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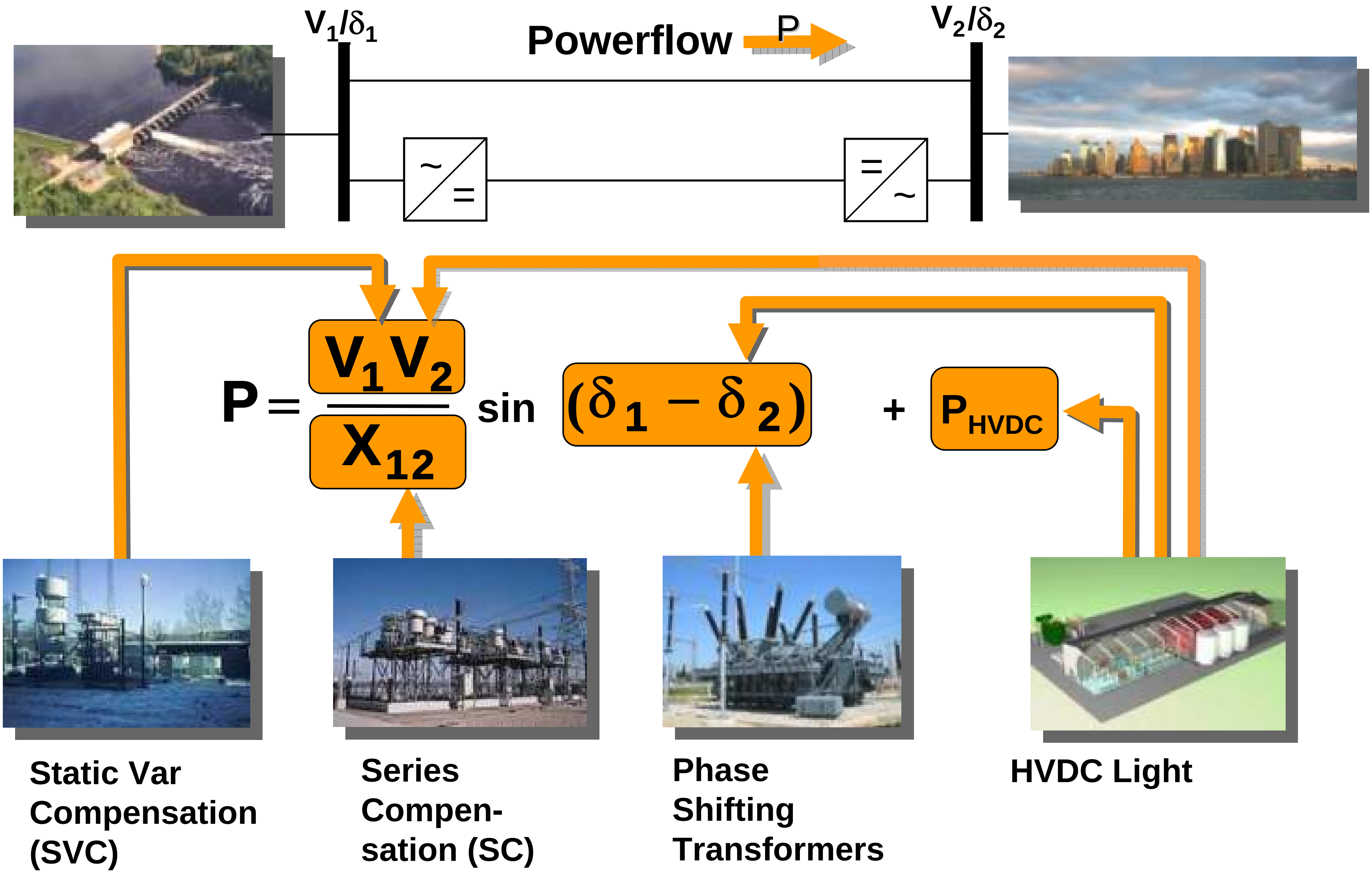
ARPA-E Power Technology Workshop, Feb 9, 2010

