IRENA Innovation Week Panel Electric Highways

Siemens EM DG PTI

 siemens.com/power-technologies

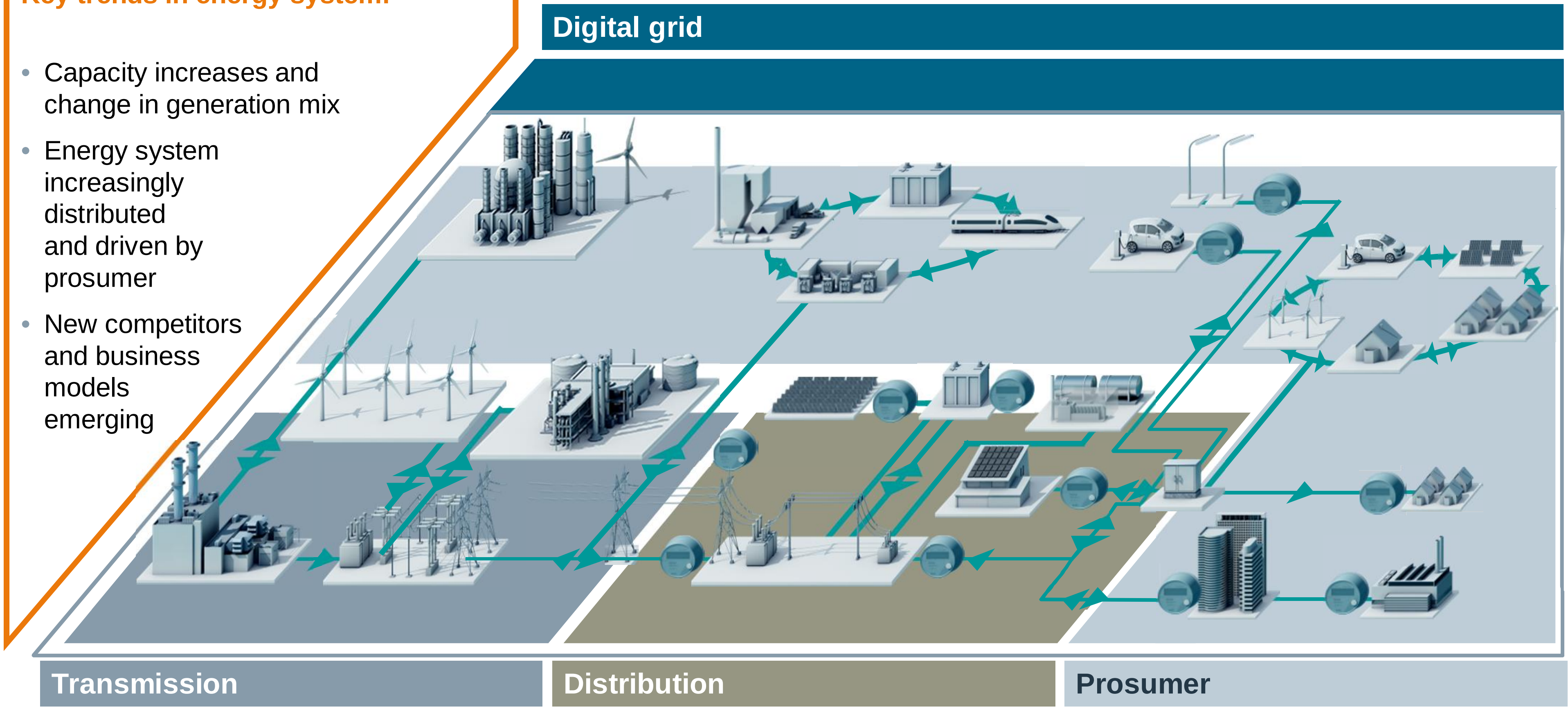
Power supply systems are changing fundamentally

SIEMENS

Key trends in energy system:

- Capacity increases and change in generation mix
- Energy system increasingly distributed and driven by prosumer
- New competitors and business models emerging

