EXTRA HIGH VOLTAGE TRANSMISSION TECHNOLOGIES

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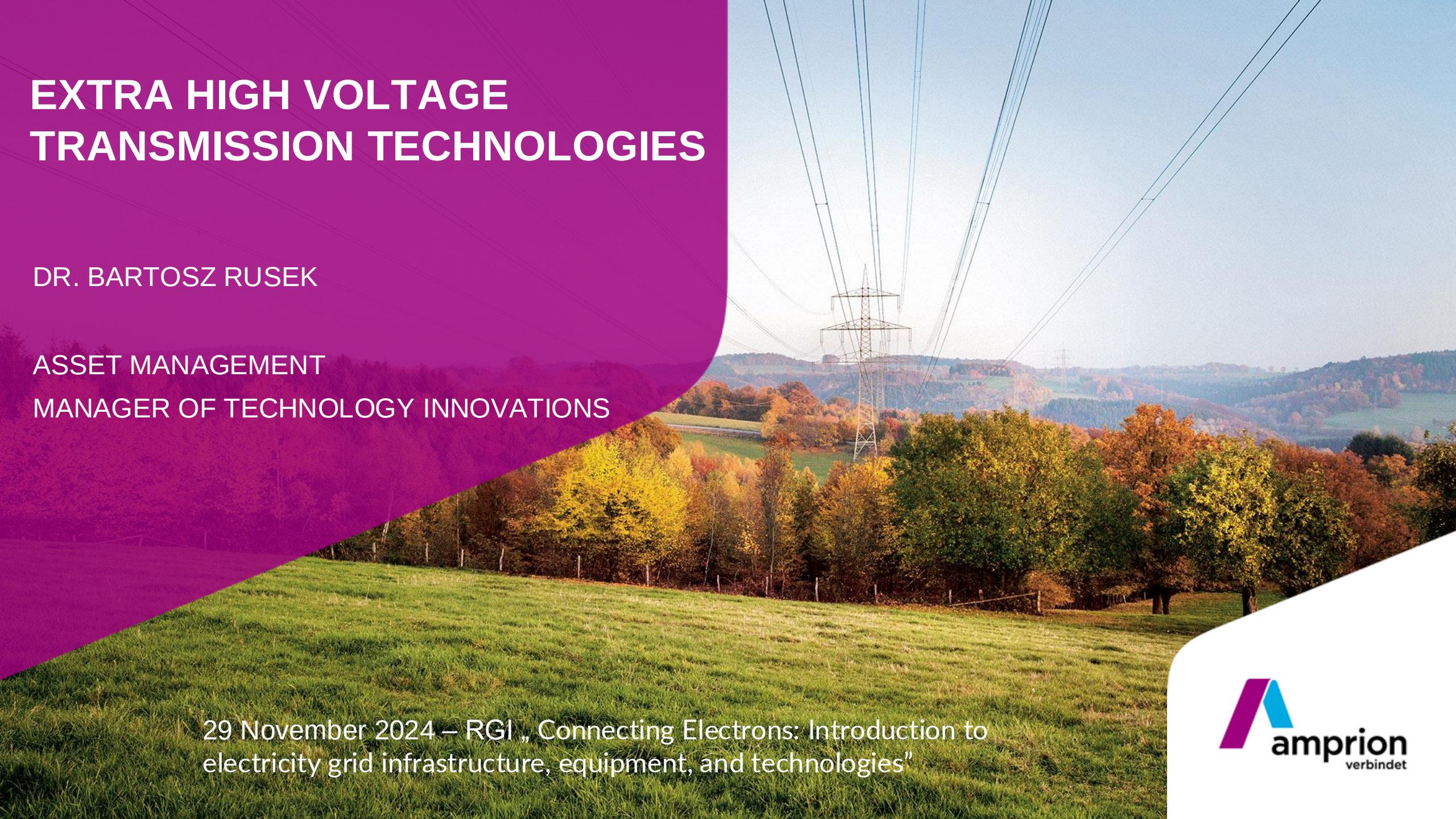
ASSET MANAGEMENT

MANAGER OF TECHNOLOGY INNOVATIONS



29 November 2024 – RGI „ Connecting Electrons: Introduction to electricity grid infrastructure, equipment, and technologies”

amprion
verbindet

ABOUT AMPRION

29 Mill.

people live in our grid area. Around a third of Germany's economic output is generated in this region.

