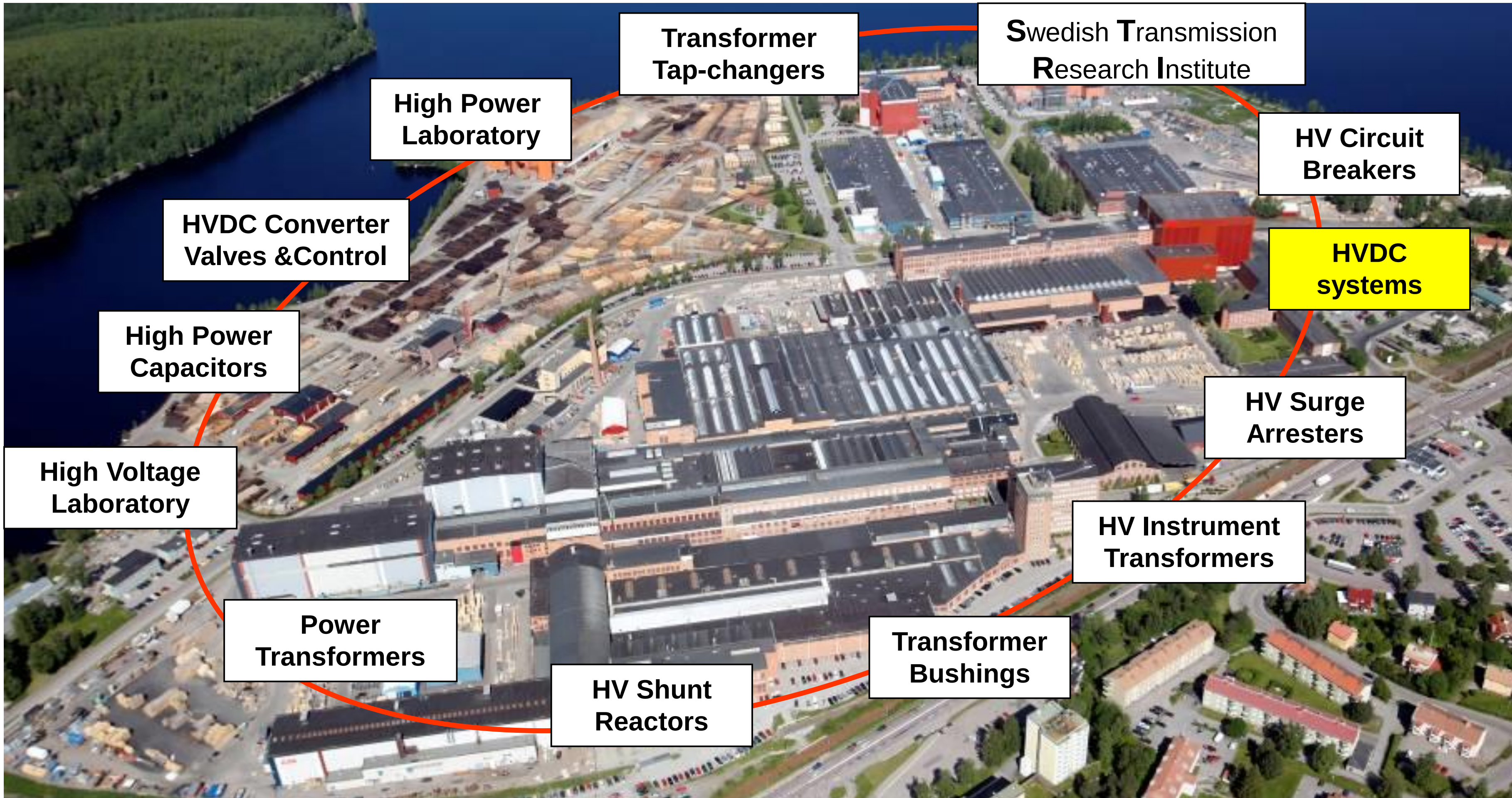
Jan G. Johansson, Senior Sales Manager - HVDC, 15-10-20 Cable seminar 2015

# HVDC converter technology
## Long distance transmission with low losses

# ABB in Ludvika
## A world center of high voltage



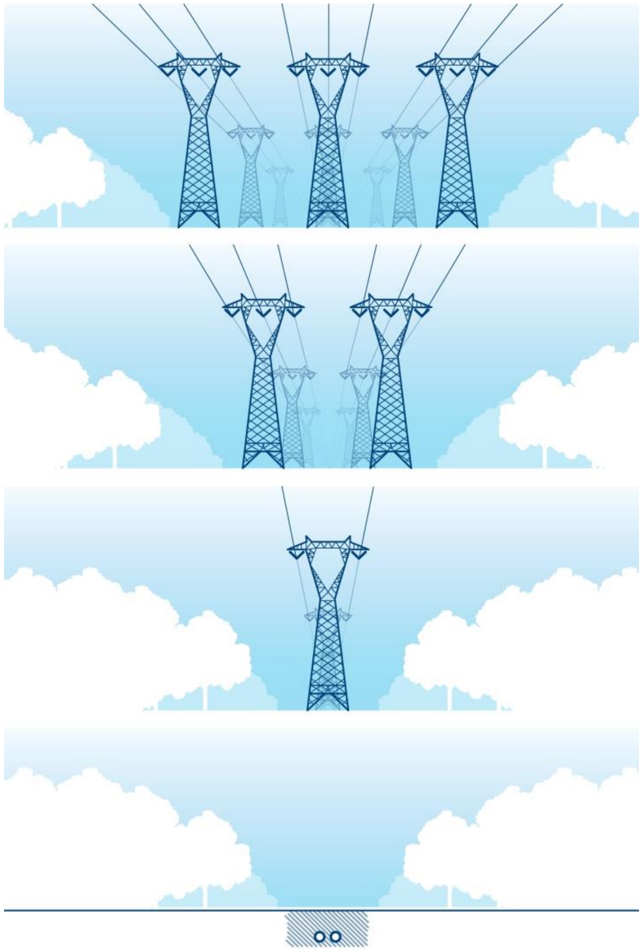
# HVDC Technology
## Traditional reasons for use

- Interconnection of asynchronous networks
- Bulk power transmission of long distances
- Submarine cable transmissions (> 50-100 km)
- Power flow control

# General trends affecting the electricity sector

- Reformation of regulations
- Globalization - increased cross boarder investment
  - Shared spinning reserve, controllability of HVDC
- Increased electricity trading
  - Controllability of HVDC
- Increased urbanization
  - City center infeed with HVDC
- Increased demand on power quality
  - Controllability of HVDC Light
- Increased use of renewable production
  - Remote and intermittent, controllability of HVDC
- Reduced implementation times
  - HVDC Light with underground cables
- Transmission monopoly challenged
  - Merchant transmission with HVDC Light