- Grid control
- Grid applications
- Prosumer applications



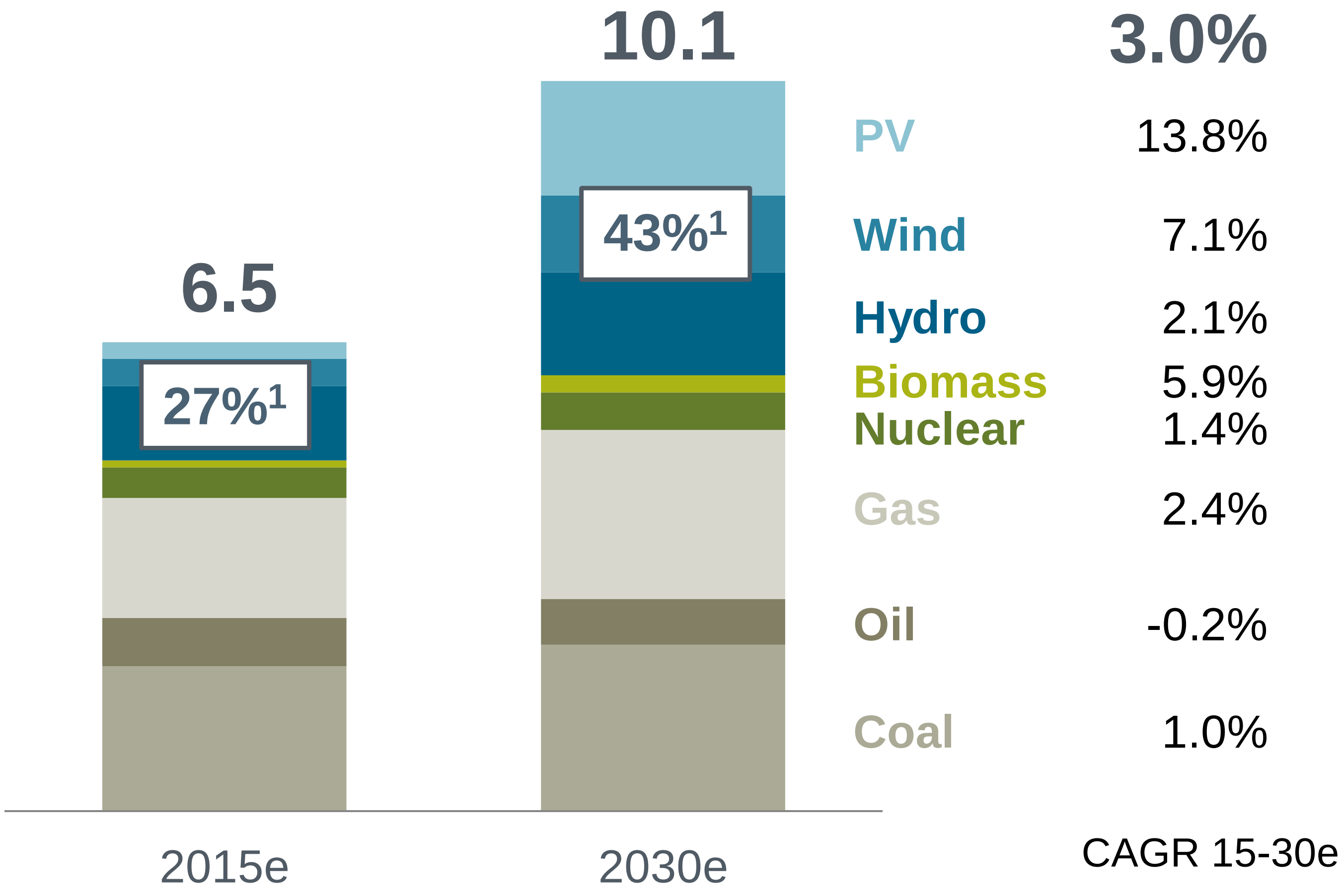
Transmission
- HVDC
- HVAC

Distribution
- Primary distribution
- Secondary distribution

Prosumer
- Critical power
- Distributed energy systems
- Building & construction electrification

Changes in global generation mix until 2030

Global generation capacity (TW)



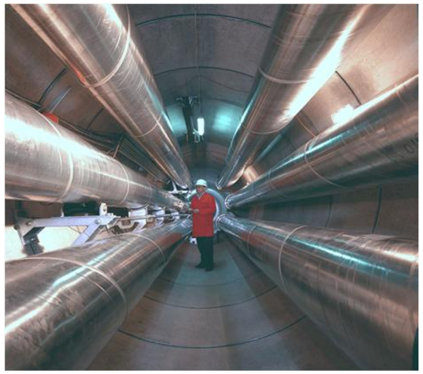
1 Share of Renewables in %

- Further electrification and change in generation mix drive generation capacity increase by 3% p.a.
- 50% of capacity additions in distributed energy systems
- PV with strongest increase in generation capacity