27.5 BN

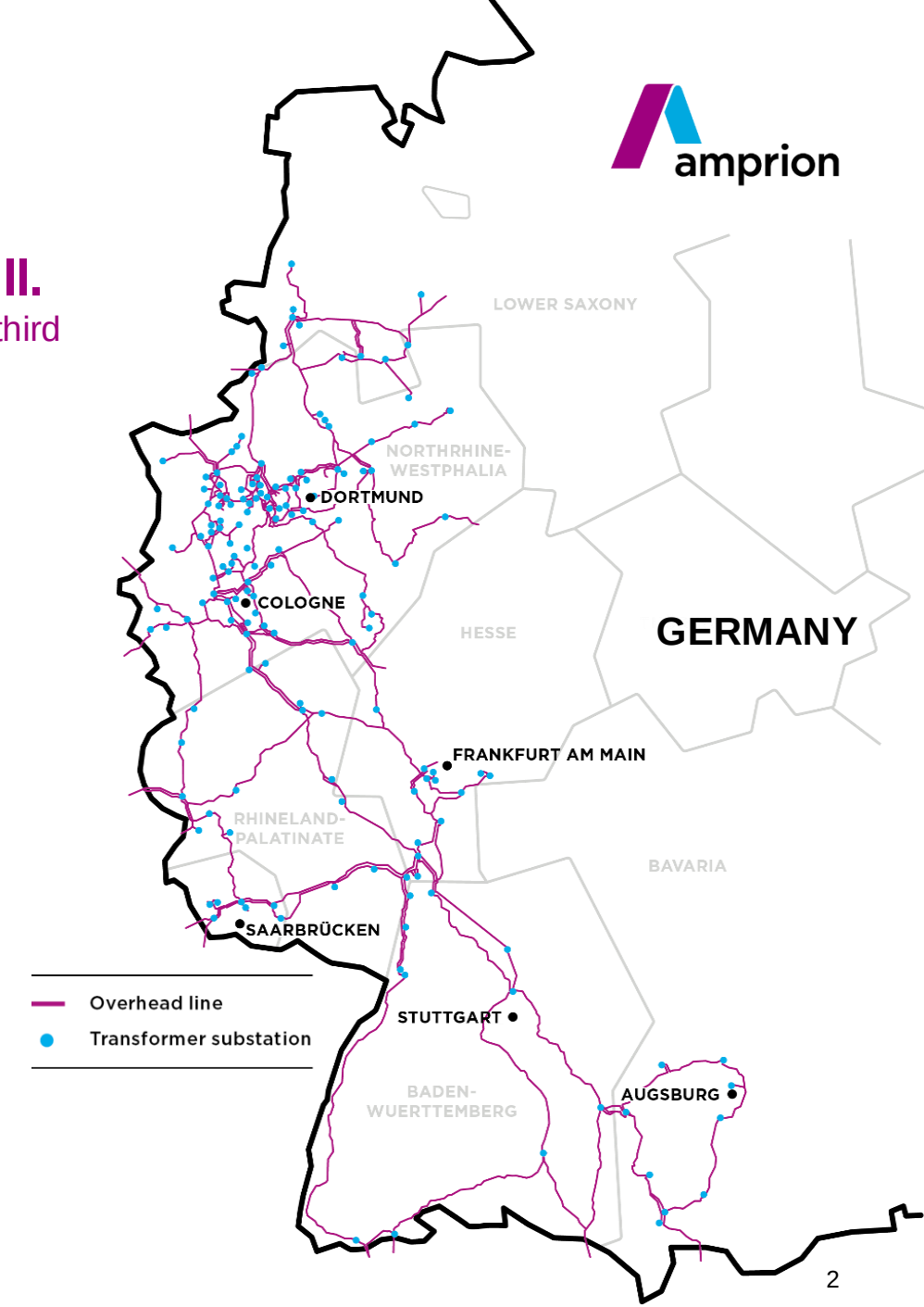
euros will be invested in grid expansion over the next five years until 2028.

11,000 KM

is the length of our transmission grid. It stretches from the North Sea to the Alps.

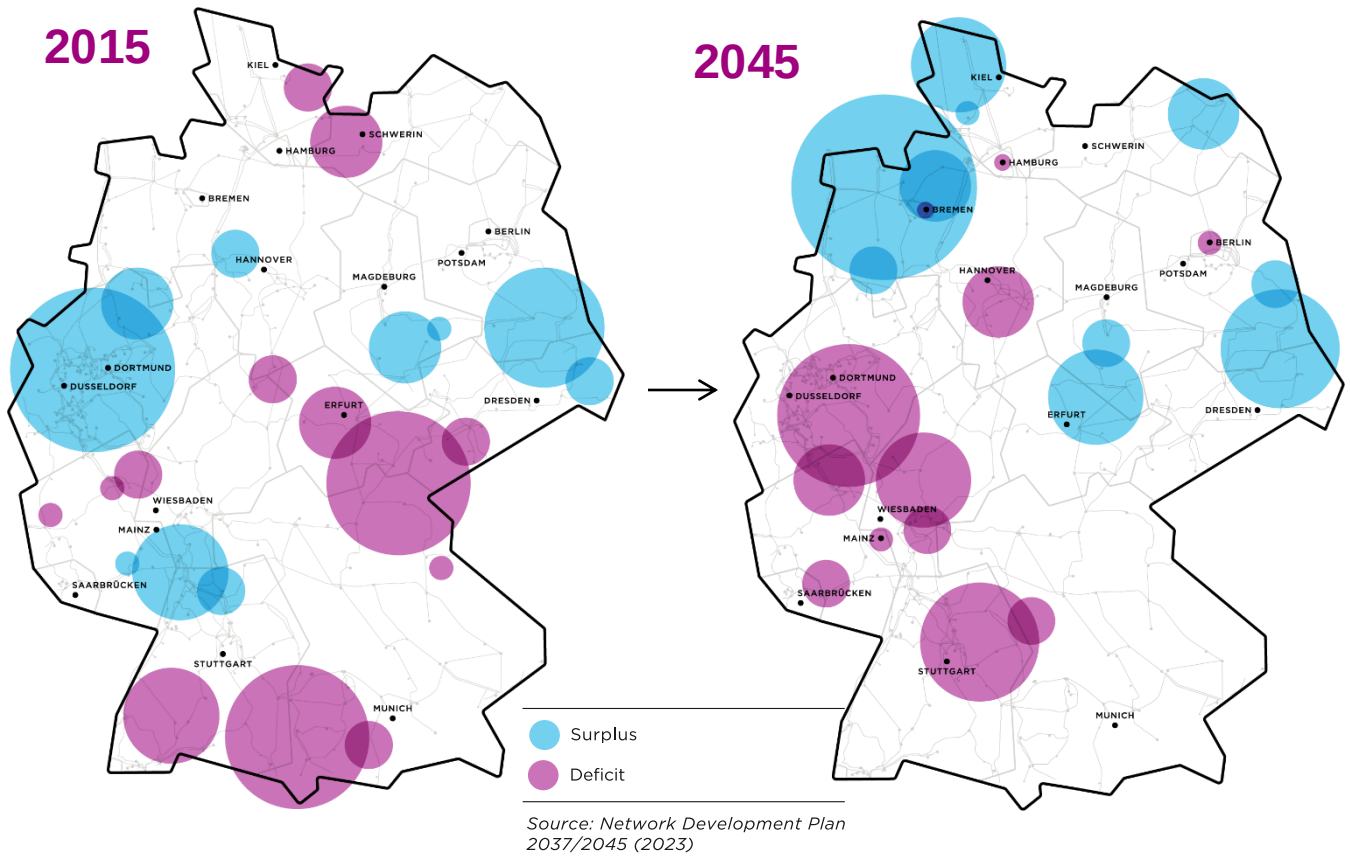
>2,700

employees play their part in ensuring Amprion fulfils its legal mandate.

