

Superconducting technologies to improve the environmental impacts of traction energy systems

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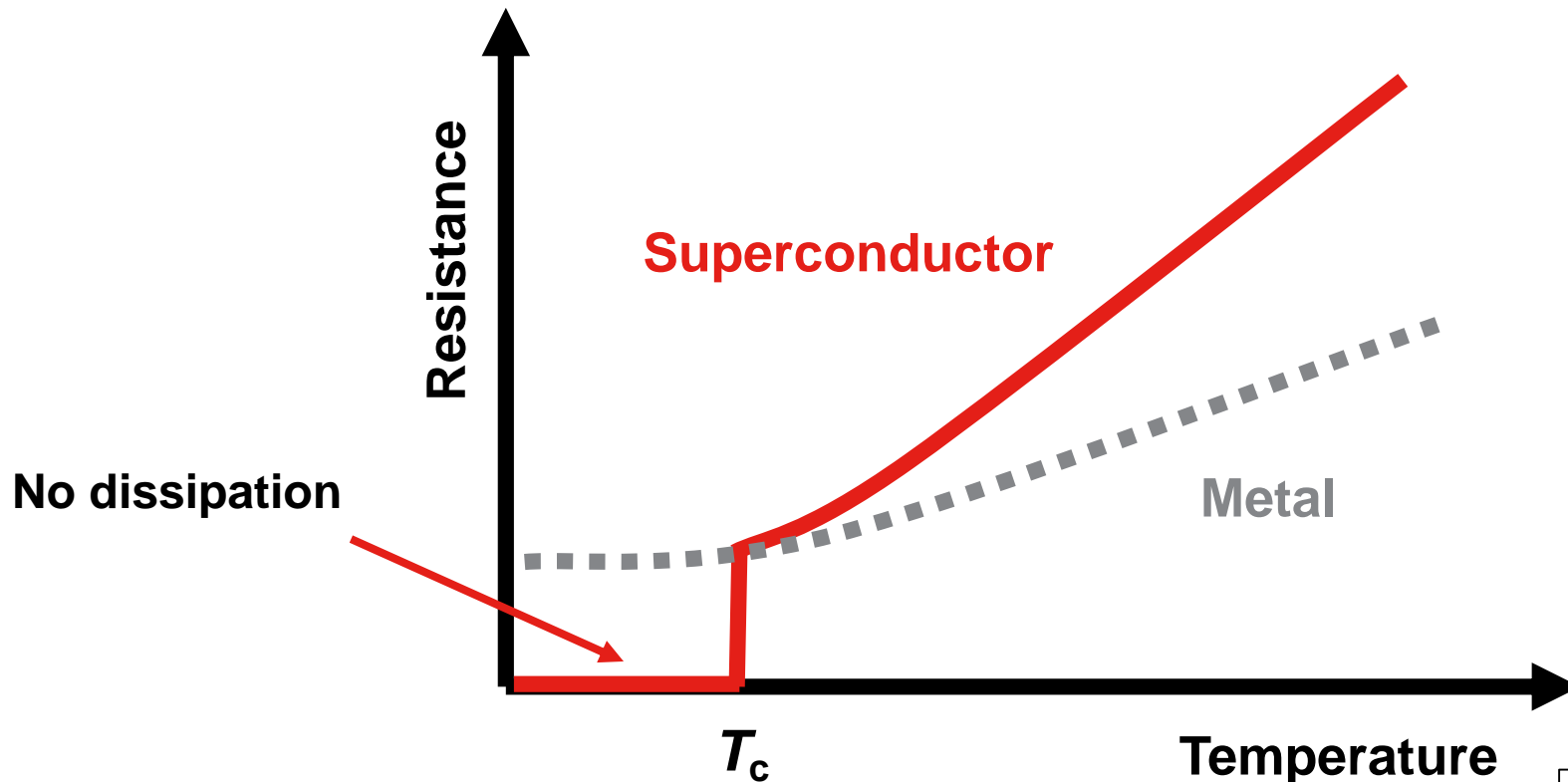
Rotterdam, 11/02/2018



- Notion of superconductivity
- Superconducting cables
- Superconducting Fault Current Limiters