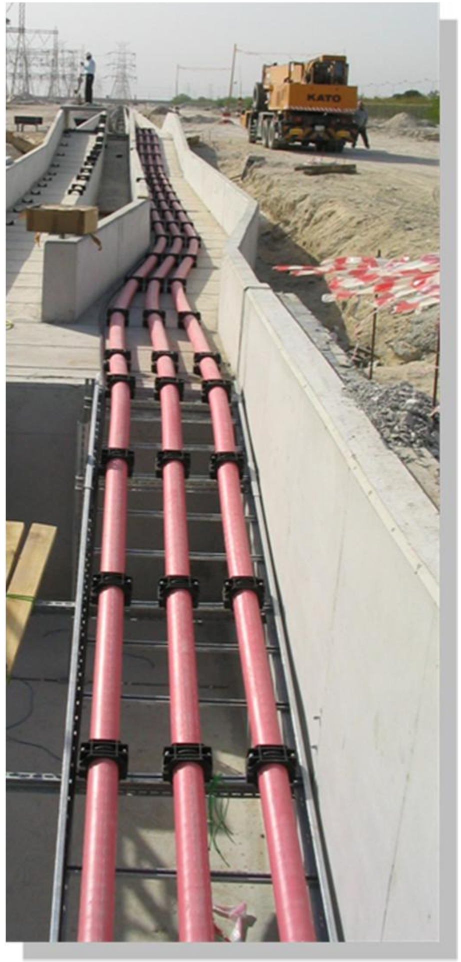
SIEMENS

Electric Highways = Energy System Backbone

Overhead line

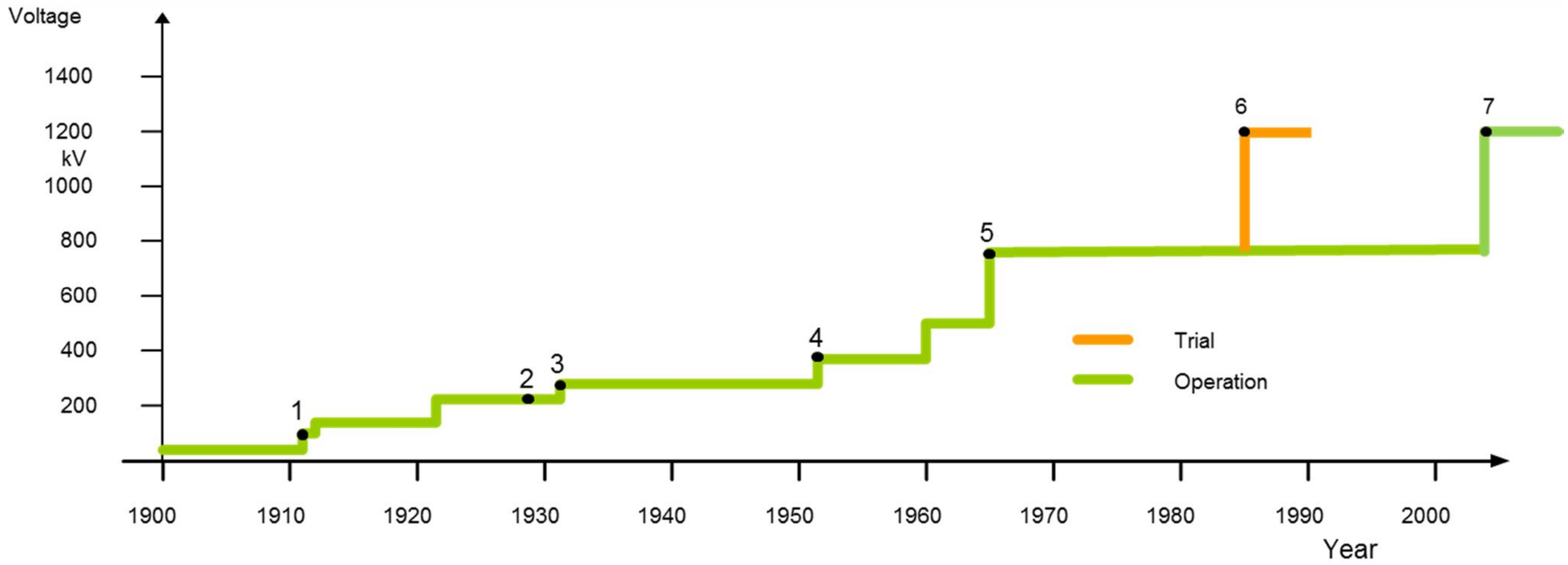


Gas insulated line



Cable

Development of AC Transmission



1	110 kV	Lauchhammer – Riesa / Germany (1911)
2	220 kV	Brauweiler – Hoheneck / Germany (1929)
3	287 kV	Boulder Dam – Los Angeles / USA (1932)
4	380 kV	Harspranget – Halsberg / Sweden (1952)
5	735 kV	Montreal – Manicouagan / Canada (1965)
6	1200 kV	Ekibastuz – Kokchetav / USSR (1985)
7	1200 kV	China, Indien, Japan

Losses:

$P_v = 3(I^2*R)$

Currents:

$I = S/\sqrt{3}U$

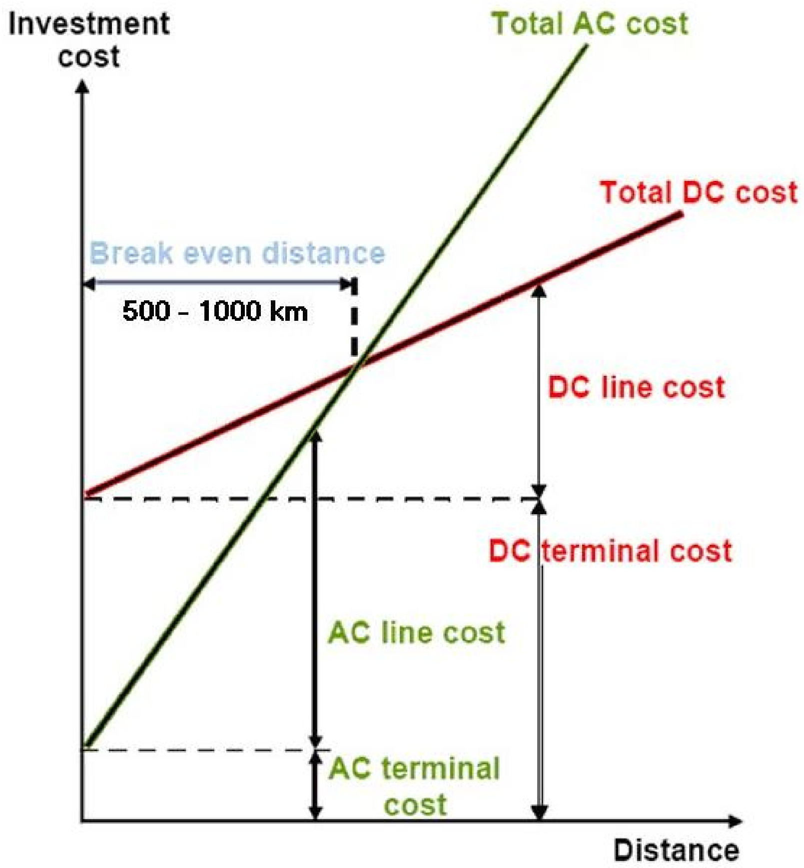
Higher Voltage = Lower Currents

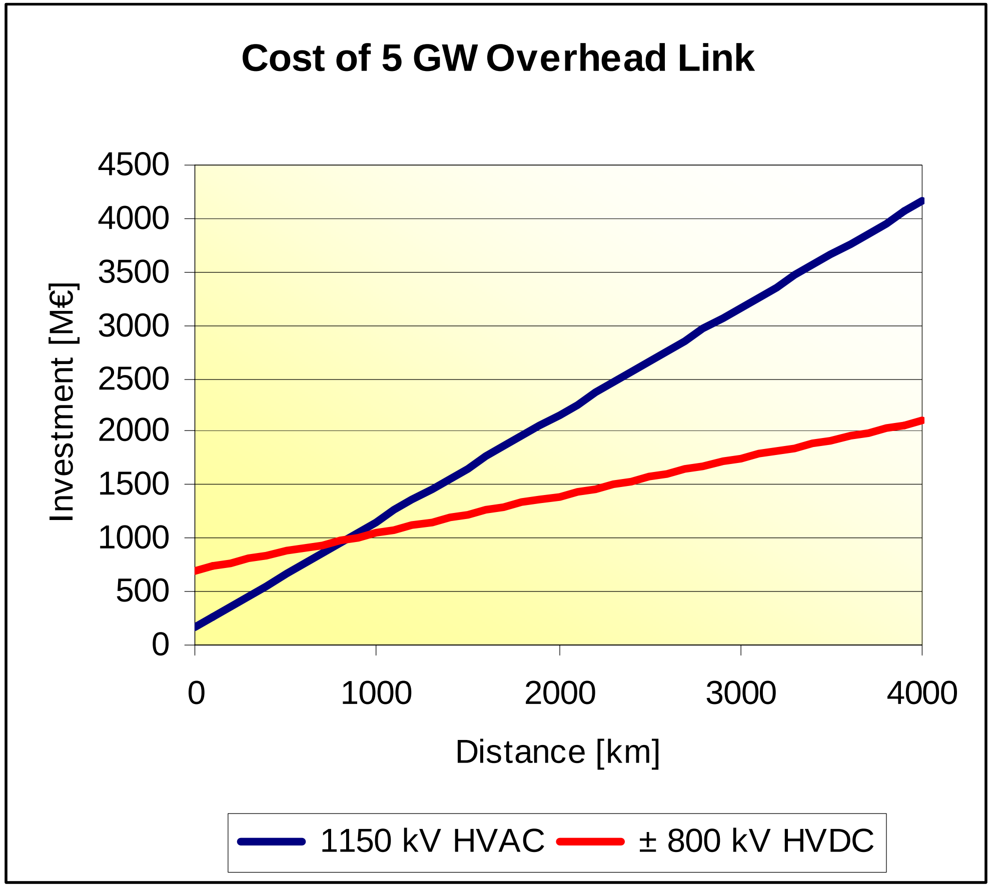
FACTS:

Flexible AC Transmission Systems

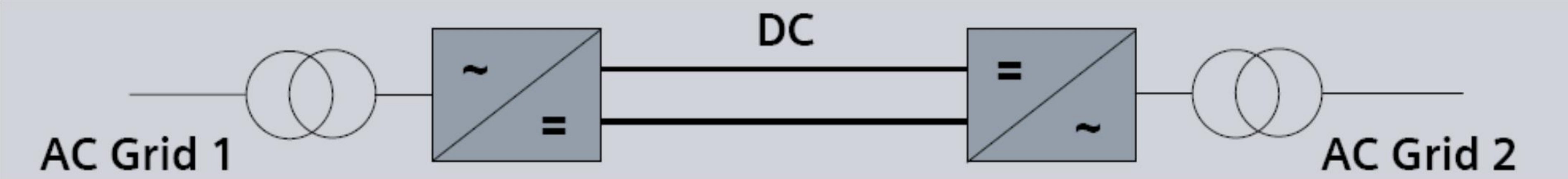
HVDC offers signficant savings for long-distance energy transport

SIEMENS





Technology for HVDC Transmission



HVDC Classic

Line-commutated
current-sourced Converter

Thyristor with turn-on Capability only

- Direct-light-triggered Thyristor (LTT)
- Up to 10000 MW
- MI Cable up to 600 kV
- OHL up to 800 kV

HVDC PLUS

Self-commutated
voltage-sourced Converter (VSC)

Semiconductor Switches with turn-on only and turn-off Capability, e.g. **IGBTs**

- XPLE Cable up to 320 kV DC
- Half bridge up to 1,56 kA
- Full bridge up to 2 kA

HVDC and FACTS have significant advantages when integrating renewables

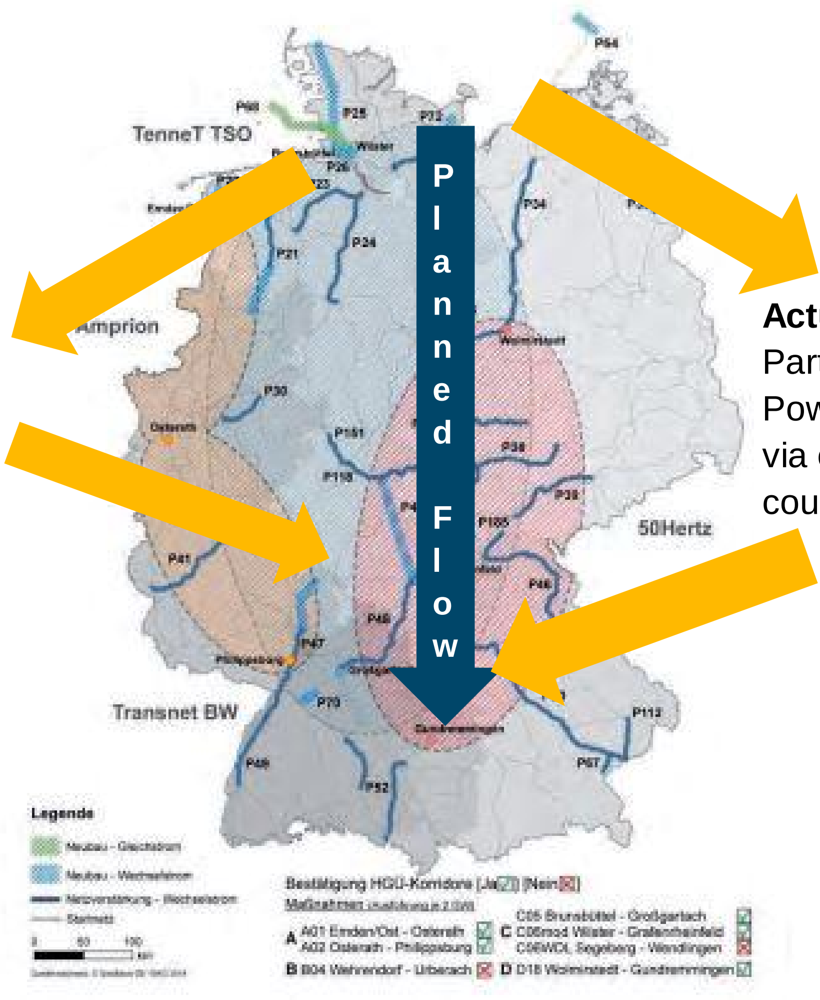
- Use of bulk power energy highways with HVDC & FACTS
- Avoidance of loop flows and overloads
- Control of power flow
- System interconnections with HVDC (Firewall) e.g. Texas
- Use of integrated AC/DC systems with FACTS & HVDC
- Support of voltage recovery after system faults
- Reduction in Transmission losses (HVDC)