# Transmission technologies
## Same power being transmitted



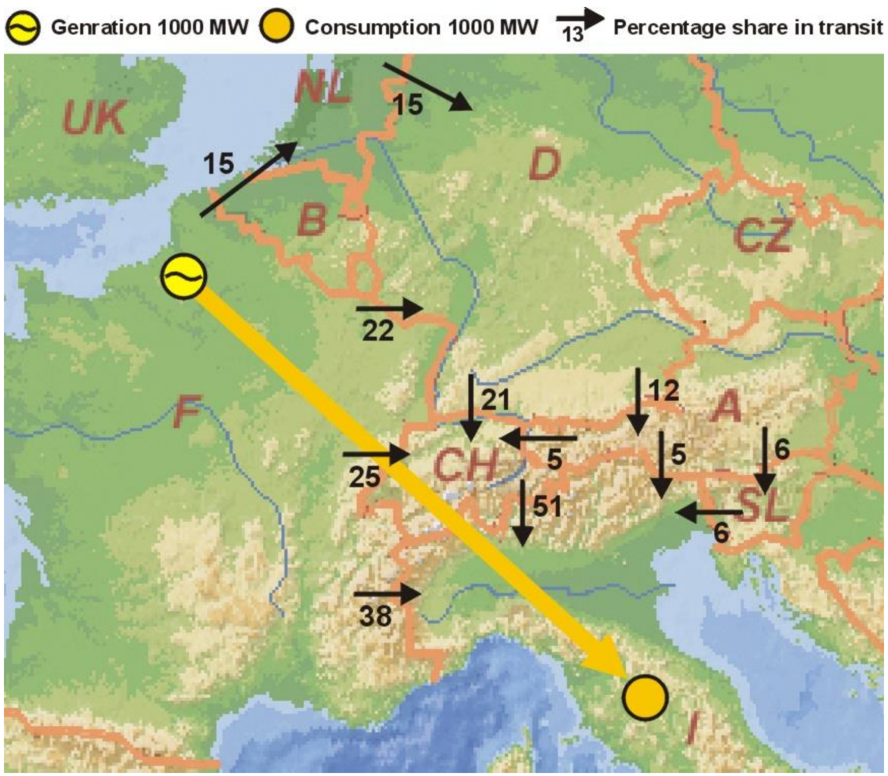
Traditional overhead line with HVAC

Overhead lines improved with FACTS

HVDC overhead line

Underground with HVDC Light cable

# Point-to-point interconnection
# Example: 1,000 MW power transmission




**Observations:**

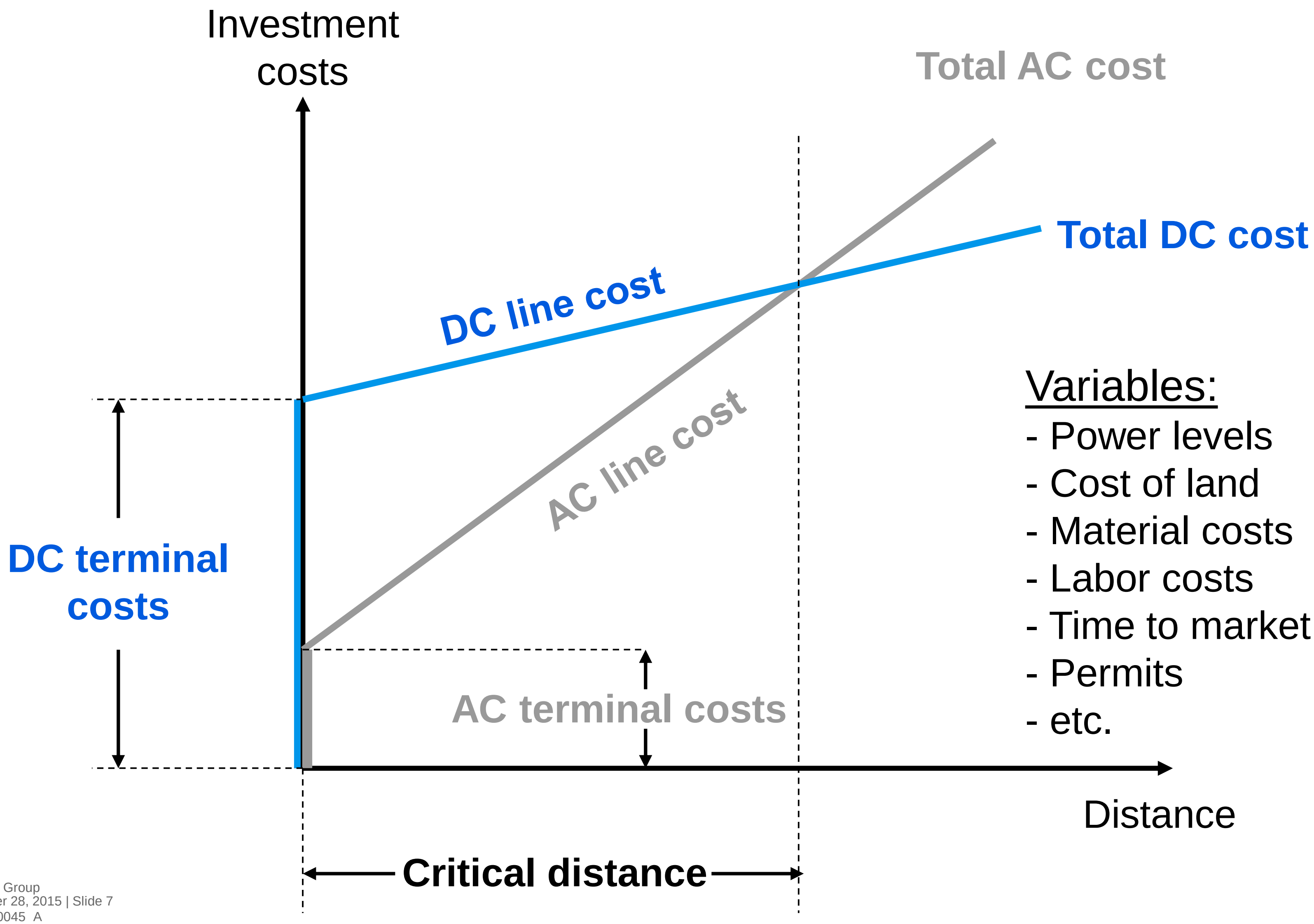
- Considerable spurious current flows created with AC

**Resulting in:**

- A need for reserve margins in the AC transmission systems
- An increase in power losses