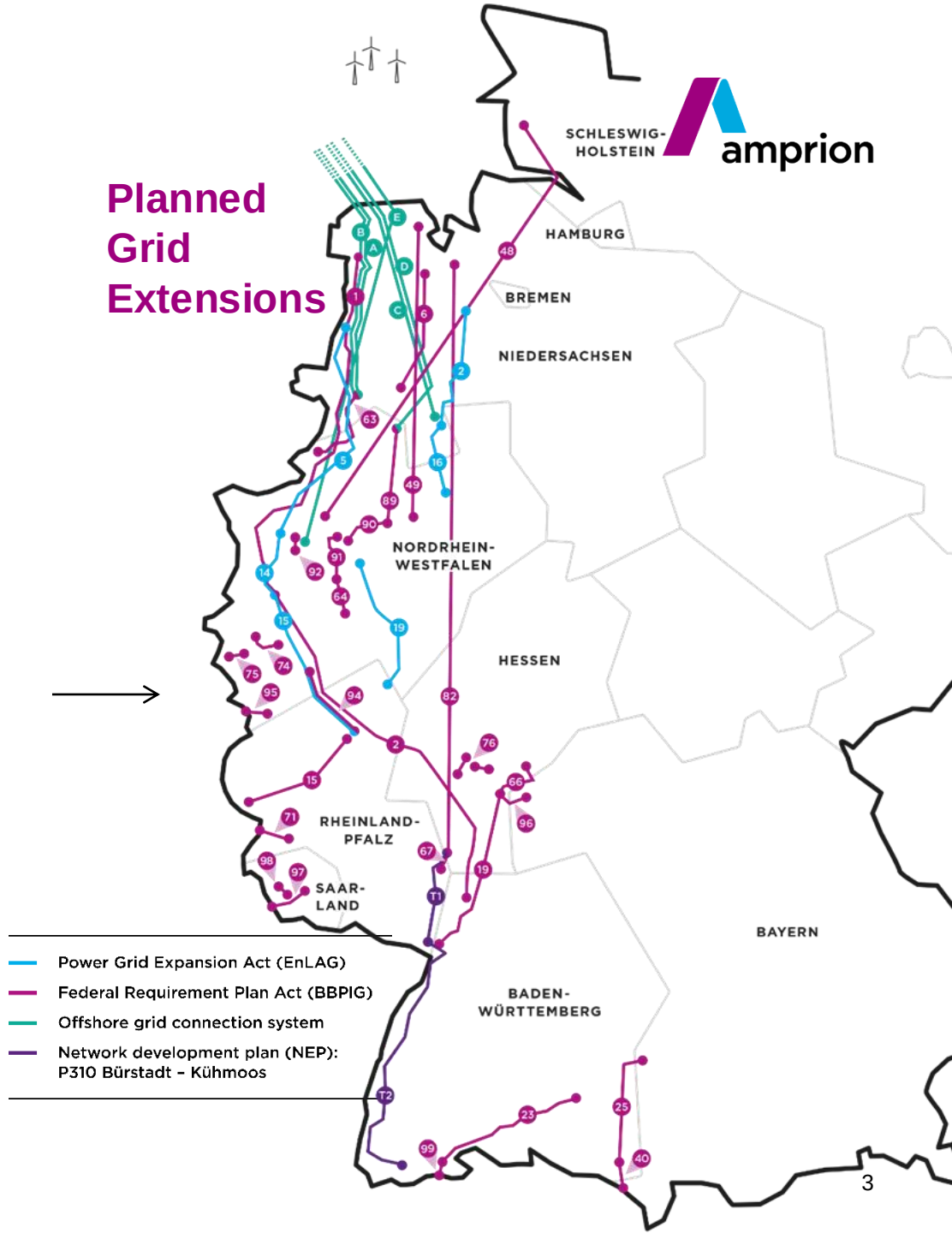


GRID EXPANSION AT AMPRION

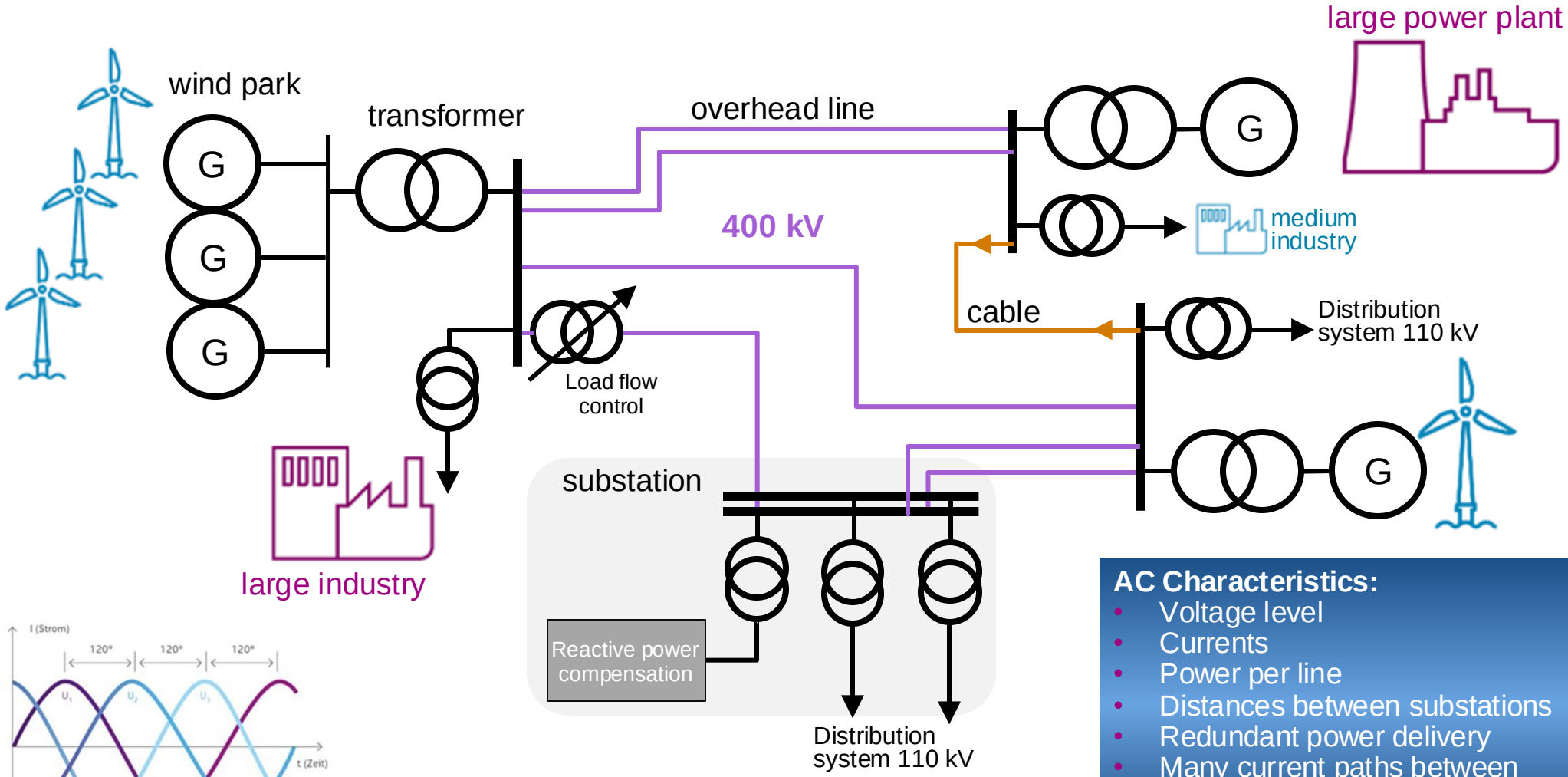
- In contrast with 2015, in 2045 power will be generated primarily where the weather conditions are most favourable – and no longer where demand is highest.
- The scope of the legally mandated grid expansion to be implemented by Amprion is around **6,800** kilometres