Superconductivity

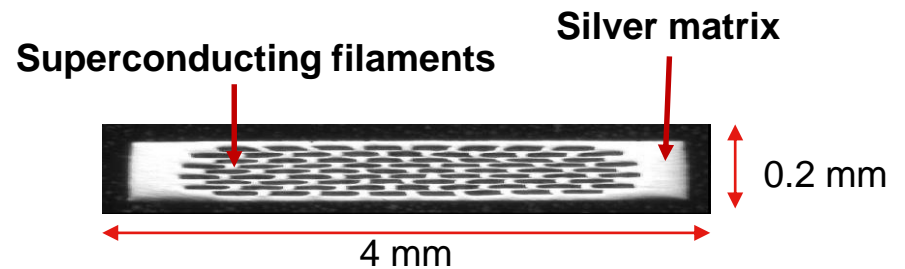
- Superconducting materials exhibit no resistance under a critical temperature T_c
- This property exists for pure metals, oxides or ceramics



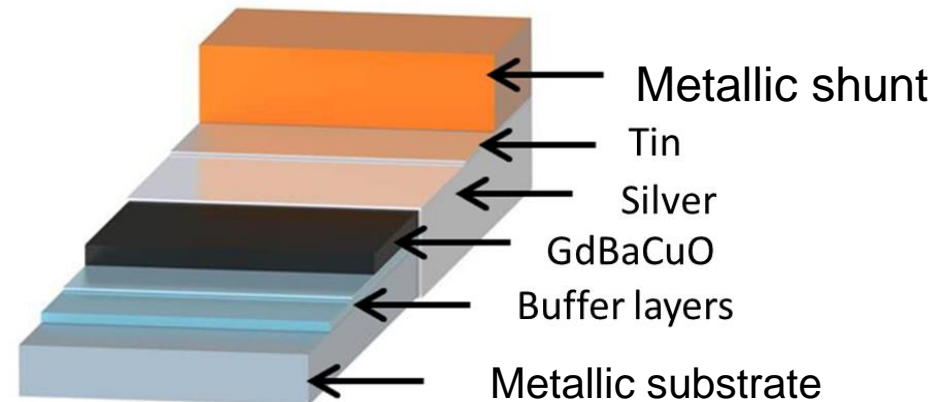
Superconducting materials

- Superconducting materials operating in liquid Nitrogen are called **High Temperature Superconductors**
- Two kinds of superconducting tapes are industrially available

- **1st generation =>**
 $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10-x}$ (BI2223) tapes