Germany: High wind generation in northern part, Load centres in South – HVDC as solution element

SIEMENS

- Interconnected system: Today Loadflow follows Ohm’s Law – leads to power flow through neighbouring countries
- HVDC connections allow to control the loadflow direction and active/reactive power.
- Avoidance of neighbouring network utilizsation and loopflows
- Use of FACTS allows voltage recovery after incidents from rapidly changing loadflows coming from renewable infeeds

Planned North-South Corridors (Blue)



Actual Flow: Part of the Power flows via other countries

Source: Bundesnetzagentur: Monitoringbericht 2015

Comprehensive power system studies for the HVDC PLUS transmission system project “Ultranet”

SIEMENS

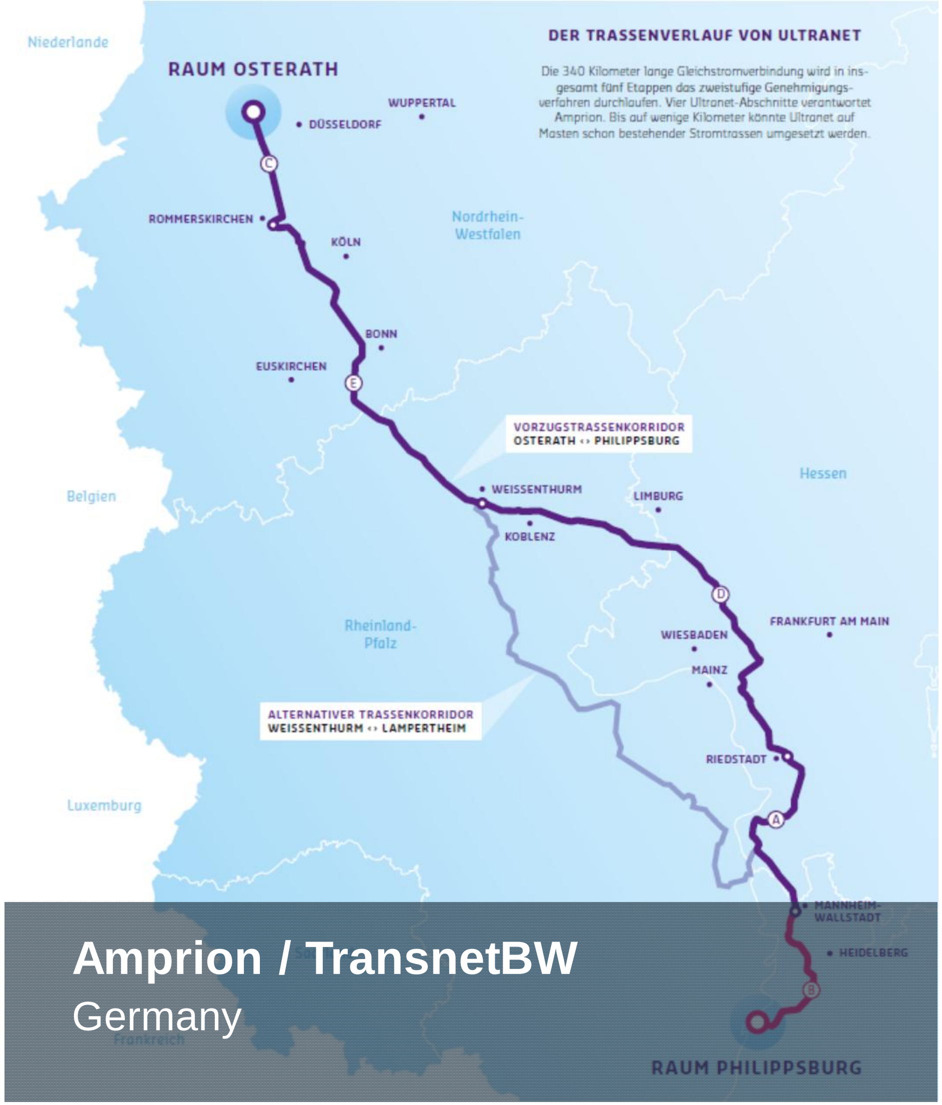
Challenge

- Realization of the first HVDC transmission link for the German transmission system based on the network development plan
- **Hybrid AC/DC** overhead line system
- Multi-terminal system enhancement in future
- First full-bridge MMC converter for HVDC transmission on DC +/- 420 kV voltage level