Source: Network Development Plan 2037/2045 (2023)



MAIN COMPONENTS OF THE EXTRA HIGH VOLTAGE ALTERNATING CURRENT TRANSMISSION NETWORK

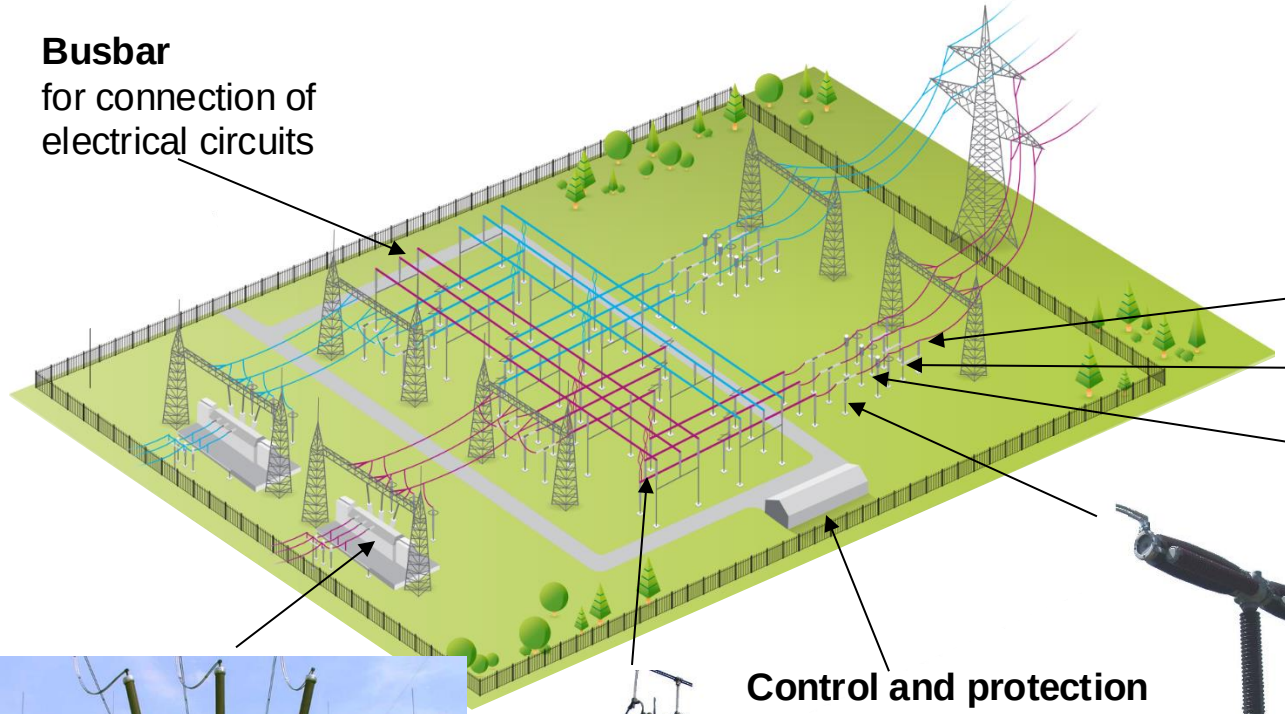


AC Characteristics:

• Voltage level	400 kV
• Currents	>2700 A
• Power per line	>1800 MW
• Distances between substations	50-200 km
• Redundant power delivery	N-1
• Many current paths between two substations are possible	meshed grid

EHV SUBSTATIONS ARE GRID CONNECTION POINTS

Busbar
for connection of electrical circuits



Transformer
for energy transfer between networks of different voltage

Disconnector
for configuration

Control and protection
for operation of equipment and fault detecion

Circuit Breaker
for current interruption

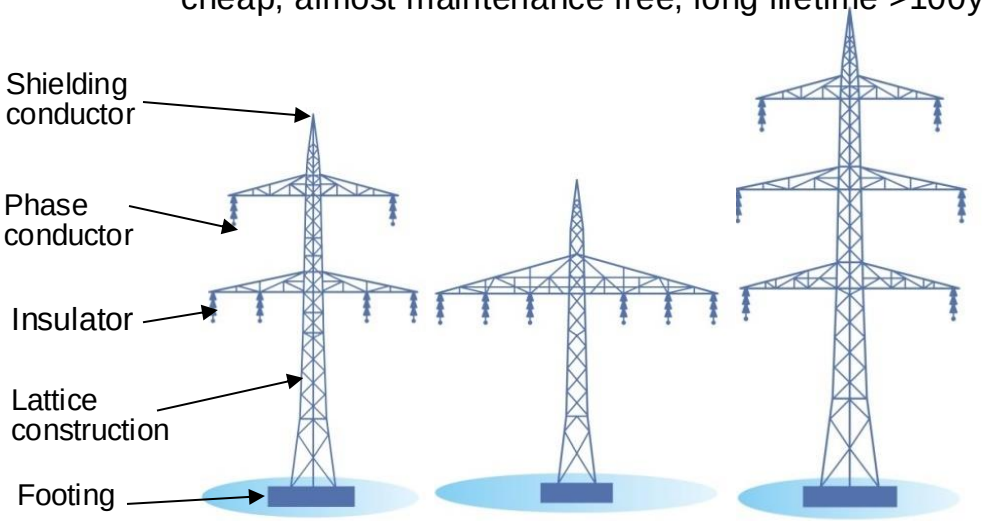
Combined voltage and current transformer
for measurements

