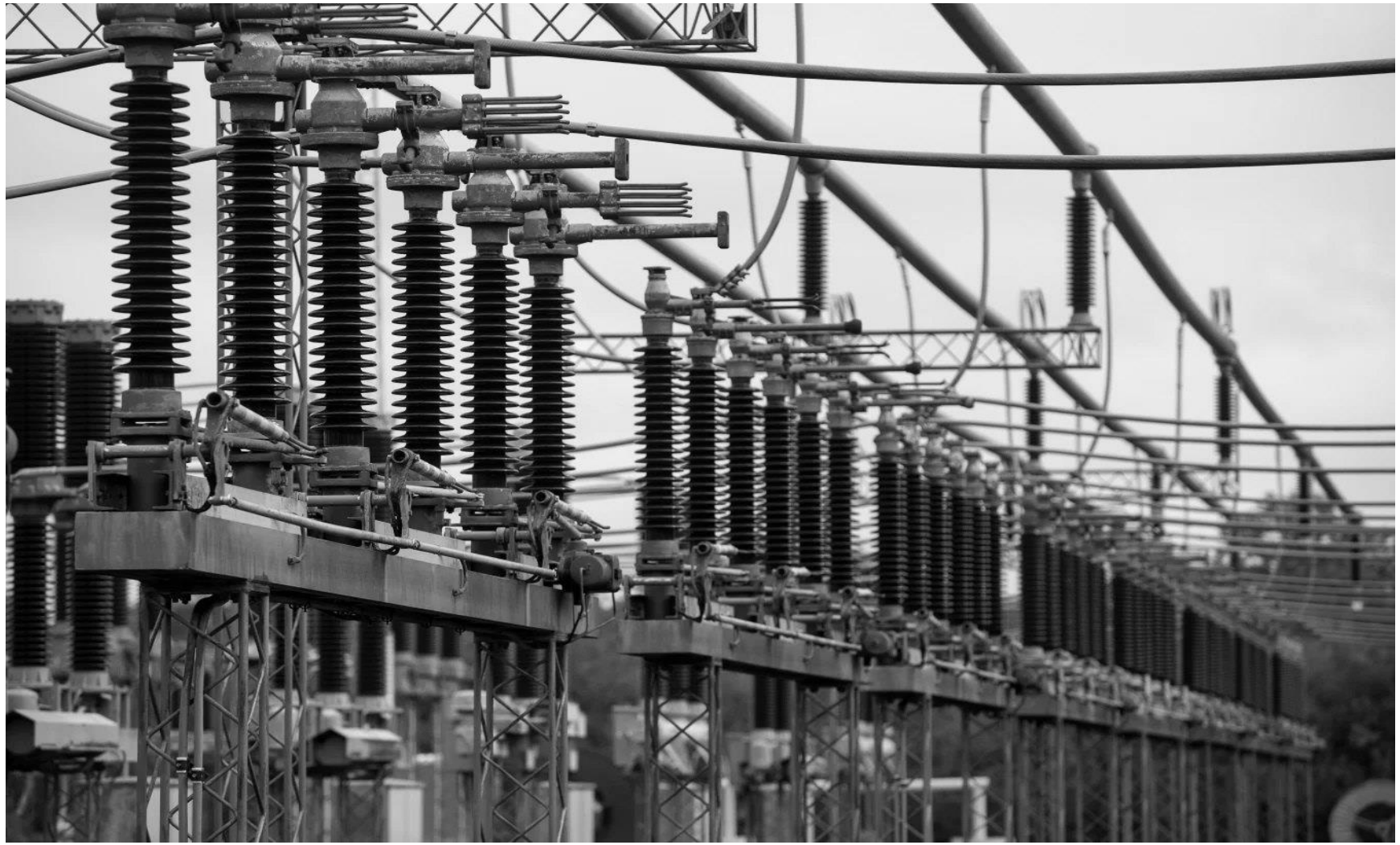


Summary

- The integration of the SuperLink cable combined with a network optimization appears as an attractive solution for future high loaded grids
- Without SuperLink, the grid still remains very dependent on the thermal power plants
- Grid optimization and total cable length reduction can be further investigated if more superconducting cables comes into consideration
- Network remains stable
  - No increase on fault current levels



Thank you very much for your attention!



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Questions?

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SuperLink

Bundesministerium für Wirtschaft und Klimaschutz