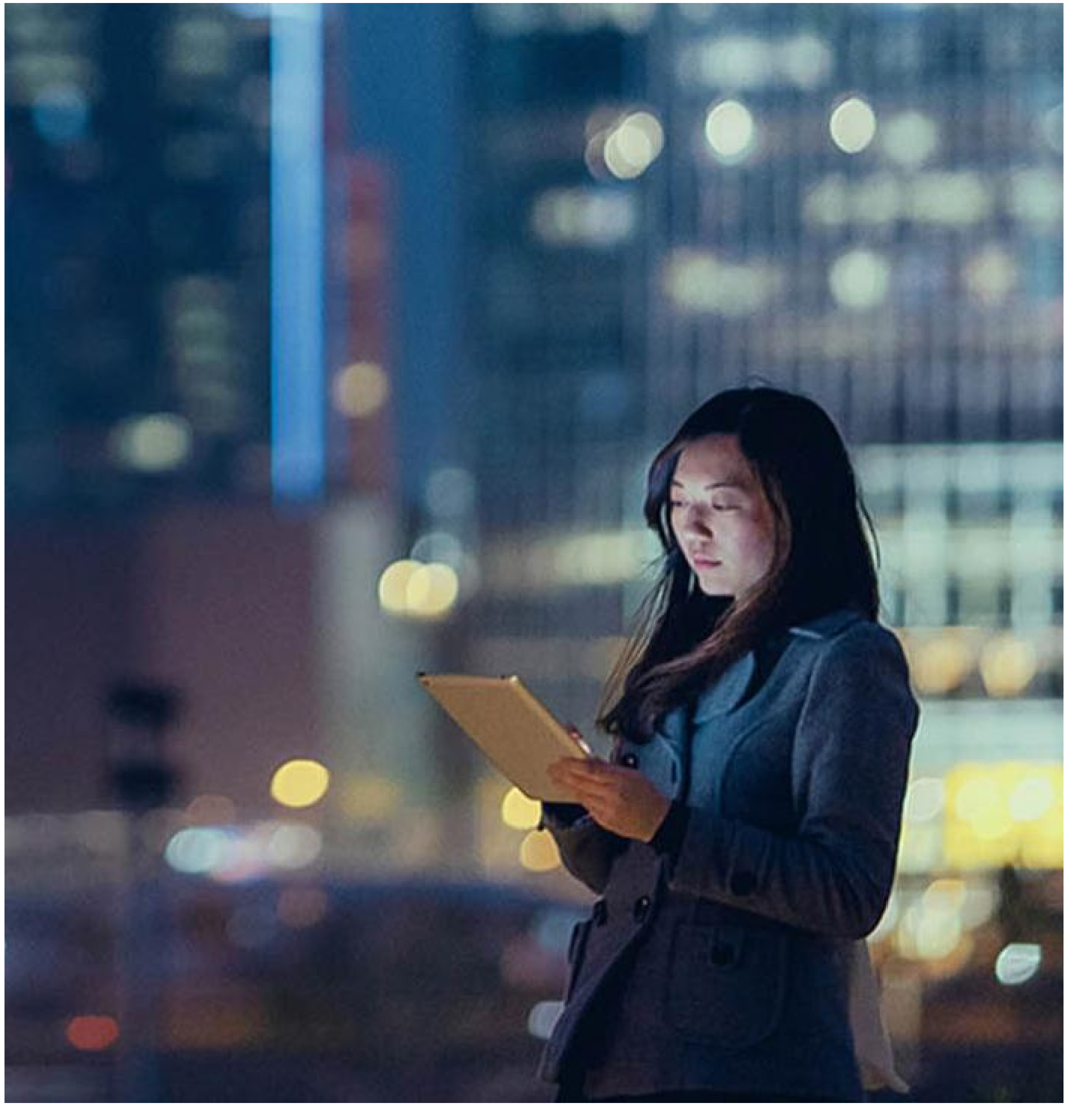
Solution

Pioneering project requiring full set of system studies for the “Engineering and design phase” comprising, including

- Investigation of AC/DC interaction in order to reach the targeted system performance
- Integrated view on the entire system
- Harmonic impedance
- Transient interaction (AC protection)
- EMT system study
- Resonance interaction study
- Network reduction for real-time digital simulation



Contact



Michael Schneider
Head of PTI

Freyeslebenstr. 1
91058 Erlangen (Germany)