Surge arresters
for overvoltage protection

Disconnector and **earthing switch**
for maintenance s purpose

EHV OVERHEAD LINES AND DYNAMIC LINE RATING

Lattice towers
cheap, almost maintenance free, long lifetime >100y

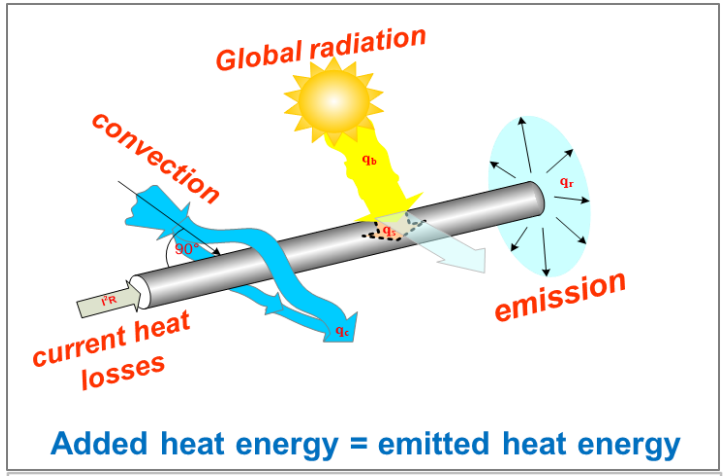


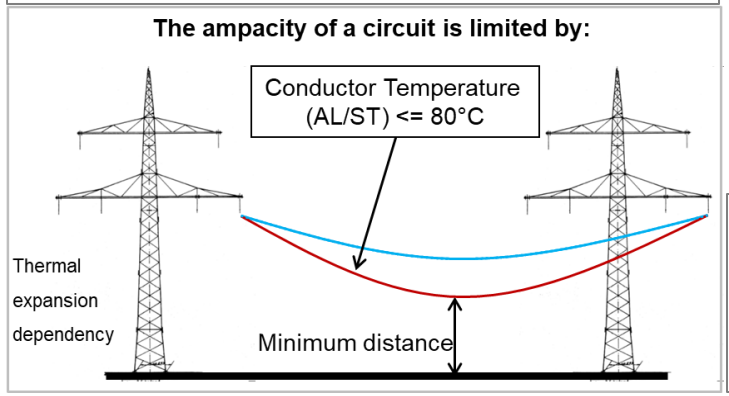
Lattice construction and footing

Insulator

Conductor

Dynamic Line Rating – adapts the maximal current currying capability of overhead line to the present weather conditions.
The sag of conductor is dimensioned for 35°C ambient temperature, which occurs seldom in a year. The remaining time the ambient Conditions are more favourable for energy transmission.





Monitoring of weather conditions in thermal hot-spots for conductor sag validation and weather forecasts necessary

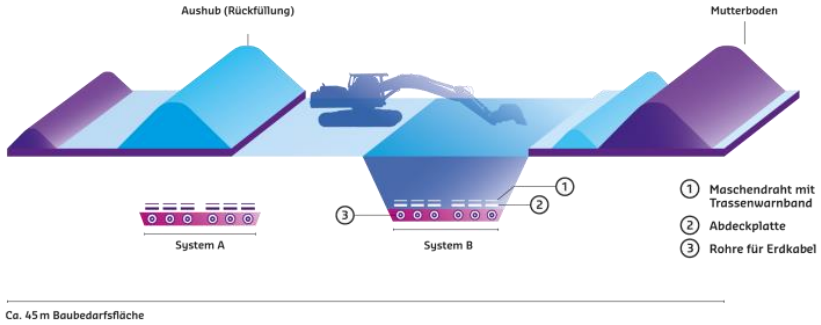
EXTRA HIGH VOLTAGE POWER CABLES

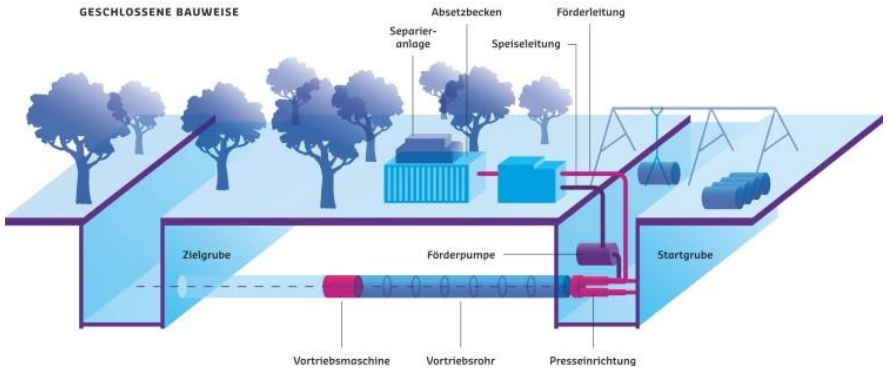
4 Cooper conductor

3 Insulation

2 Metallic Sheath

1 Outer Sheath





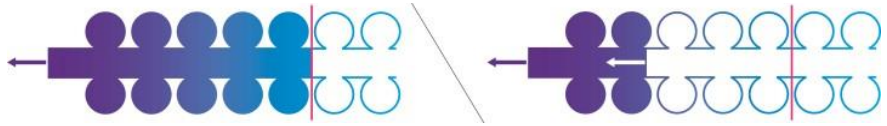
Cable joint

Note: Due to significant capacitance and reactive power demand, the lengths of EHV AC cables are limited up to 50km. Hence most of HV AC lines are overhead lines.