High Voltage DC Technologies

From “AC *vs* DC” to “AC *and* DC”



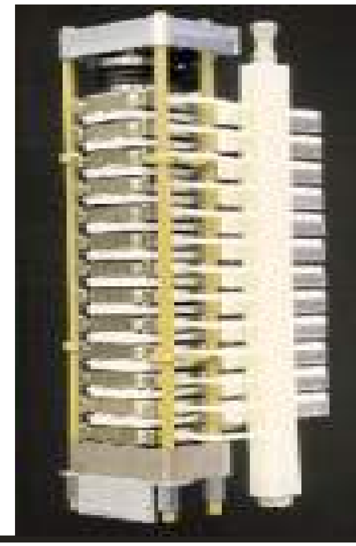
FACTS = Flexible AC Transmission System

HVDC Technology development

Mercury Arc Valve
HVDC (Phased out)

Thyristor Valve
HVDC Classic

IGBT (Transistor) Valve
HVDC Light



1954 — **1970** — **1980** — **2000** — **Year**

Pros: Low losses
Cons: Reliability
Maintenance
Environment

Pros: Reliable
Scalable
Cons: Footprint

Pros: Controllability
Footprint
DC Grids
Cons: Losses

Longquan, China - HVDC Converter Station

3000MW ± 500 kV
HVDC Classic

HVDC interconnection: ultrahigh-voltage DC

Customer: SGCC
Year of commissioning:
2010-2011

Customer need

- Development of renewable hydro power 2,000 km from load centre

ABB's response

- Worlds longest and largest transmission system
- ± 800 kV UHVDC, 6,400 MW

Customer benefits

- High efficiency: 93 %
- Compact: land use 40 % less than conventional technologies
- Reliable transmission: forced unavailability < 0.5 %