E-mail:
michael.f.schneider@siemens.com

siemens.com/power-technologies

Backup

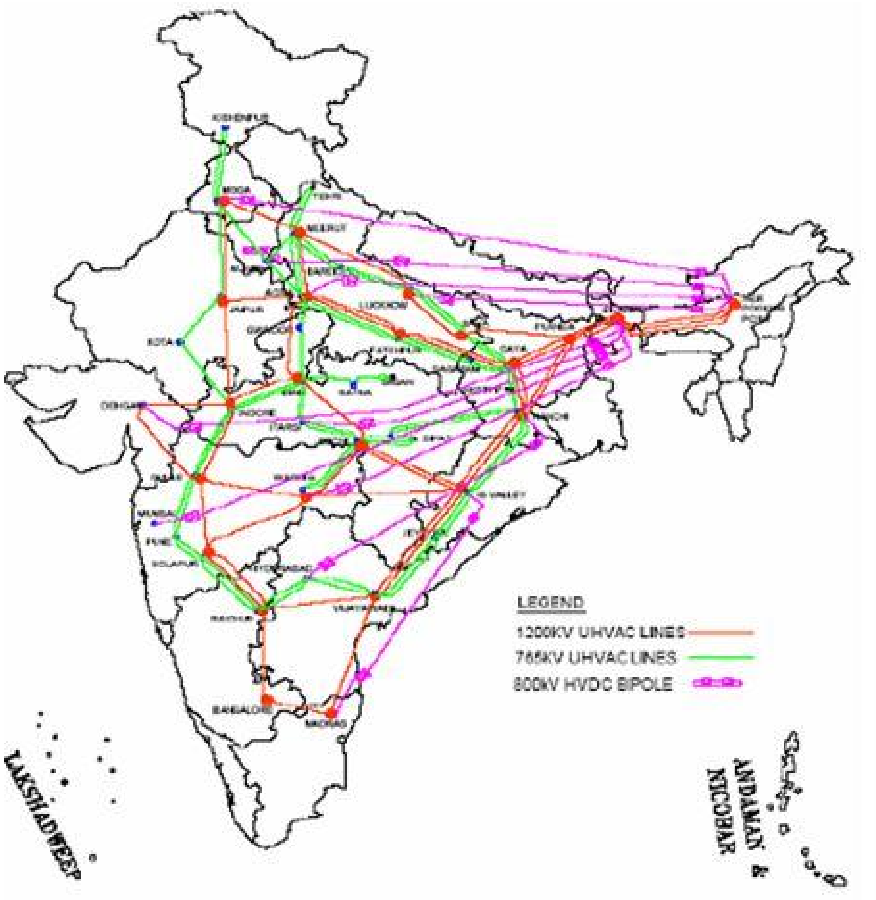
AC/DC Hybrid systems – Example India

India develops an AC/DC Hybrid system and foresees to operate in 2027:

- 1200kV AC Lines (Red)
- 765kV AC Lines (Green)
- 800kV DC Bipolar (Purple)

(Source: Central Electricity Authority)

The HVDC corridors allow for a controlled power flow for long distances and accross challenging geographies in North East



Feasibility study of HVDC PLUS for Japanese transmission networks

SIEMENS

Challenge

- Feasibility study of HVDC PLUS for future applications in the Japanese transmission grid
- Evaluation of replacement of existing LCC technology by VSC converters

Solution

- Workshop with customer delegation focused on basics of VSC technology and operation in the Japanese grid
- Preliminary basic design of MMC converters for selected application cases defined by the customer
- Performance of feasibility study for these application cases and comparison to existing LCC technology
- Model development in the software tools PSS®SINCAL and PSS®NETOMAC
- Demonstration of VSC operating diagram and fault ride through performance

Customer benefit

- Introduction of VSC converter technology for high voltage applications and future grid development
- Technical and economical comparison of existing LCC technology with new VSC based solutions for the grid

J-Power EPDC
Japan

Comprehensive stability study for the Vietnamese transmission network

SIEMENS

Challenge

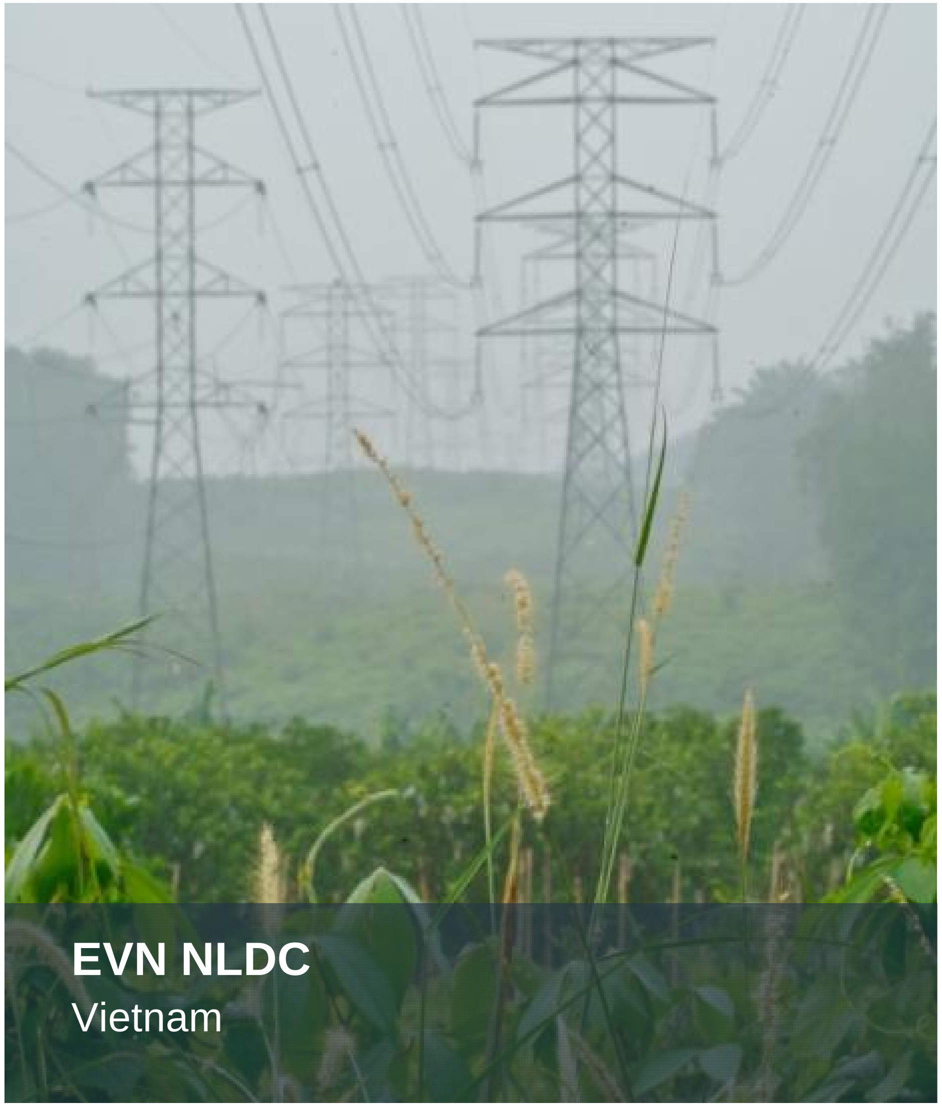
- Identification and evaluation of problems related to the system stability
- Revision and completion of the database for power stability studies and possible solutions for enhanced system stability
- Requirement of training and technical transfer