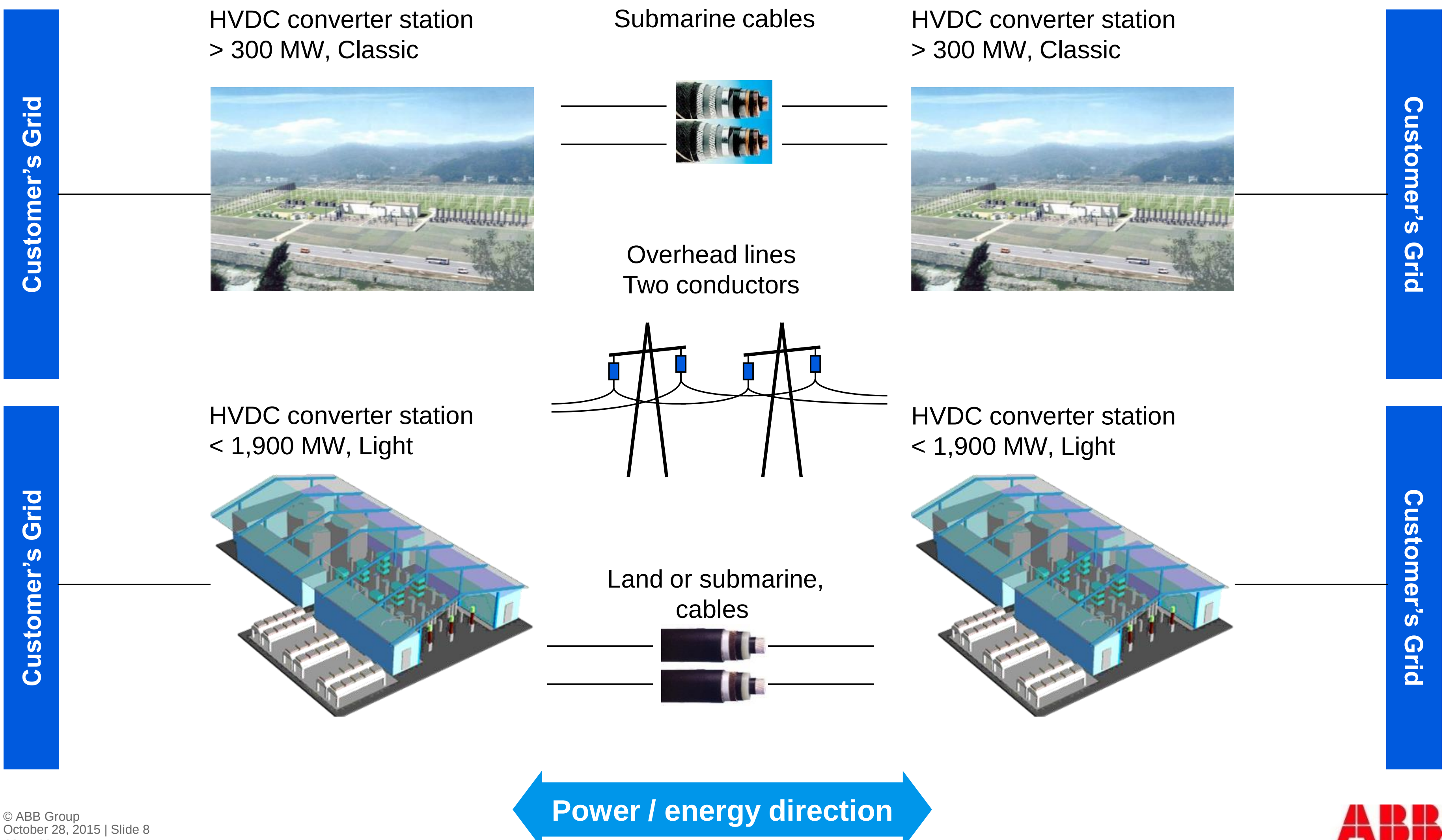
With HVDC point-to-point interconnection spurious current flows and overloads are eliminated in the intermediate zones

# HVDC or HVAC?
## Investment costs versus distance




Variables:
- Power levels
- Cost of land
- Material costs
- Labor costs
- Time to market
- Permits
- etc.

# What is an HVDC transmission system ?



# Unique advantages with HVDC

- Practically independent of power angles, frequencies and voltage variations in interconnected AC-networks
- Permits fast and precise active power control (Dispatch, modulation, frequency control etc…)
- The interconnected (AC-)systems can operate independently
  - No need for coordination of dispatch/frequency control
  - No need for common rules of reserve, “load shedding”, transient stability limits or temporary frequency variations
  - No disturbance propagations from one system to the other
- An HVDC-link can support an AC-system during disturbances
- No need to over-dimension an HVDC-link for stability reasons
- No risk for over-loading and subsequent tripping of an HVDC-link
- No contribution to the short-circuit level

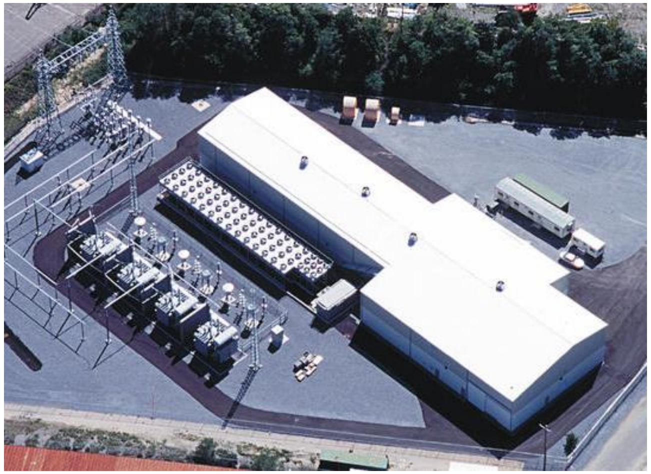
# HVDC technologies

600 MW
200 x 120 x 22 m
6 acres
73 feet high

**HVDC Classic (Current Source Converters)**

- Line-commutated thyristor valves
- Switched reactive power control
- HVDC converter transformers
- Typical design: Valve building plus switchyard
- Minimum short-circuit capacity: $\geq 2 \times P_d$

550 MW
120 x 50 x 11 m
1.5 acre
36 feet high



**HVDC Light (Voltage Source Converters)**

- Self-commutated IGBT valves
- Continuous, and dynamic reactive power/voltage control
- Typical design: Most equipment in compact building
- No minimum short-circuit capacity, Black start
- Easily expandable to more terminals