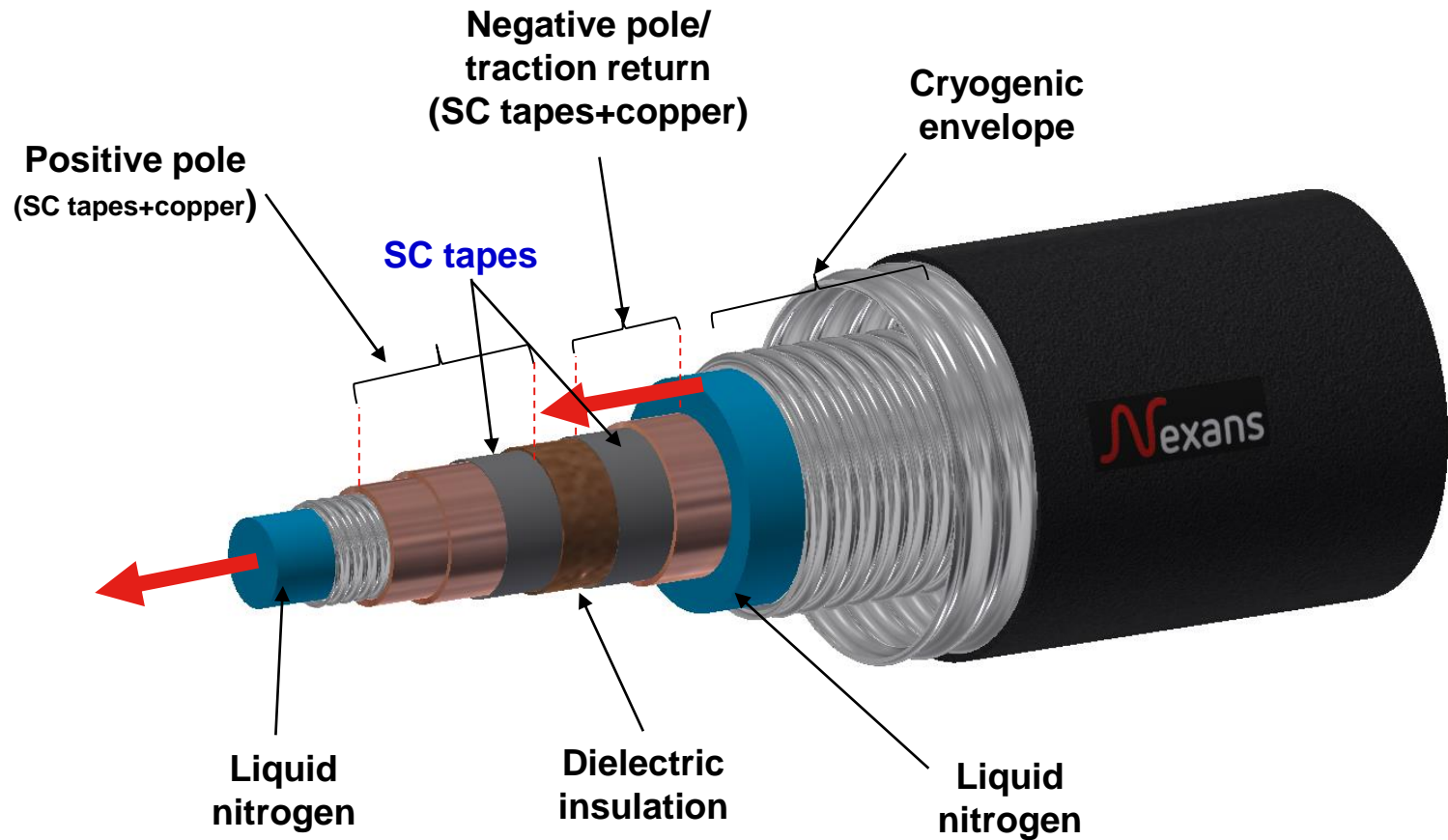
- **2nd generation =>**
 $\text{REBa}_2\text{Cu}_3\text{O}_{7-x}$ tapes
RE rare earth (Gd, Y,)



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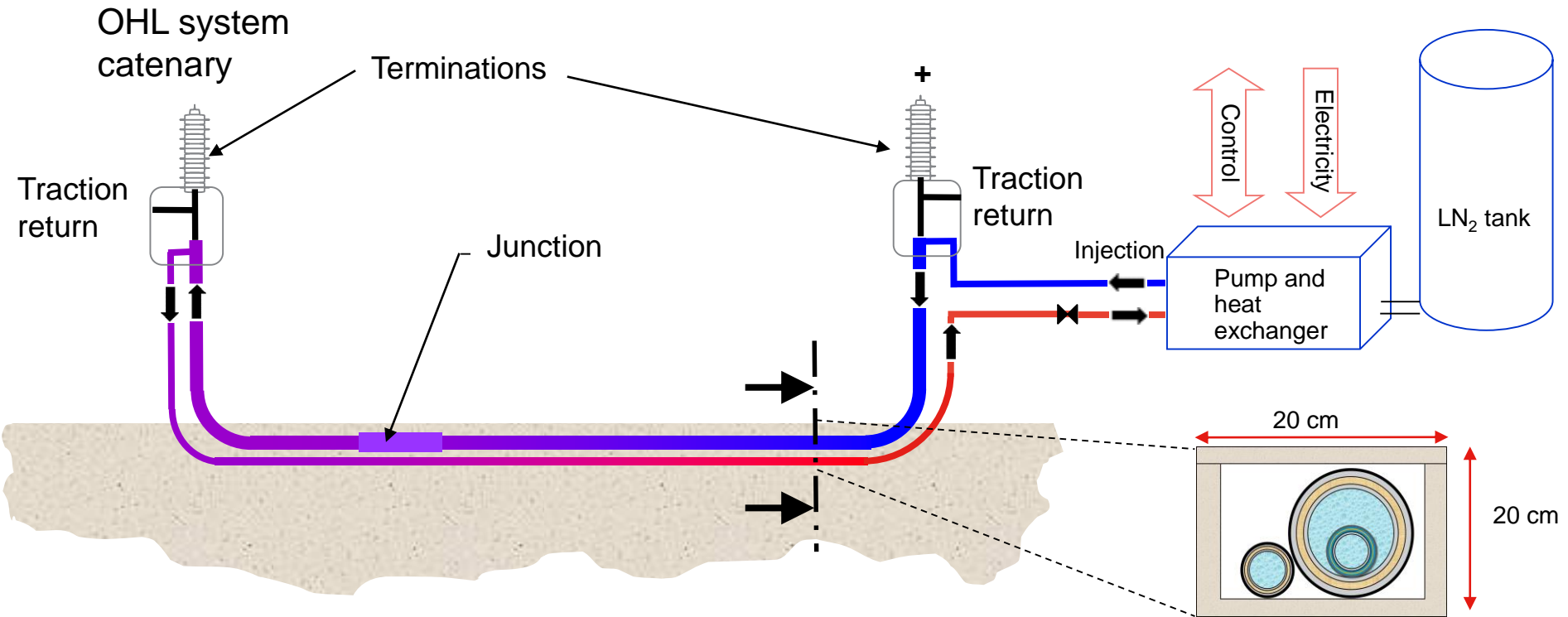
DC Superconducting cables for traction