REACTIVE POWER COMPENSATION

- Reactive power is a property of electrical circuit to temporarily store the energy
- The reactive power is similar as bags on a tube. Assuming we are going to transmit water. First the bags will be filled in before we see water at the other end

- The water transport occurs in both direction with frequency of 50Hz so the bags are filled in and emptied regularly.
- Should the bags be too big, the water will not reach the far end, before the flows turn over. Should they be too small, at the far end will be received much more water as expected



- In reality we need to compensate the size of bags (or reactive power) to keep the voltage in designed bandwidth

Reactors for voltage decrease

Capacitor banks for voltage increase

Synchronous Condenser
for both increase and decrease
of voltage with rotating weight (inertia)

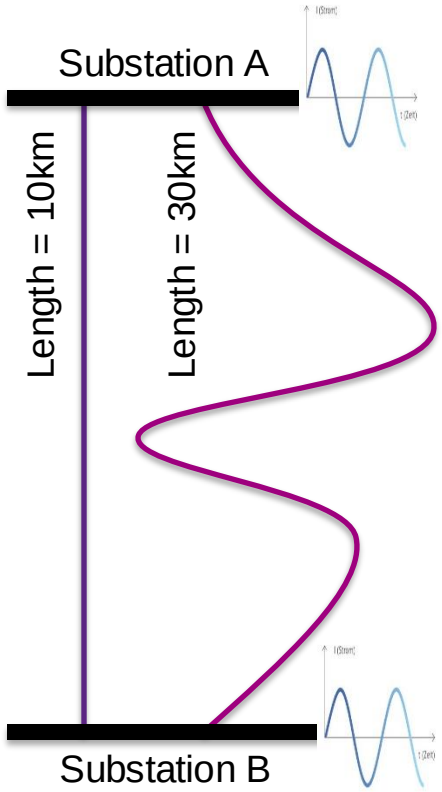
Rotating phase shifter

Static Synchronous Compensator
for both increase and decrease
of voltage no inertia but very fast

Power electronic

OPTIMISATION OF POWER FLOWS FOR OPTIMAL LINE LOADING

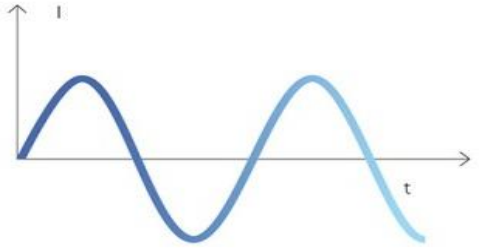
- Let us try to transport energy with trucks of the same size between two substations.
- It is clear, that if they take different routes, they will not reach the goal at the same time.
- However, due to the property of electrical grid (equal frequency) they must reach the goal at the same time
- Hence the track on shorter route must be bigger and slower while on longer route smaller and faster.
- The same happens with transportation of electricity over lines of different length.
- Lines will not be equally loaded. Hence, the infrastructure will not be optimally used.



- **Conventional solution**
  - Phase shifting transformers

- **Unconventional solutions like**
  - Thyristor Controlled Series Compensation
  - Modular Static Synchronous Series Compensation
  - others

WHY DO WE NEED HVDC?



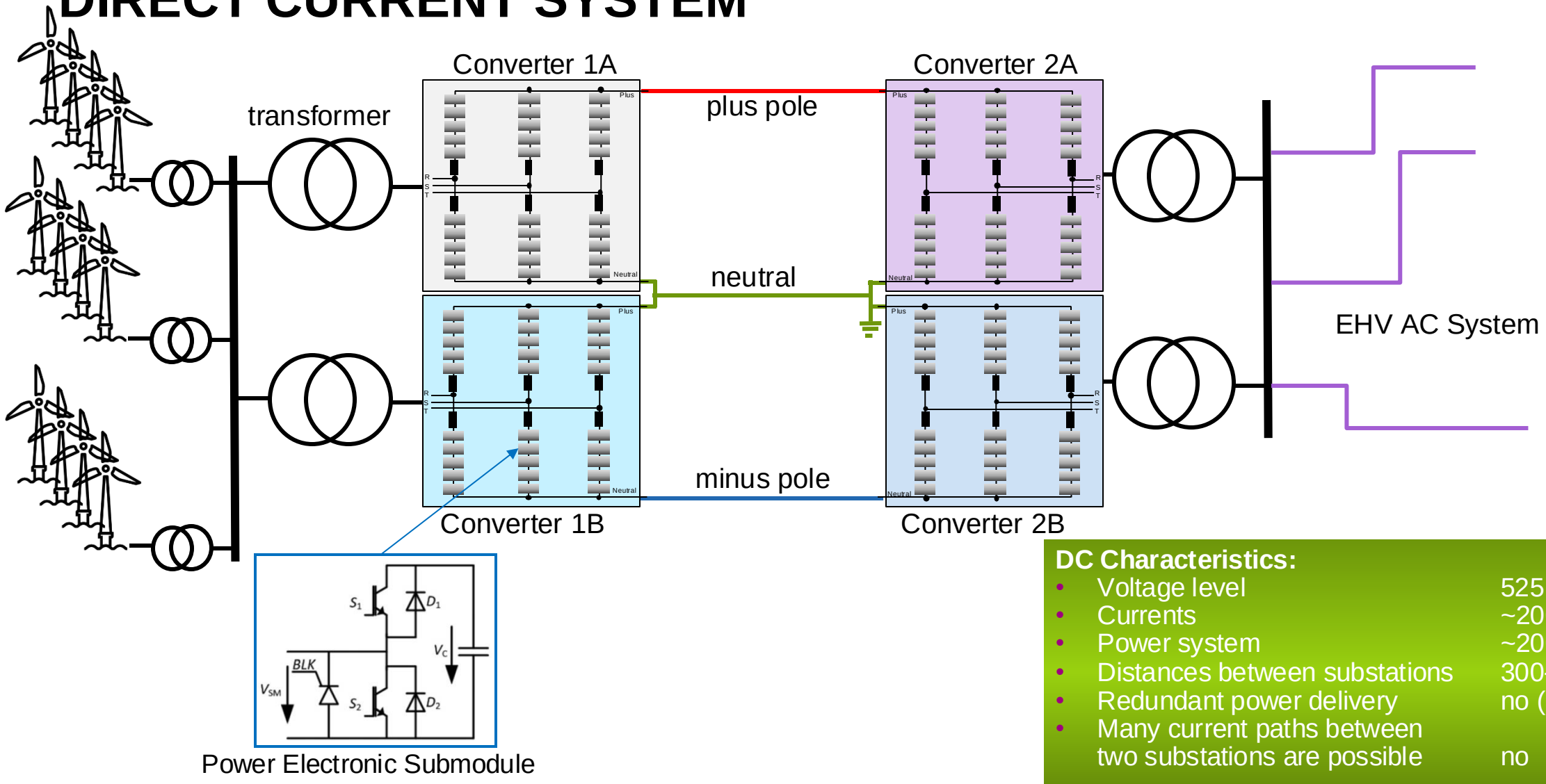
High Voltage Alternating Current

- Easy transformation of power between networks of different voltage levels
- Easy and cheap extension of the existing networks
- Easy management of faults and outages in the grid
- Very good service experience, availability of components, reliability of components