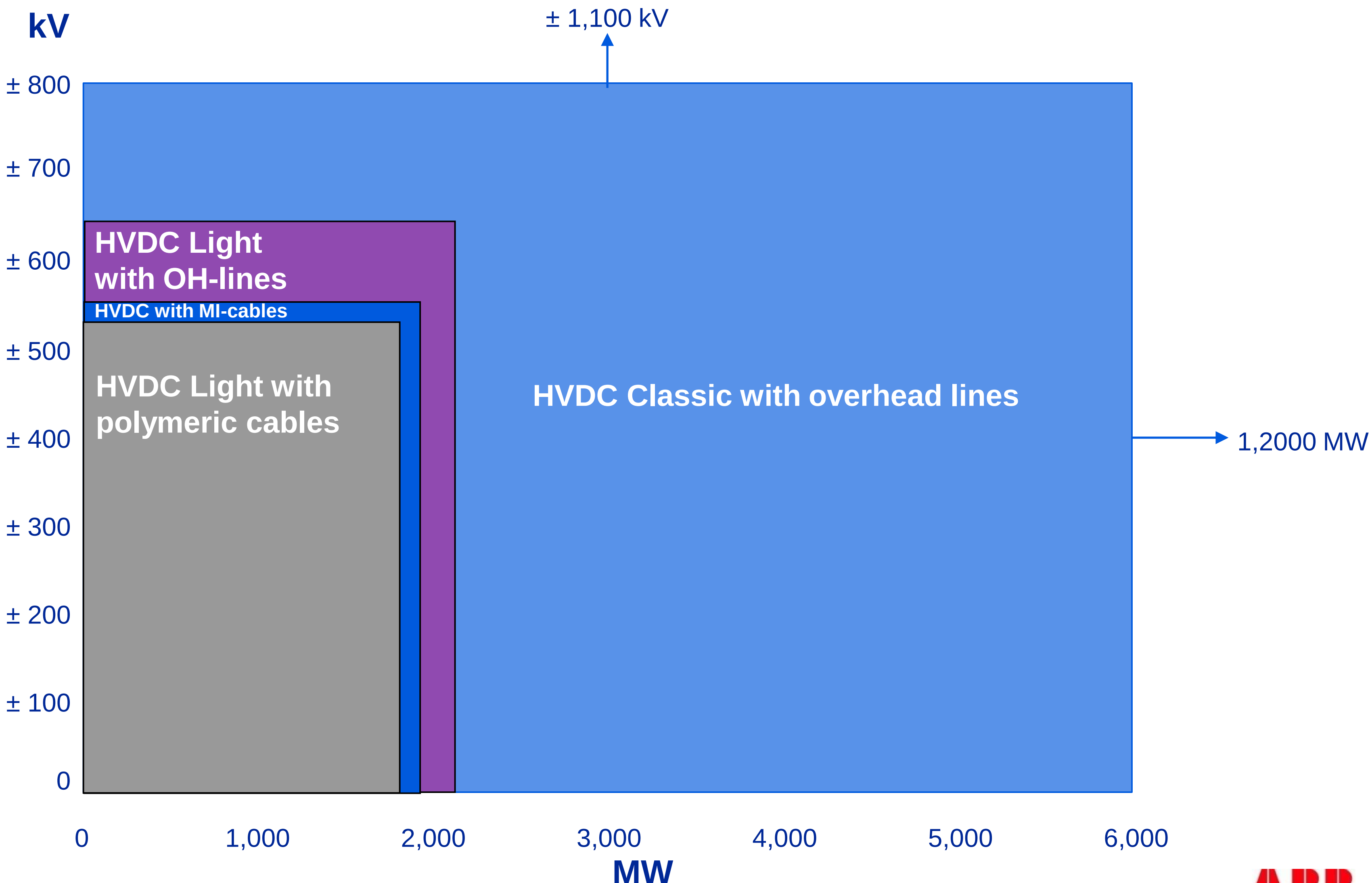
# HVDC Light with underground cables
## Efficient use of land and Right-of-Way

- No limit in distance
- More power, compared to equivalent AC-cables
- Two cables for each circuit
- Conversion of AC overhead lines to HVDC

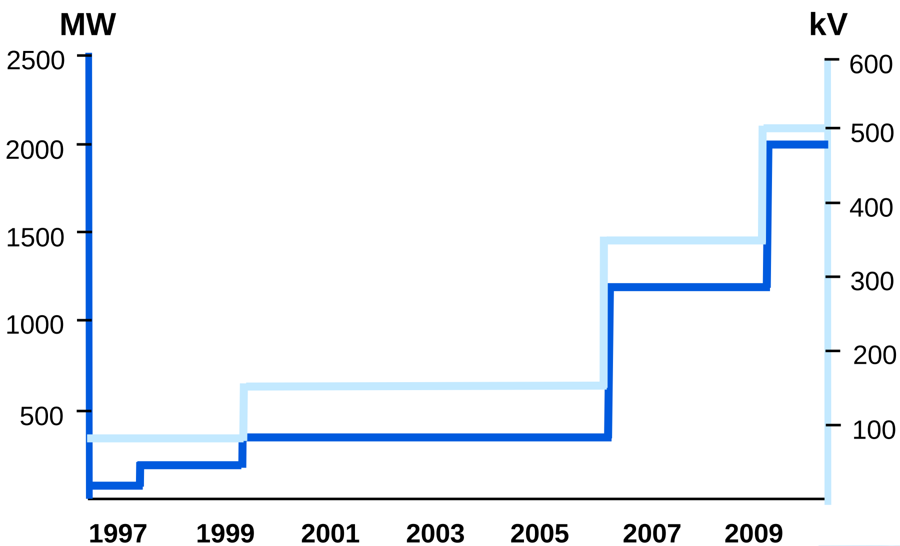
# HVDC Light
## Additional reasons for use of this technology

- Integration of renewable energy;
  - Simplified interface (with AC-network);
    - Voltage support
    - Management of Grid code
- Reduced implementation time
  - Simplified permit process due to use of cables
- Increased power quality requirements;
  - Independent control of active and reactive power
    - Statcom-function in each converter
- Connection to passive networks (black start)

# HVDC Light versus HVDC Classic
## Comparative ranges



# HVDC Light
# Technical development





Hällsjön
3 MW
± 10 kV


Gotland
50 MW
± 80 kV


Cross Sound
330 MW
± 150 kV


Estlink
350 MW
± 150 kV


BorWin1
400 MW
± 150 kV


Caprivi
300 MW
+ 350 kV

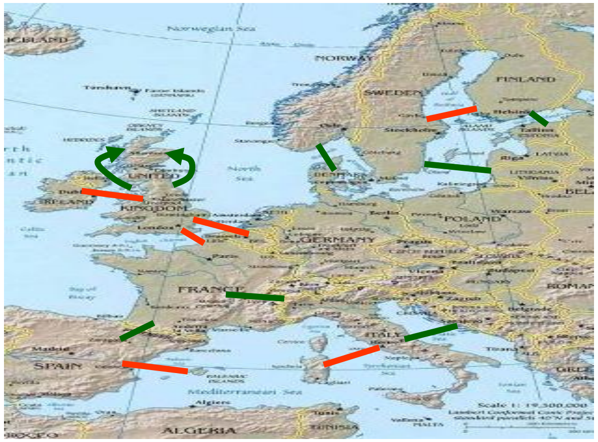

East-West
Interconnector

500 MW
± 200 kV


DolWin1
800 MW
± 320 kV


Skagerrak 4
700 MW
500 kV

# HVDC is a growing technology





- Connecting remote generation
- Offshore wind connections
- Interconnecting grids
- DC links in AC grids
- Power from shore

# …. with more applications to come


Remote sun power

City center infeed

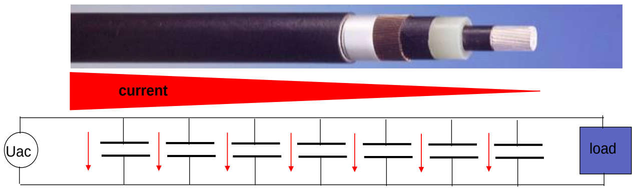
, and increasingly:

Upgrades

# HVDC Offshore applications

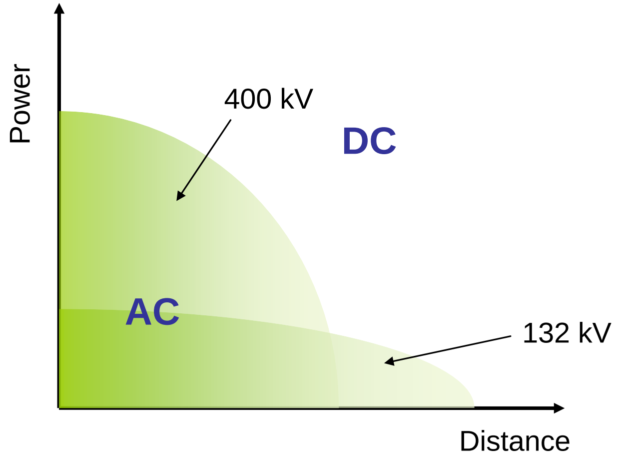
- Power From Shore
  - Electrification
  - Pre-compression systems
- Offshore Renewables (wind, tidal etc)
- Interconnectors
- Offshore grids

# Submarine cables
## HVAC or HVDC?




Aspects to take into account

- Distance
- Power
- Depth



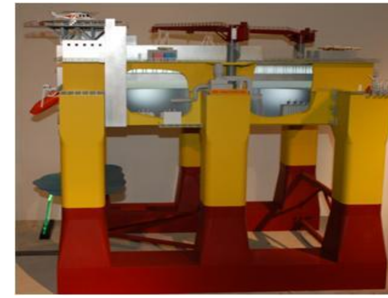

No exact general rules, but *roughly*

- Less than 50 km – generally AC
- More than 150 km – generally DC
- Between 50-150 km – depends

# Our knowledge is based on a number of completed
## and ongoing offshore power projects

Princess Amalie
120 MW
AC-connection

Borwin 1
400 MW
HVDC-connection



Dolwin 2 900 MW
HVDC-connection

Valhall
80 MW HVDC
Power from shore

Thornton Bank
325 MW
AC-connection

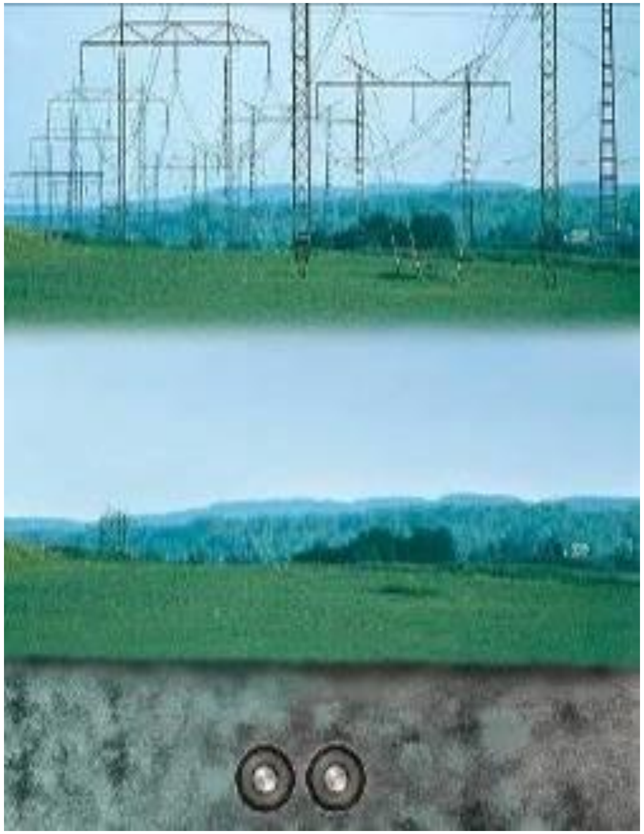
Troll 1 & 3
80+80 MW HVDC
Power from shore