Bipolar superconducting cable for 1750 V DC with current from 5 to 15 kA



Superconducting cable system, installation

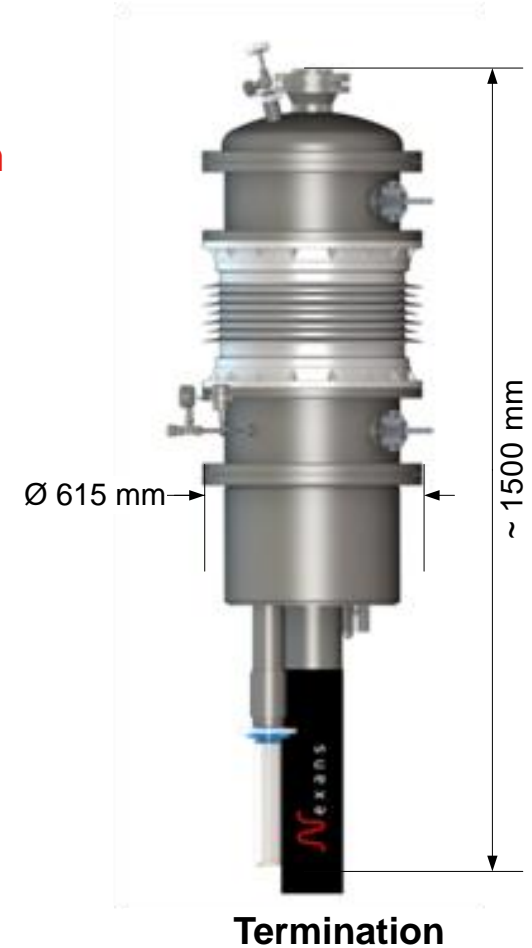
Bipolar superconducting cable for 1750 V DC with current from 5 to 15 kA



- The cable is cooled down with liquid nitrogen at 6 to 9 bars
- The increase of liquid temperature along the length is counterbalanced by the heat exchanger