Solution

- Data collection, PSS®E data base, measurements
- Generator stability, small signal stability, frequency stability, voltage stability, recommendations to improve stability
- Improvement of dispatch function (DSA)
- Improvement of protection
- New functions for the regional 3 dispatch centers
- New compensation equipment for 500/220 kV

Customer benefit

- Improvement of reliability and stability of the Vietnamese system
- Risk reduction of system brown outs and black outs
- Higher safety of operation



Calculation and planning for grid integration of EEA generation

SIEMENS

Challenge

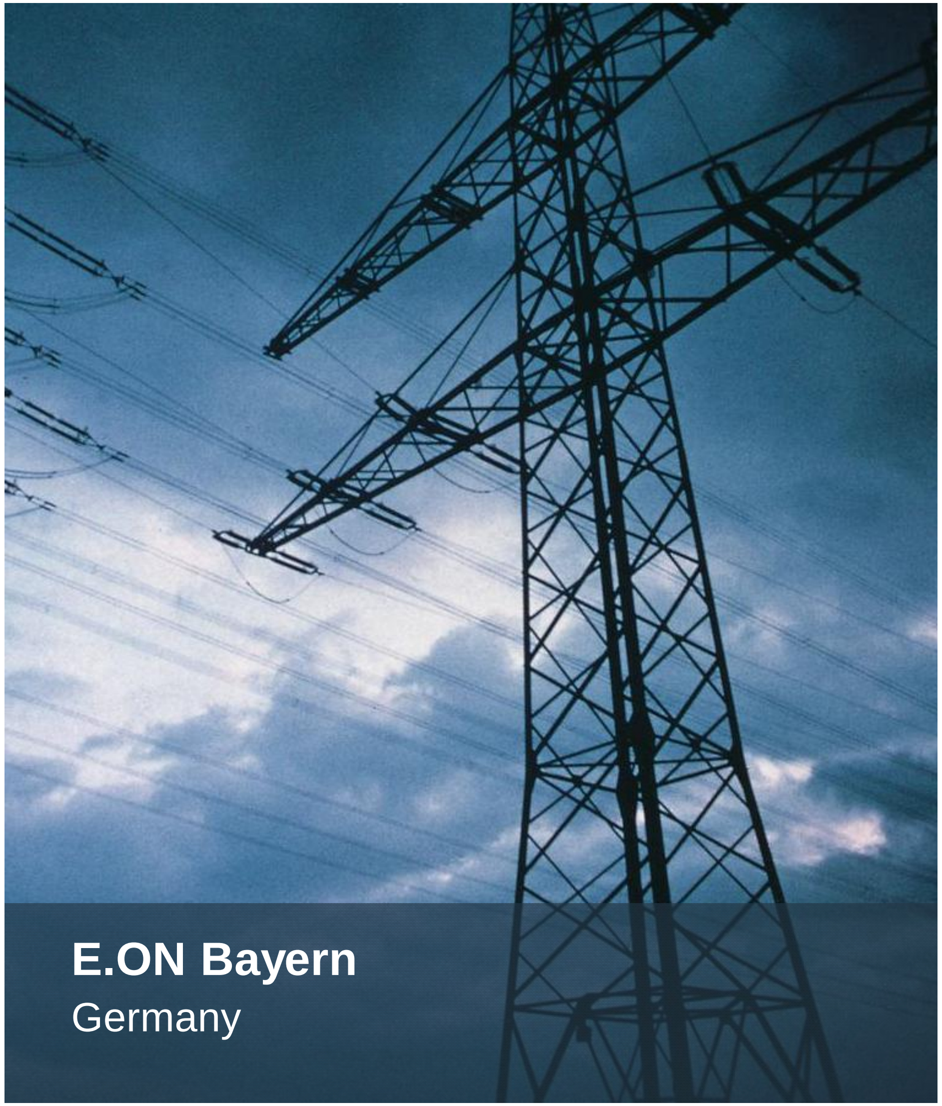
- Technical elaboration based on available on-site data sources
- Representation of elaborations to different divisions

Solution

- Integration of numerous distributed power generation systems into the service area of E.ON and checking on the grid compatibility
- Provision of alternatives for a technical and economical reasonable connection point

Customer benefit

- Fast handling in spite of heavy workload



Small Signal Analysis for Integration of Manitoba Hydro BP III HVDC Link (POD Tuning)

Challenge

- Identification of poor damped system inter-area modes where MH participates in.
- Analysis of participation and impact of the new BP III HVDC link on inter-area modes of interest.

Solution

- Based on Small Signal Analysis results, the BPIII HVDC Power Oscillation damping Controllers (POD) were tuned to provide positive damping to targeted inter-area modes

Customer benefit

- Proper use of available BP III HVDC POD controllers to provide positive damping to reduce risk of stability issues critical inter-area oscillations modes associated to MH

Manitoba Hydro
Canada

Comparison of capabilities

- **Gas Insulated Power Transmission Lines** are successfully under operation since more than 40 years, more than 750 km GIL tubes installed worldwide
- **Main advantages** of Power Transmission Lines (compared to power cable systems):
  - ✓ Very high power transmission with low losses
  - ✓ No ageing, >40 years of lifetime
  - ✓ No fire load
  - ✓ Very low electromagnetic fields
  - ✓ Low reactive power demand
  - ✓ Elbow
- **DC Power Transmission Lines („DC GIL")** under development:
  - ✓ ±500 kV , up to 5000 A DC → up to 5 GW
  - ✓ All the main development tests are successfully passed
  - ✓ First directly buried test installation for long term investigations in 2016
- **Mobile Factory principle** for direct laying on ground
  - ✓ High increase of installation speed
  - ✓ Large reduction of costs for GIL
  - ✓ Cost efficient installation of large transmission lines