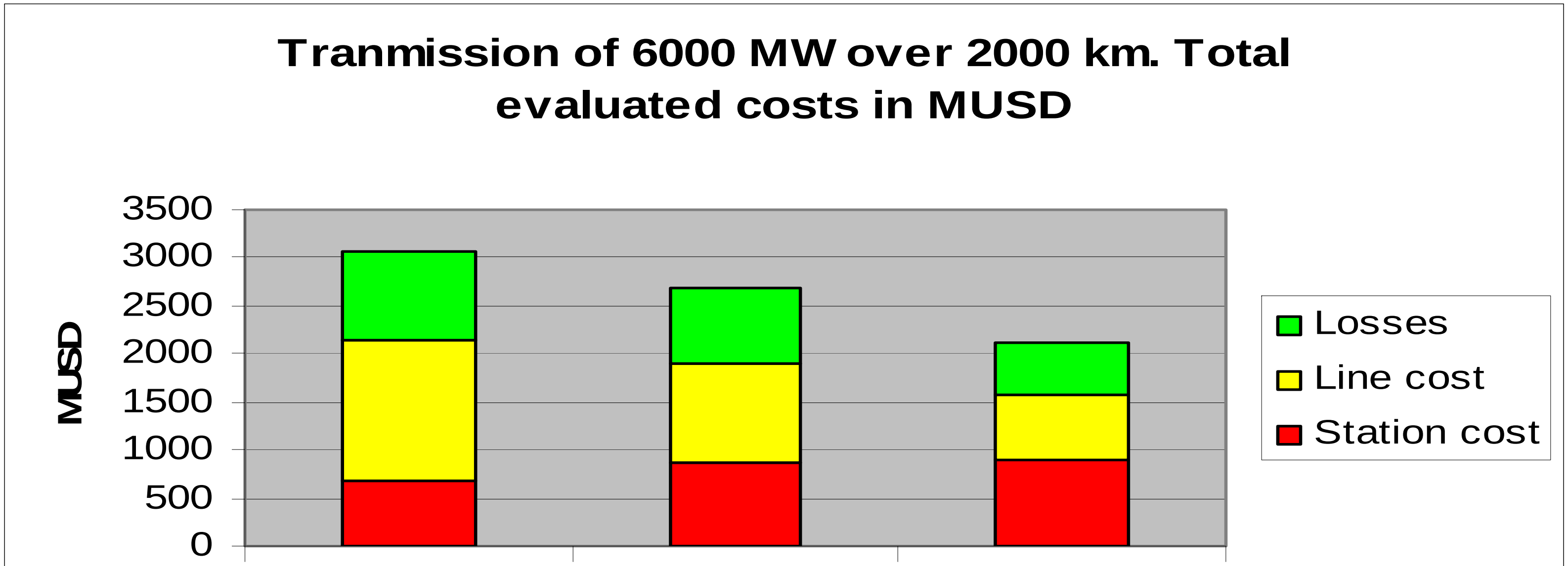
800 kV DC wall bushing

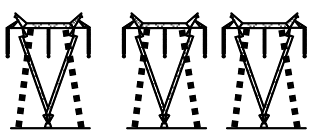
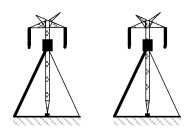
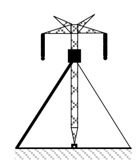
800 kV HVDC transformer

- ABB's first 800 kV HVDC transformer successfully tested