Superconducting cables for traction

DC superconducting cable 1750 V with current between 5 to 15 kA



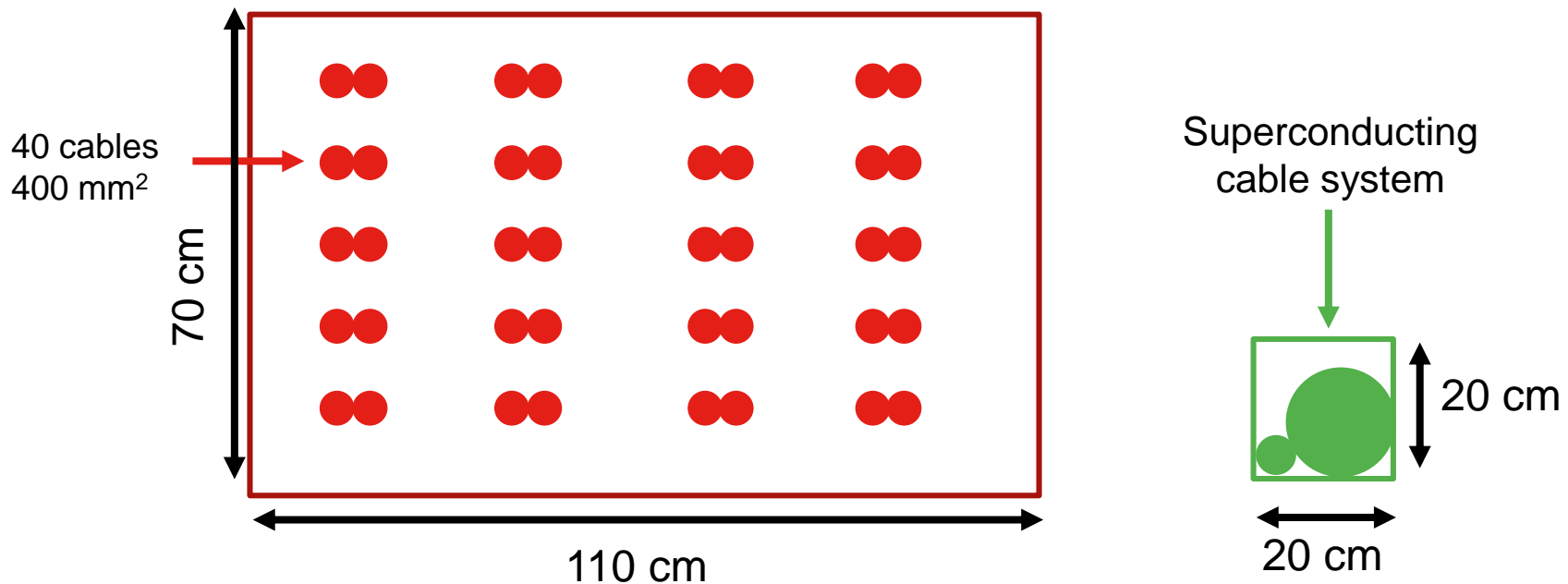
Nominal current	5 kA	10 kA	15 kA
Power transmitted	9 MW	18 MW	26.5 MW
Cable core diameter	53.2 mm	55.6 mm	58 mm
Cable diameter	150 mm	150 mm	150 mm

Superconducting cables for traction

Reduction of cable size by 20!

- Superconducting cables allow the reduction of cable size and right of way in ultra dense urban area

Footprint for 15 kA cable system with return current



Superconducting cables for traction

An environmental friendly solution !