Dolwin 1
800 MW
HVDC-connection

- Gjøa 40MW AC, 100km

Goliat 60MW AC, 100km

# HVDC Light
## Underground cable systems

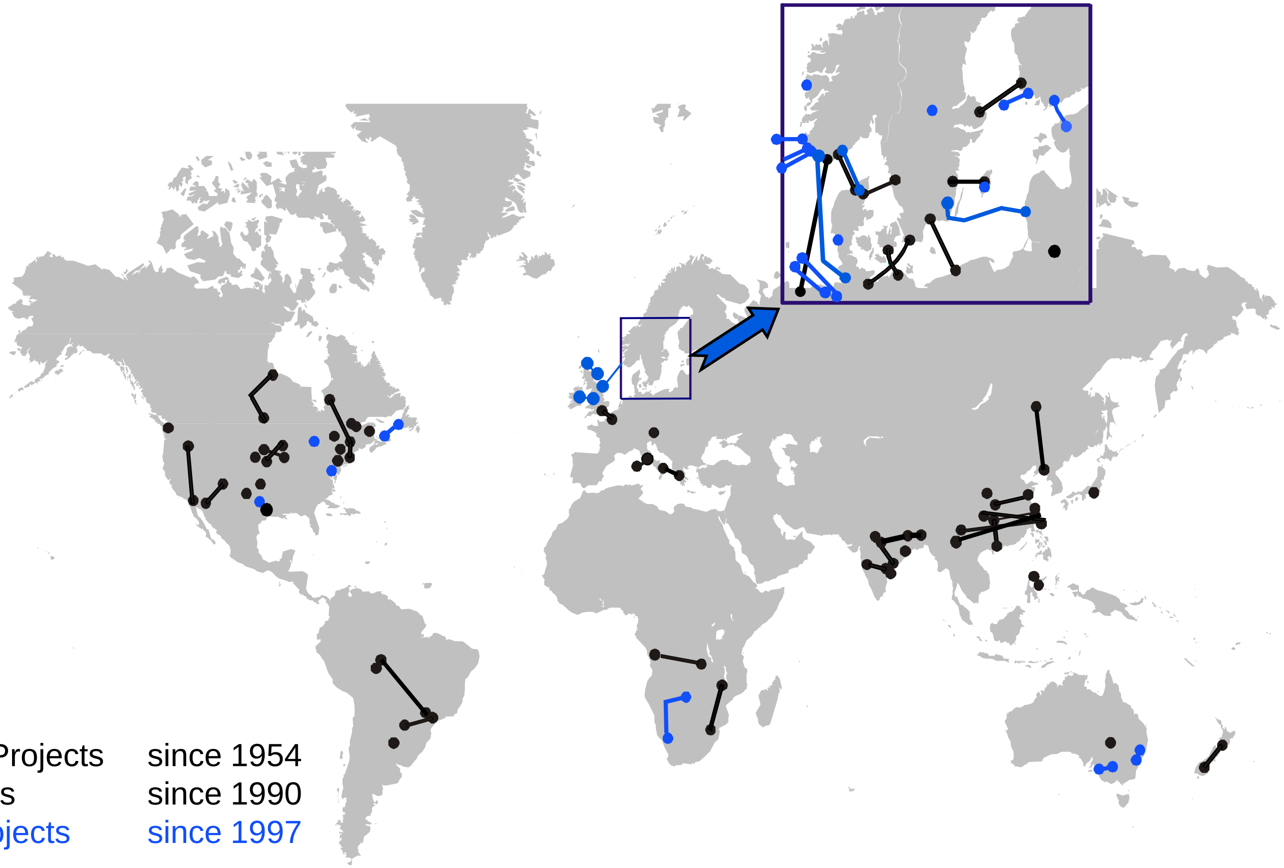


### References
- 2,000 km installed HVDC Light cables
- Murraylink, the world´s longest land cable (180 km)

### Features
- Light weight extruded cable
- Prefabricated joint technology

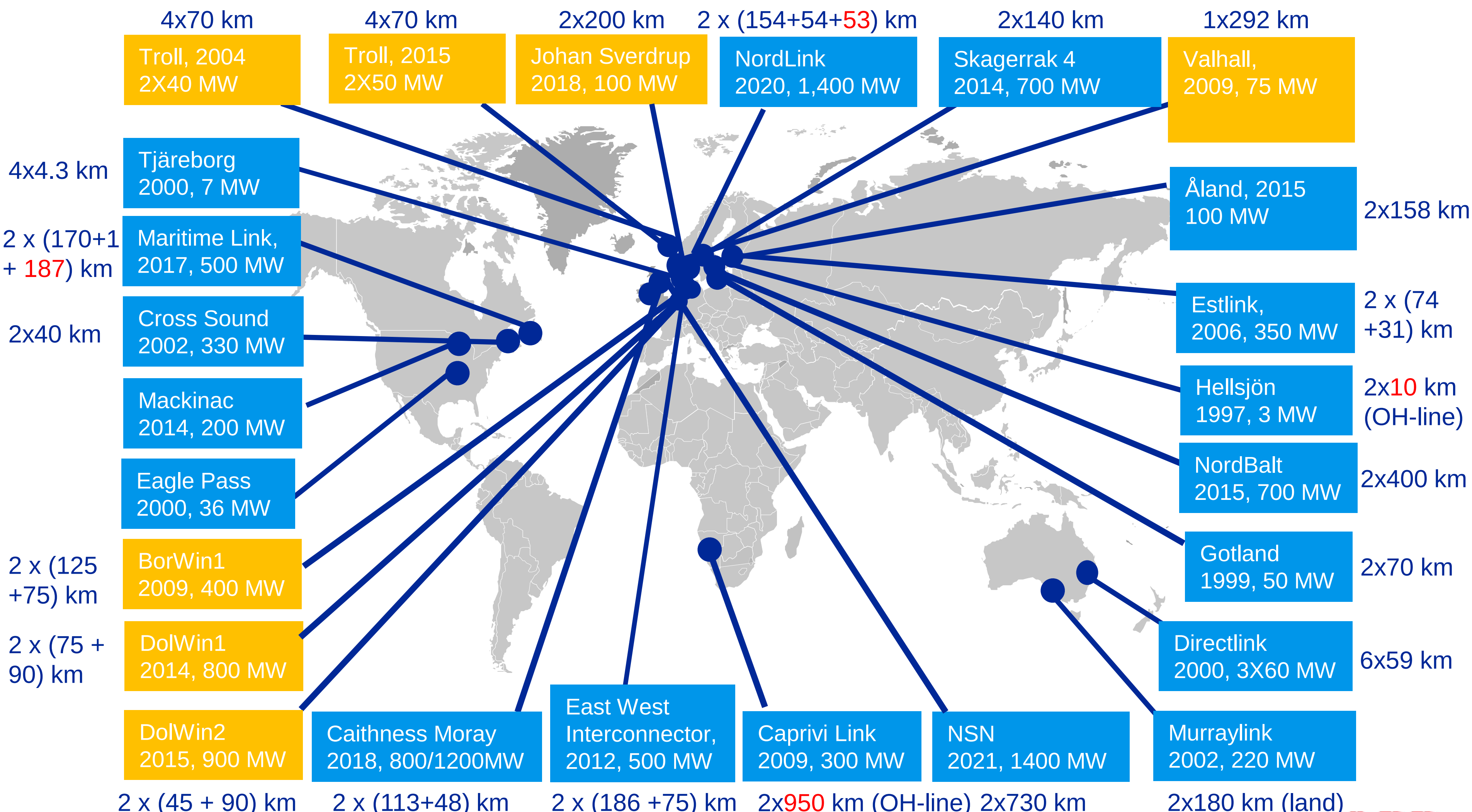
### Economic
- No distance limitation
- Full utilization – no reactive power
- Two cables vs. three cables for AC
- Light, flexible and simpler design
- Timely permitting
- No induced circulating currents
- Easier transport and installation
- Share ROW without increasing exposure

# ABB has supplied to more than half of the 190 HVDC projects
## The track record of a global leader



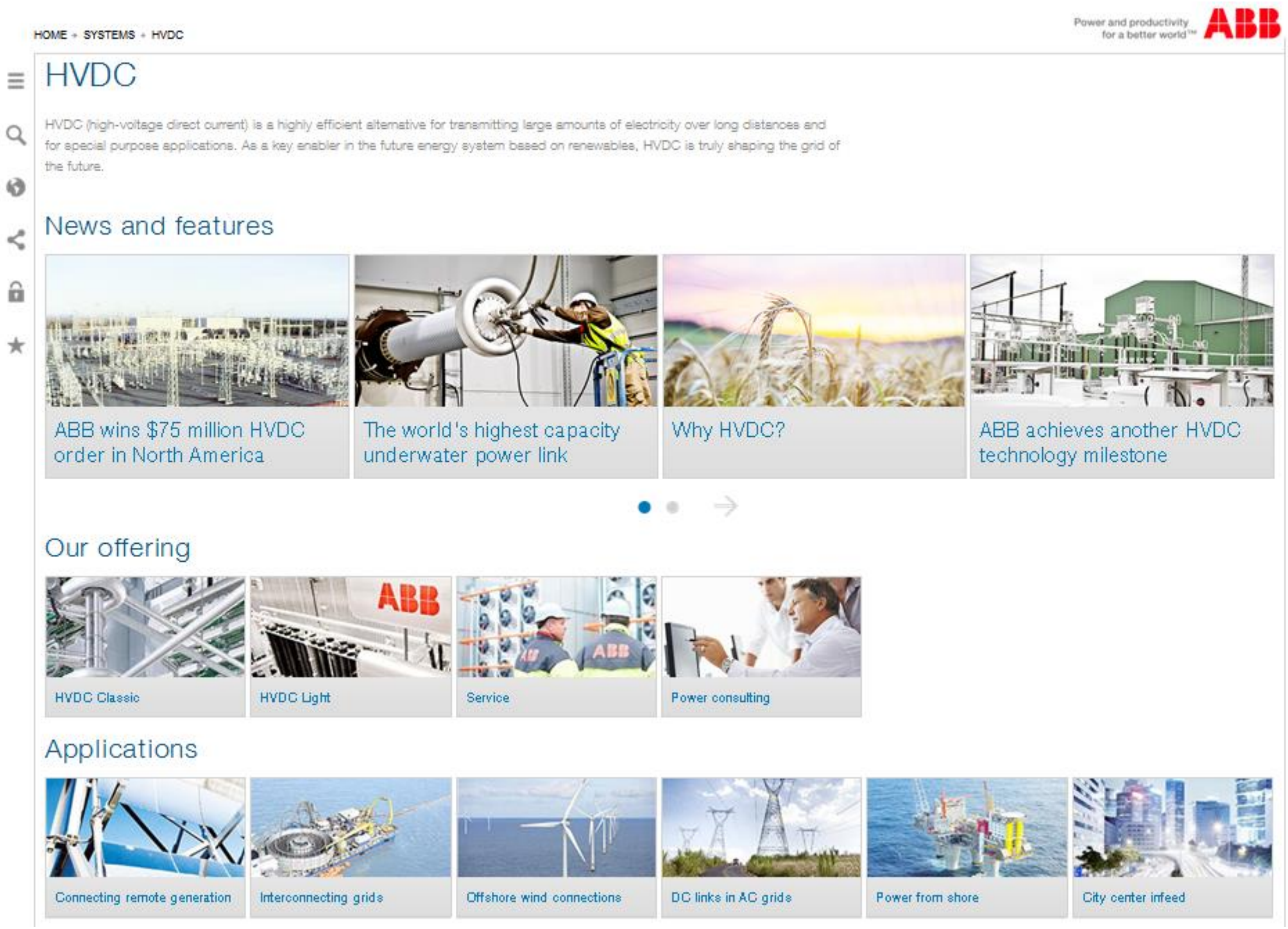
60 HVDC Classic Projects since 1954
24 HVDC Upgrades since 1990
25 HVDC Light Projects since 1997