High Voltage Direct Current

- point to point energy transmission over hundreds of kilometres (building bridges above existing HVAC)
- use of long cable sections offshore and onshore with high public acceptance in Germany
- full controllability of the transmitted power
- no reactive power compensation needed

MAIN COMPONENTS OF THE EXTRA HIGH VOLTAGE DIRECT CURRENT SYSTEM



DC Characteristics:

• Voltage level	525 kV
• Currents	~2000 A
• Power system	~2000 MW
• Distances between substations	300-700 km
• Redundant power delivery	no (50% possible)
• Many current paths between two substations are possible	no

BASIC COMPONENTS OF CONVERTER STATIONS

Smoothing reactors

Surge arrester battery

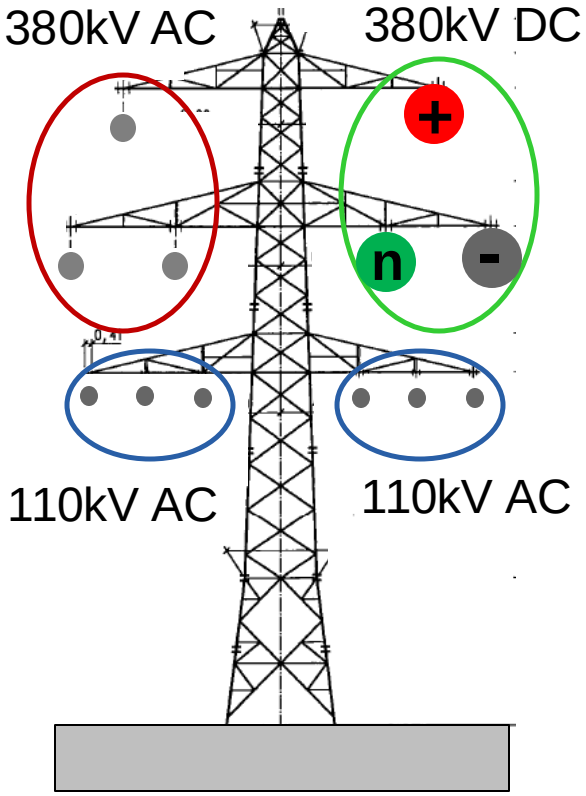
±320kV 900MW station

Transformers

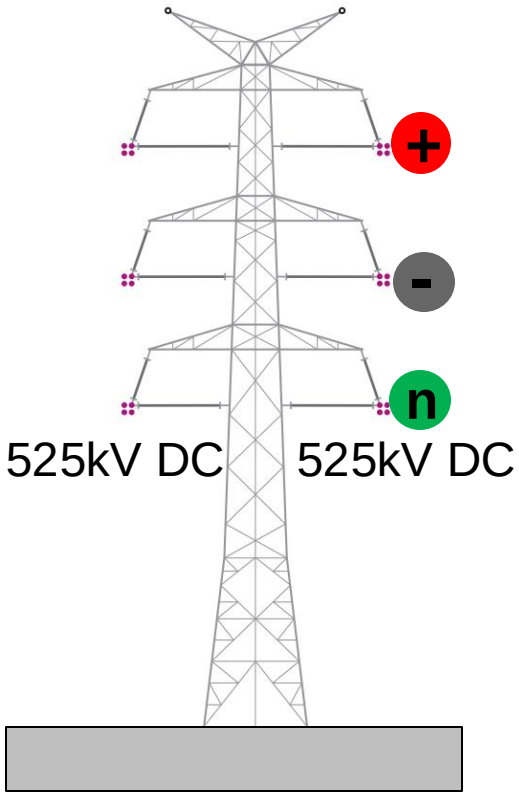
Converter hall with switching valves

EHV DC OVERHEAD LINES AND CABLES

Hybrid AC-DC tower



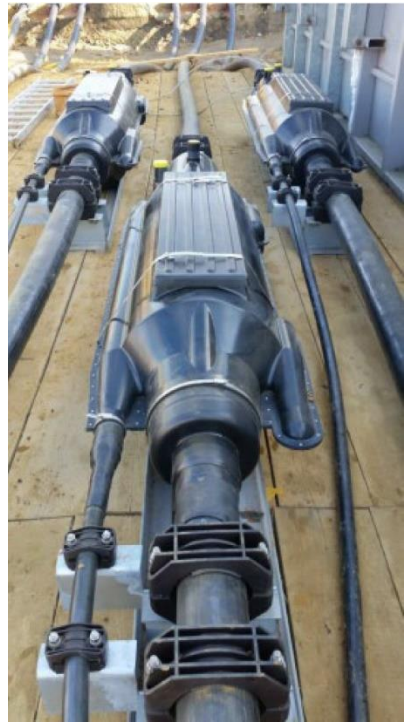
HVDC tower



EHV DC cables differ from AC cables especially in insulation

Cable termination

Cable joints

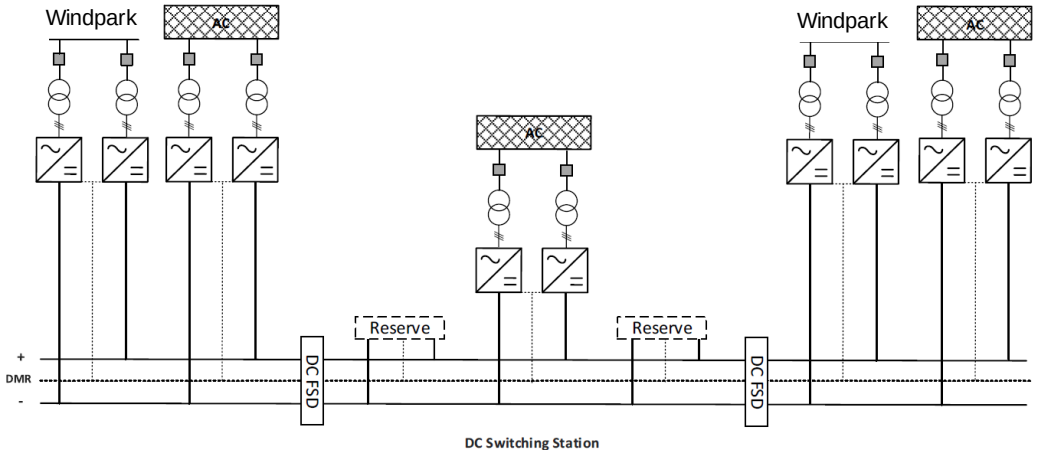


525kV Power cable

(Source: Broschüre Hochspannungskabel von ABB, Stand 01/2015)