1) Reduction of the operation cost

- By a factor 3 for a 15 kA for a 2.5 km cable

2) Reduction of installation cost and permitting by the small cable section

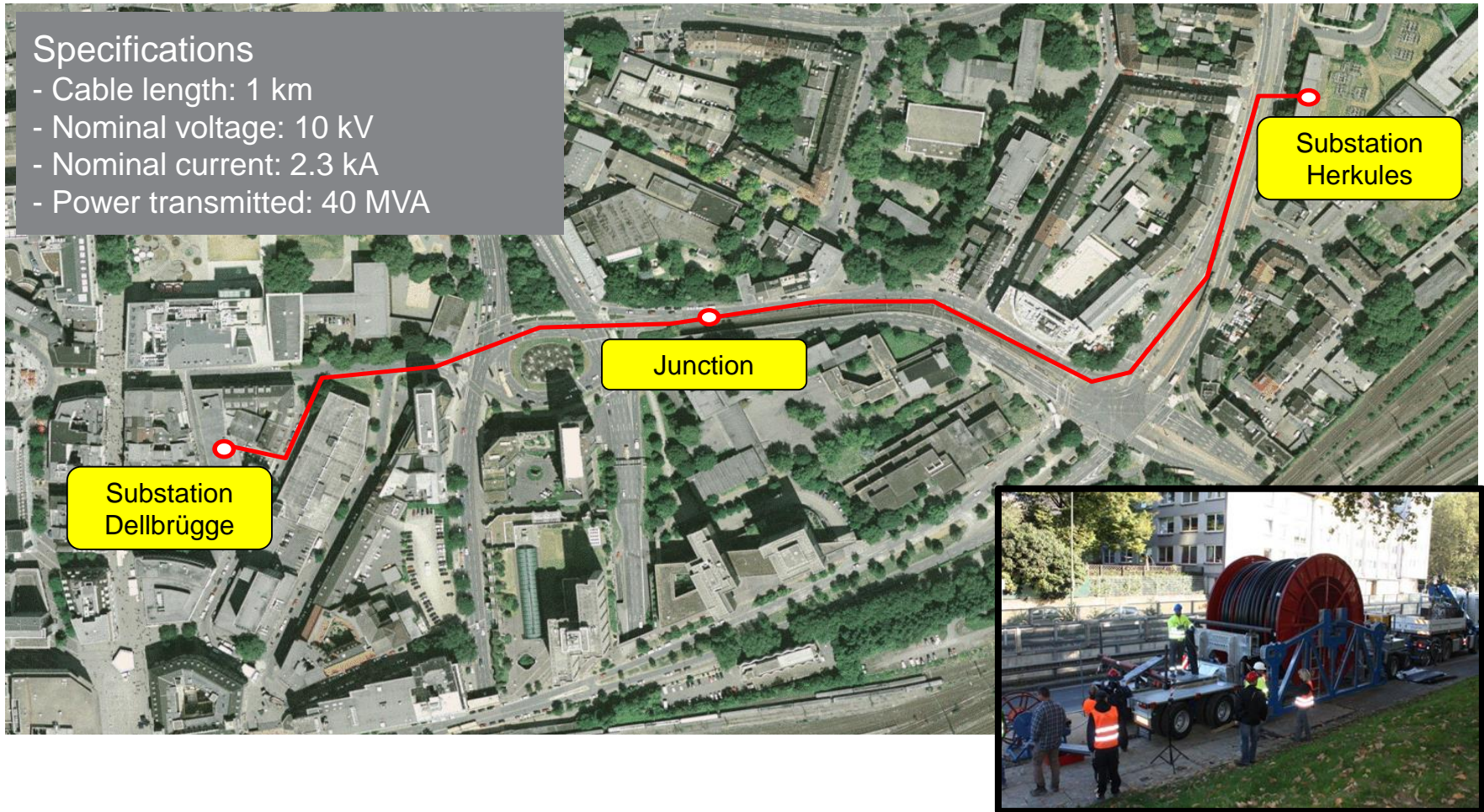
3) No heat generated on the cable during operation