# HVDC Light project references
## 25 projects – 4 offshore O&G and 3 offshore wind



# Future overlay DC grid of Europe
## HVDC Light is required

# ABB HVDC web portal
# www.abb.com/hvdc



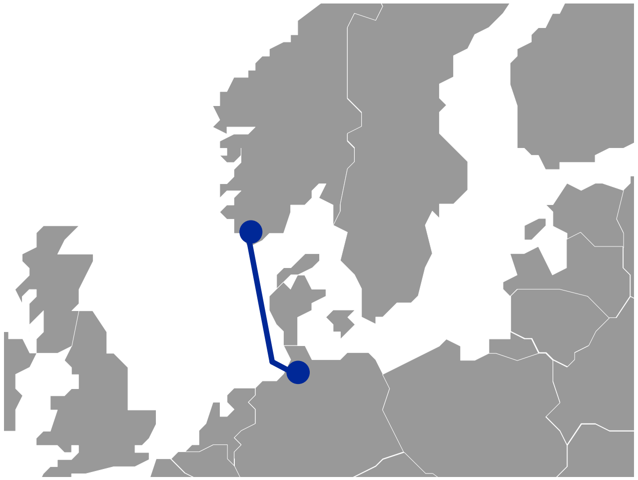
# NordLink, Norway – Germany
## Europe’s longest HVDC link – 624 km

Customers:

NordLink Norge AS, owned by Statnett in Norway

DC Nordseekabel GmbH & Co. owned by TenneT and KfW in Germany

Year of commissioning: 2020



### Customers’ need

- Meet EU’s target for $CO_2$ reduction
- Security of supply

### ABB’s response

- Two 1,400 MW, ±525 kV HVDC Light® converter stations
- 525 kV DC subsea and land MI cables for over 200 km of the route

### Customer’s benefits

- Daily and seasonal fluctuations in power demand can be met by using the other country’s renewable surplus power
- Higher availability

# Johan Sverdrup
## Norway

Customer: Statoil

Year of commissioning: 2019

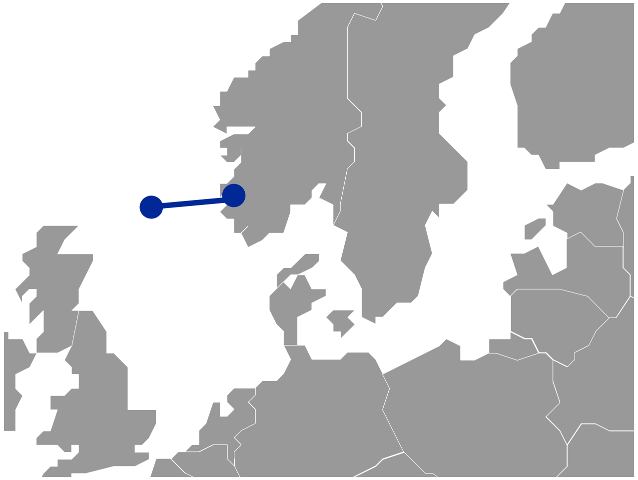


Photo credit: Statoil ASA

### Customer's need

- Enable power supply from mainland to platform complex to minimize emission of large amounts of $CO_2$

### ABB's response

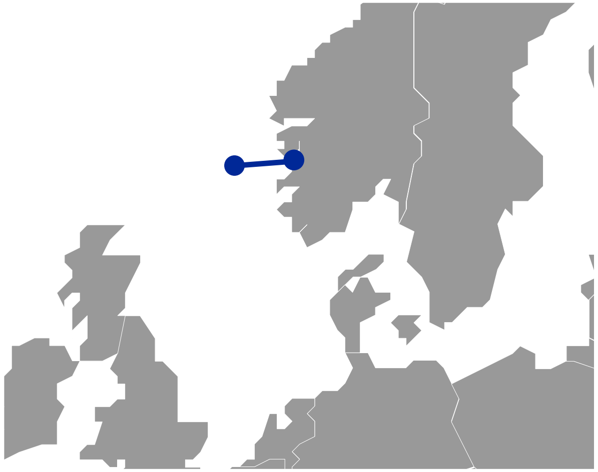
- Two 100 MW ±80 kV HVDC Light converter stations

### Customer's benefits

- Reliable power supply
- Better and safer work environment on platform
- Lower operation and maintenance costs

# Troll A 1&2 and 3&4
## Norway

Customer: Statoil
Year of commissioning: 2005 & 2015



**Customer's need**

Enable power supply from mainland to platform to minimize emission of large amounts of $CO_2$ and unnecessarily high fuel consumption