- World's highest-voltage power link with record capacity of 6.4 GVA
- 2000 km HVDC transmission corridor Xiangjiaba hydro plant to Shanghai
- Capable to supply 30 million people
- Developed and tested in one year

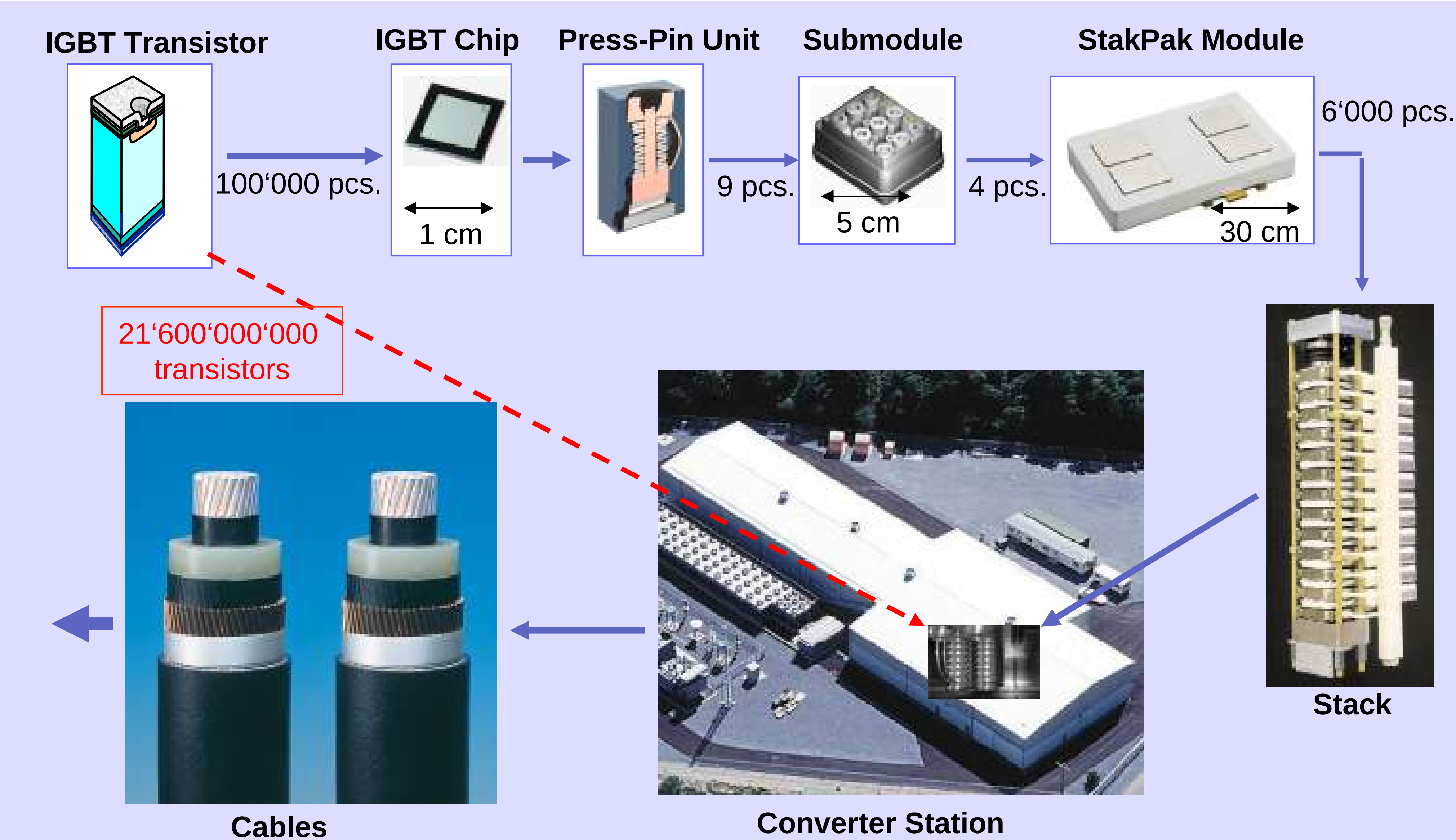
- **For each of the two converter stations 24 transformers are required.**