- No effect on vegetation and surroundings

4) No Electro-magnetic emission

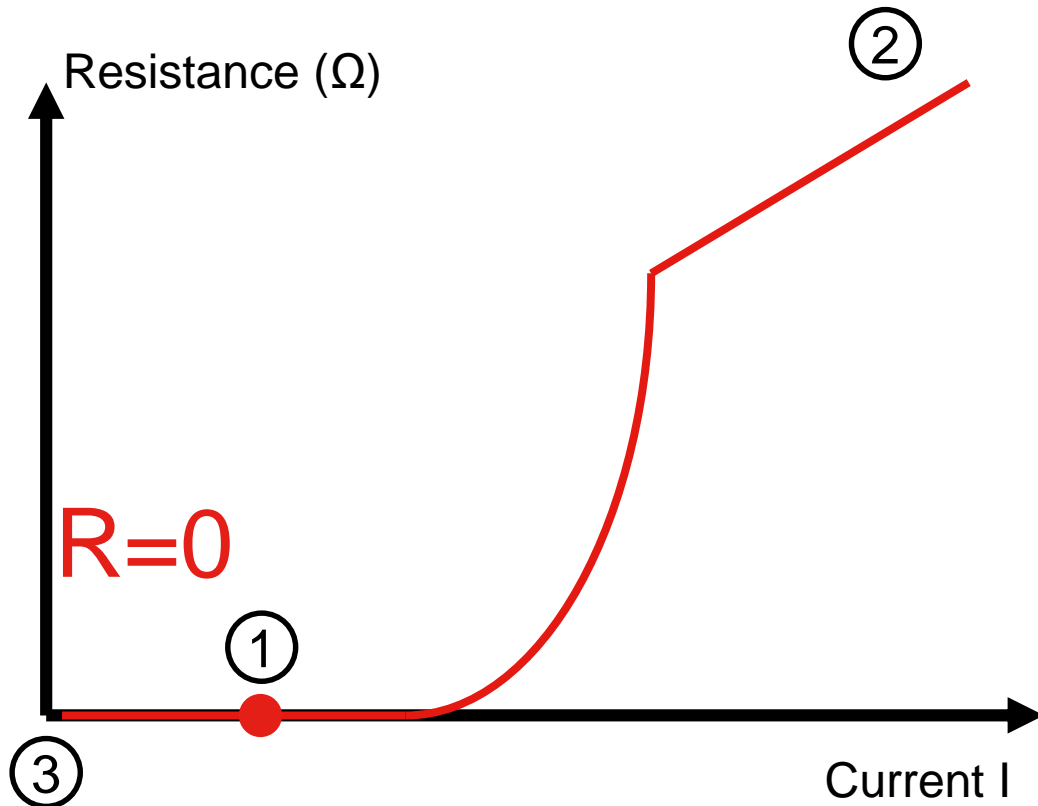
Nearly 5 years of non-stop operation in distribution grid !

Example of ampacity project in the city of Essen (Germany)



- Notion of superconductivity
- Superconducting cables
- Superconducting Fault Current Limiters