**ABB's response**

Turnkey 2x44 MW ±60 kV HVDC Light® offshore transmission system

Turnkey 2x50 MW ±66 kV HVDC Light® offshore transmission system

DC sea cables

VHF (Very high frequency) motors

**Customer's benefits**

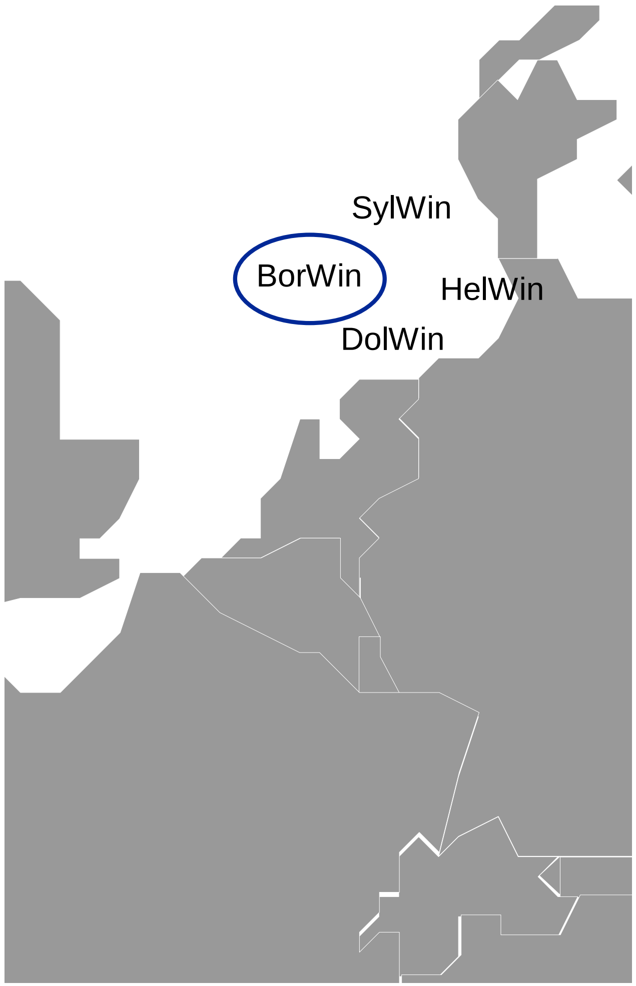
Lower $CO_2$ emissions

Better and safer work environment on platform

# BorWin1 – the world's most remote offshore wind park
## Germany

Customer:
TenneT

Year of commissioning:
2009




### Customer's need

- 200 km long subsea and underground power connection
- Robust grid connection

### ABB's response

- Turnkey 400 MW HVDC Light system
- Full grid code compliance

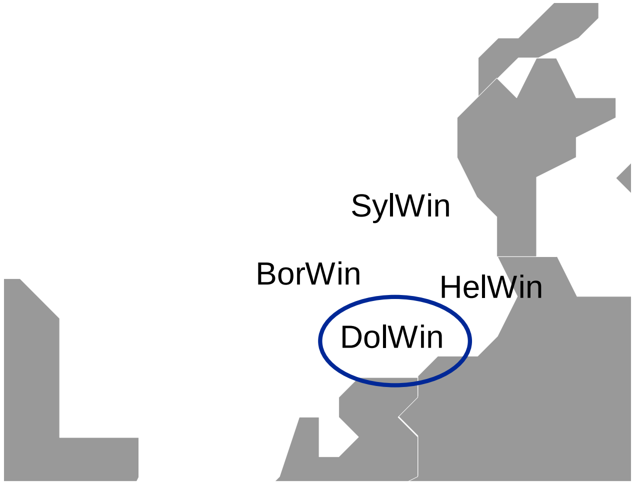
### Customer's benefits

- Environmentally friendly power transport
- Reduce $CO_2$ emissions by nearly 1.5 million tons per year by replacing fossil-fuel generation
- Supports wind power development in Germany

# DolWin1
## Germany

Customer: TenneT

Year of commissioning: 2013




### Customer’s need

- 165 km long subsea and underground power connection
- Robust grid connection

### ABB’s response

- Turnkey 800 MW HVDC Light system
- First ± 320 kV extruded cable delivery

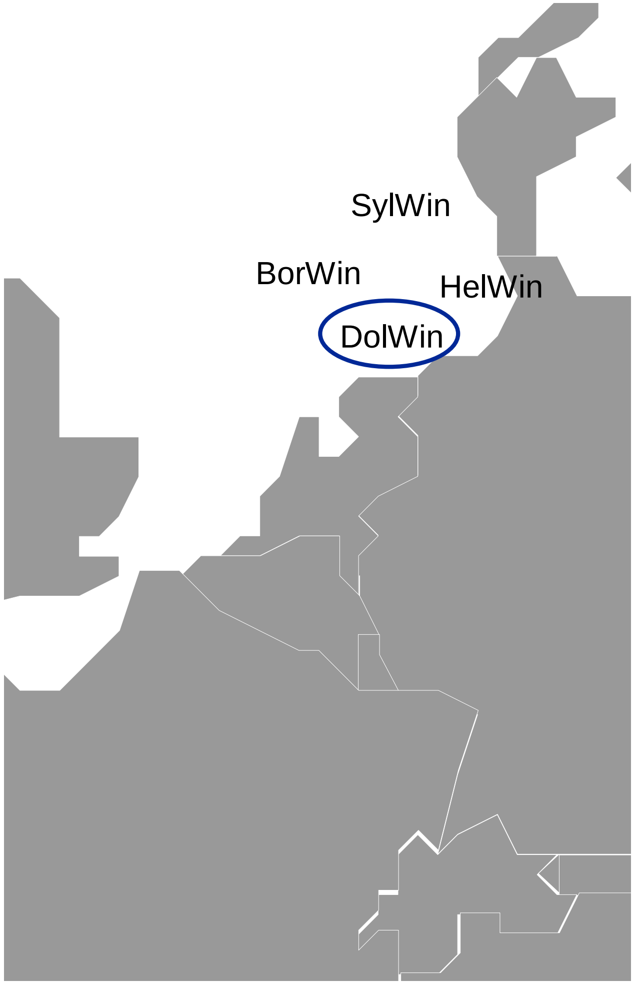
### Customer’s benefits

- Environmentally sound power transport
- Low losses and high reliability
- Reduce $CO_2$ emissions by 3 million tons per year by replacing fossil-fuel generation
- Supports wind power development in Germany

# DolWin2
## Germany

Customer: TenneT

Year of commissioning:
2015




### Customer's need

- 135 km long subsea and underground power connection
- Robust grid connection

### ABB's response

- Turnkey 900 MW HVDC Light system
- ± 320 kV extruded cable delivery

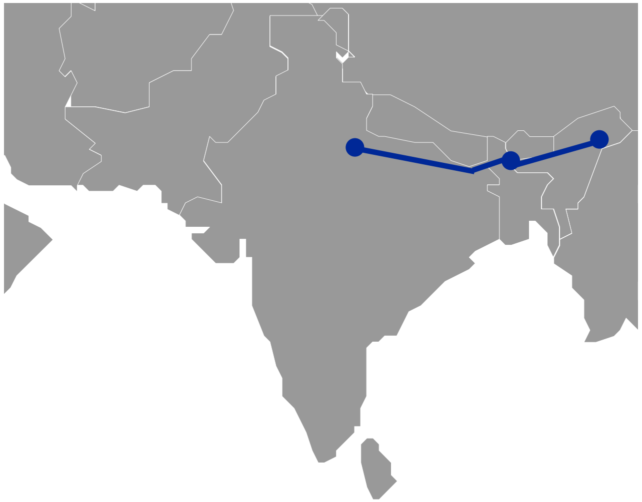
### Customer's benefits

- Environmentally sound power transport
- Low losses and high reliability
- Reduce $CO_2$-emissions by 3 million tons per year by replacing fossil-fuel generation
- Grid connection 90 km inland

# North East – Agra
# India

Customer:
Powergrid Corporation in India Ltd.

Years of commissioning:
2014 - 2015



**Customer's need**

Transmission of 6,000 MW hydropower from the north-eastern parts of India to the region of Agra – over 1,700 km

**ABB's response**

Turnkey 6,000 MW ±800 kV UHVDC system

Multiterminal – three converter stations

**Customer's benefits**

Low losses – 6 %

8,000 MW converter capacity, providing redundancy for loss of one converter with retained transfer capacity

Effective use of right-of-way

Power and productivity
for a better world™