800 kV DC for long distance bulk power transmission

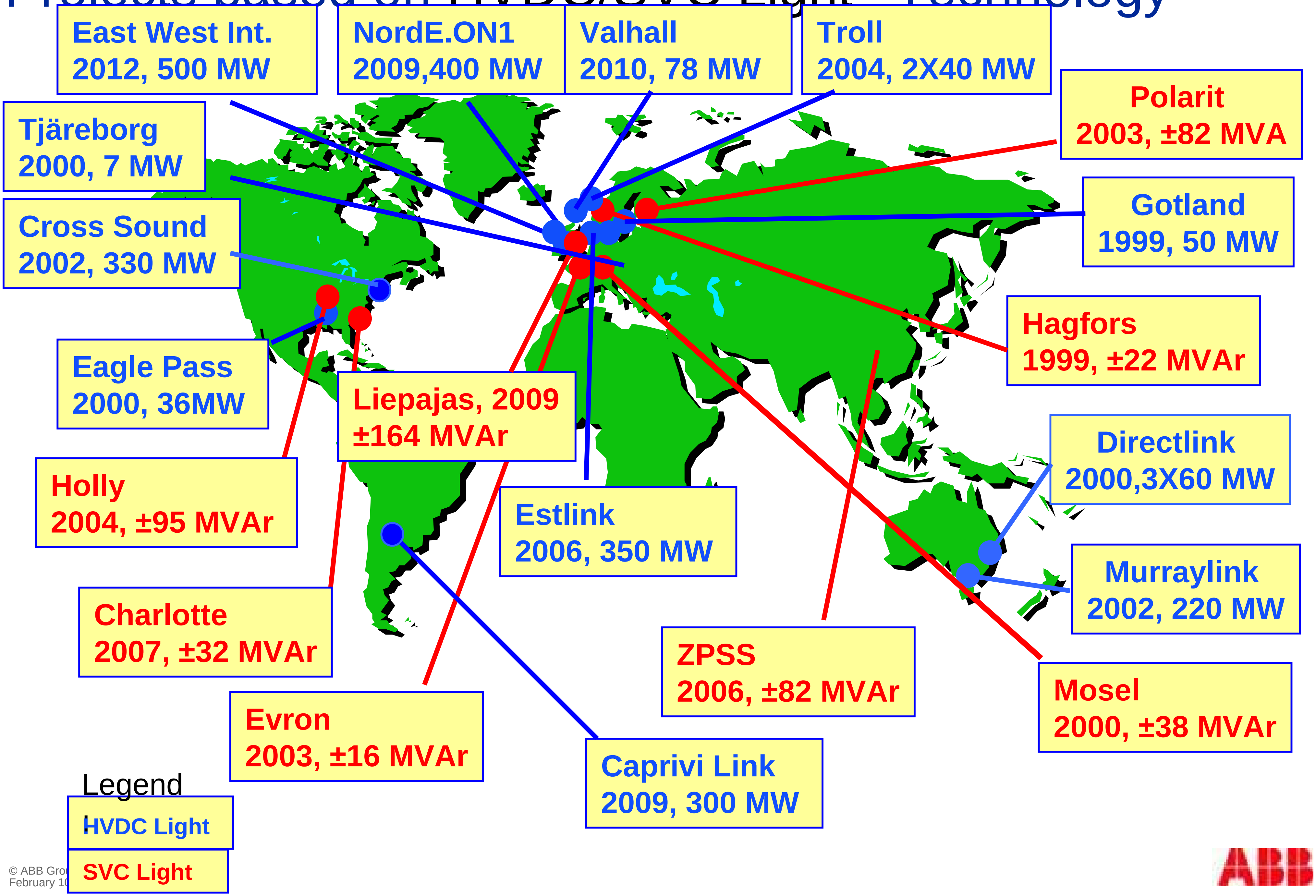


	765 kV AC	500 kV DC	800 kV DC
Number of lines:			
Right of way (meter)	**~300**	**~ 120**	**~ 90**

Stacking up: HVDC Light



Projects based on HVDC/SVC Light® Technology



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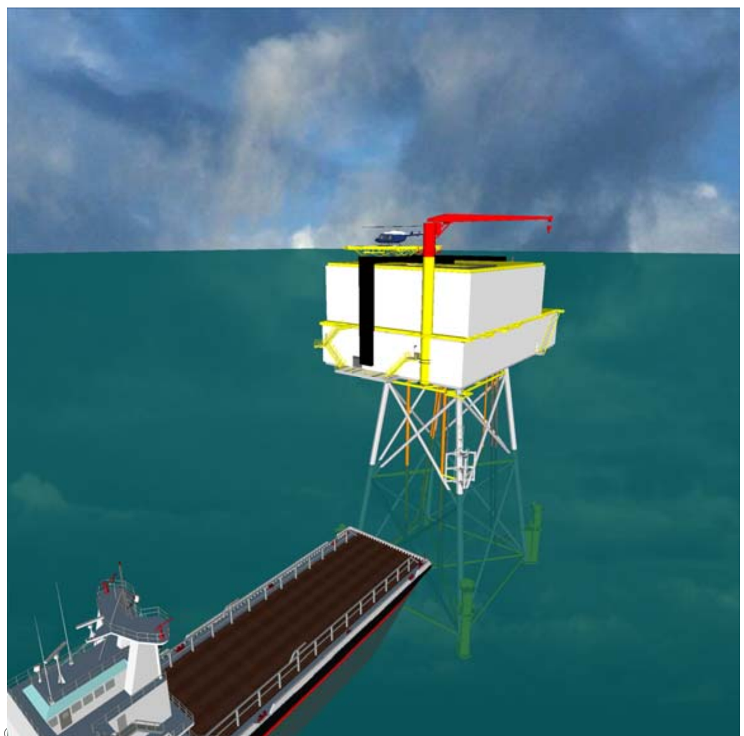