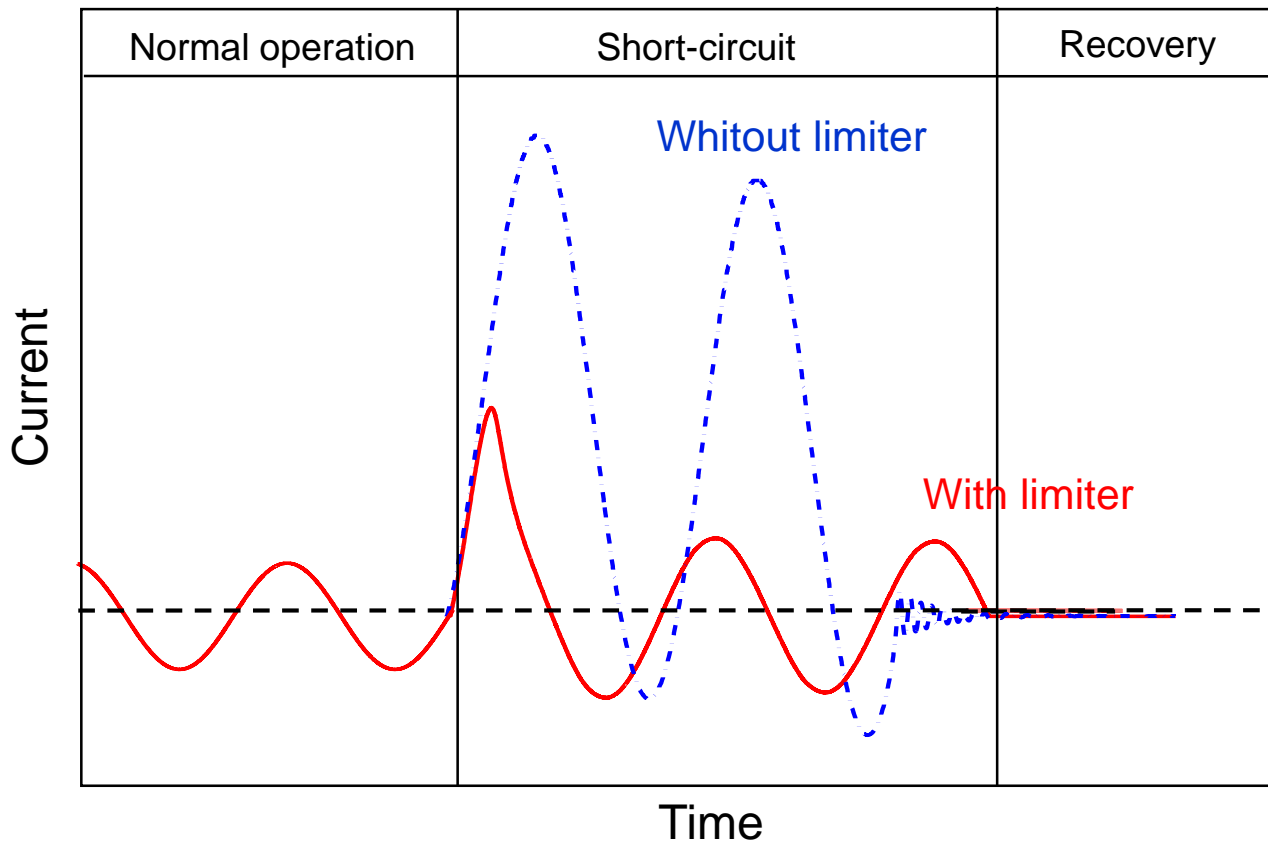
$R \approx \text{Ohms}$



Principle of limitation:

- 1: Normal operation, no resistance
- 2: Surge increase of the current, apparition of resistance
- 3: Current switch off, recovery time required (material to cooldown below T_c)

AC Fault Current Limiters



Reduction of short circuit current values

➔ new specifications for sub station equipment
(reduction of raw materials, equipment size, weight)

AC fault current limiters

1. Instantaneous current reduction from tens of kA to only few kA
 - Reaction in 1-2 milliseconds
2. Automatic protection
 - Restart when cold again
3. No specific maintenance after a fault
4. Low operational cost
5. Can be used also in DC



Example of 25 kV AC SFCL for traction grid

Conclusions

Superconducting devices simplify electrification in ultra dense areas and offer a reduced environmental impact

1. Superconducting cable offers

- A reduction of cable size, operating losses and rights of way
- Reduction of raw materials (copper e.g.)
- No heat generated to the ground and no EMC emissions

2. Fault Currents Limiter gives new perspectives for safer future sub-stations by the reduction of short circuit currents

Guillaume Escamez

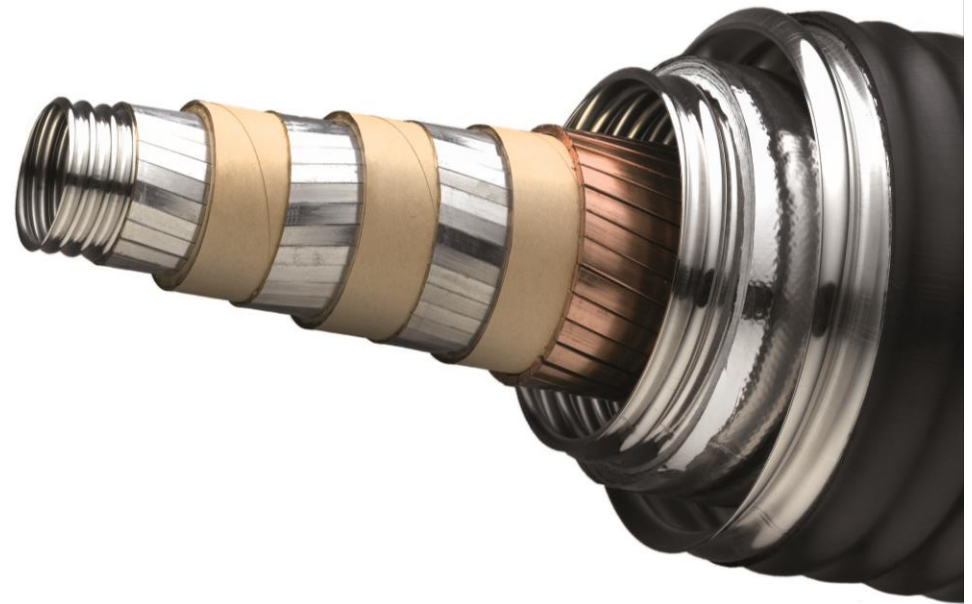
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Thank you for your attention