HVDC MULTI TERMINAL UND HVDC CIRCUIT BREAKER (AC BREAKER)

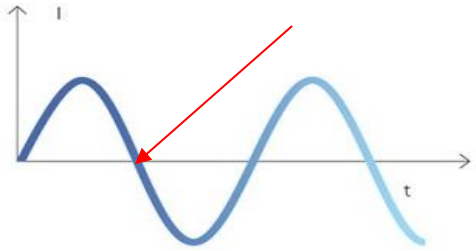
Multi Terminal HVDC System in planning phase



- DC Hub will connect 5 terminals, consisting of two offshore wind parks and three onshore converter stations.
- The busbar is going to receive two DC Fault Separation Devices (DC FSD) or HVDC Circuit breakers to selectively disconnect faulty system section
- In the future are also additional connections thinkable

The challenge for HVDC circuit breaker (or FSD):

- Conventional AC circuit breaker uses natural zero crossing of the current to interrupt the current flow



- In DC grid there is no zero crossing!

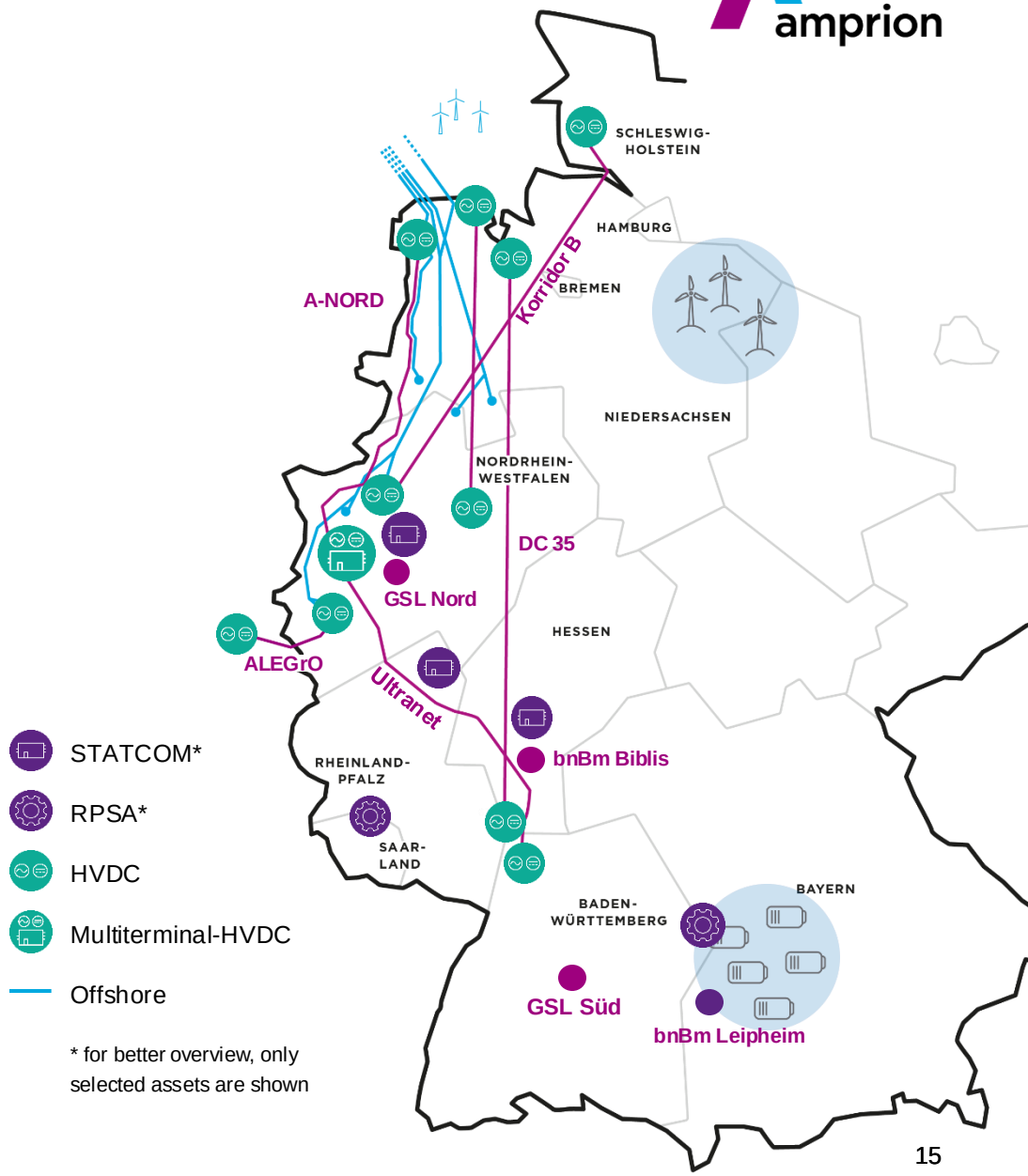
- Dozens of concepts for DC current interruption exists.
- Worldwide exist only one project with application of FSD. Hence the technology requires further development steps to be widely applied.

TECHNOLOGY CHALLENGES IN EHV GRIDS

HVAC is good for mashed grids
HVDC is good for point-2-point transmission

For system stability is HVAC decisive!
HVDC should support where it can

Energy transmission grid changes significantly and many new technologies and operational concepts are needed



VIELEN DANK FÜR IHRE AUFMERKSAMKEIT!

Sie suchen nach einer verantwortungsvollen Aufgabe und haben Lust, die Energiewende mit uns zu gestalten? **Jetzt bewerben!**