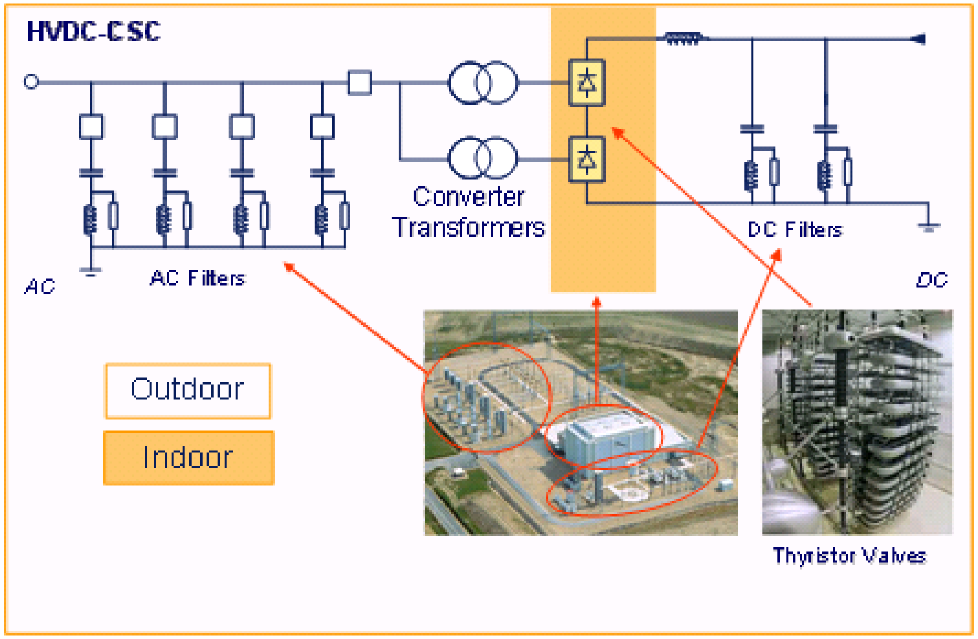
Customer

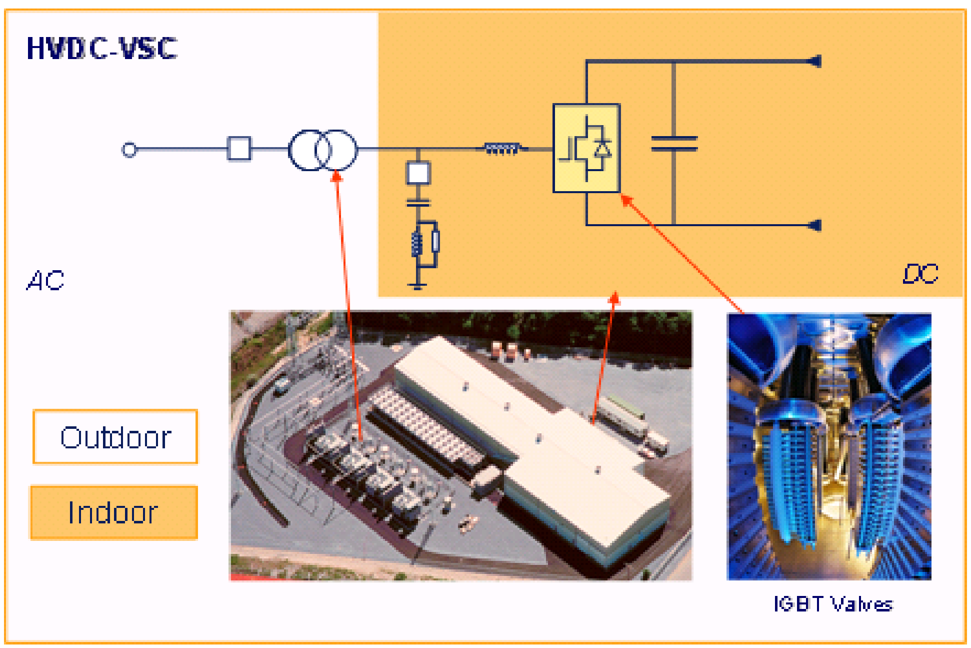
- E.ON Netz GmbH, Germany

Scope

- **400 MW HVDC Light System**
  - Two HVDC Light converter stations
  - DC Cable system
    - DC cable submarine to onshore connection (2x128km)
    - DC cable on land (2x75km)
    - 200 MW Submarine AC cable 170kV (1x1200 m)
    - Fiber optic cable (203 km)
- **170 kV GIS on platform**
- **Offshore platform structure** - jacket and topside
- … **and all Auxiliary Systems** needed to operate and maintain the Offshore station.
  - Sea Water System, HVAC, Dieselgenerators, Fire Protection, etc

HVDC Technologies - Overview





CSC-based HVDC

- Line-commutated current source converters (CSC) with thyristor valves
- 100 projects around the world, many in 1000-3000MW
- Recent effort in UHVDC, the largest project (6400 MW, ±800kV) is under construction in China

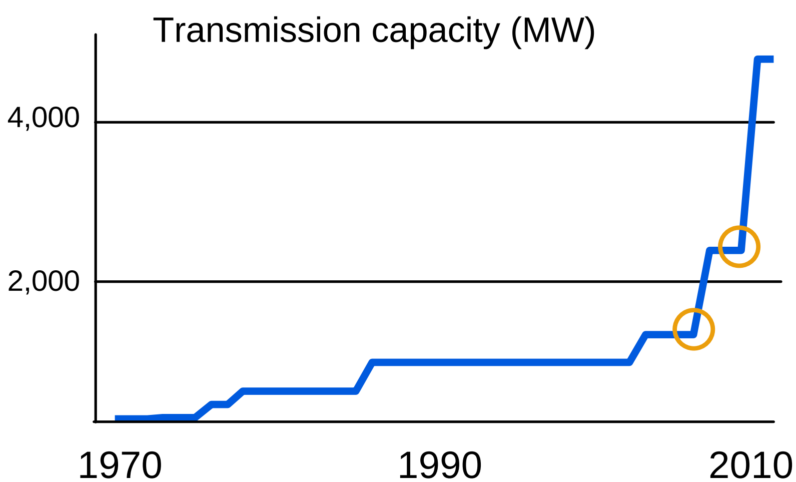
VSC-based HVDC

- Self-commutated voltage sourced converters (VSC) with IGBT valves
- 8 projects in commercial operation, several more under development
- Max power of bipole VSC-HVDC is 1200 MW with cables and 2400 MW with overhead lines

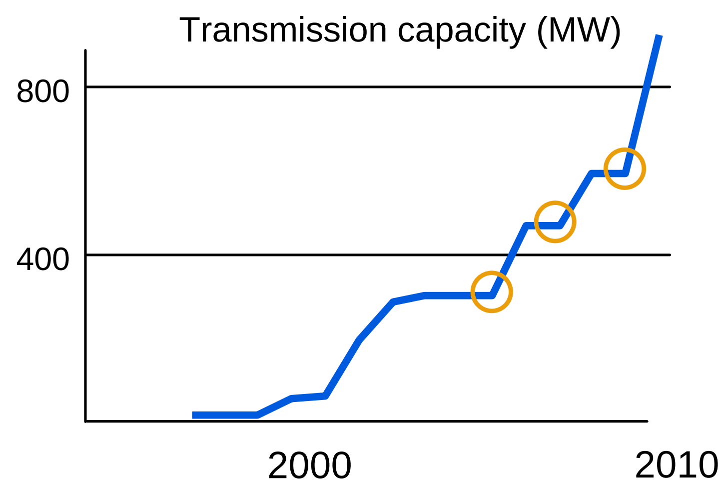
Comparison of CSC-HVDC and VSC-HVDC

Attributes	CSC-HVDC	VSC-HVDC
Converter technology	Thyristor valve, grid commutation	Transistor valve (IGBT), self commutation
Max converter rating at present	6400 MW, ±800 kV (OH line)	1200 MW, ±320 kV (cable) 2400 MW, ±320 kV (overhead)
Relative size	4	1
Typical delivery time	36 months	24 months
Active power flow control	Continuous ±0.1Pr to ±Pr (Due to the change of polarity)	Continuous 0 to ±Pr
Reactive power demand	Reactive power demand = 50% power transfer	No reactive power demand
Reactive power compensation & control	Discontinuous control (Switched shunt banks)	Continuous control (PWM built-in in converter control)
Independent control of active & reactive power	No	Yes
Scheduled maintenance	Typically < 1%	Typically < 0.5%
Typical system losses	2.5 - 4.5 %	4 - 6 %
Multiterminal configuration	Complex, limited to 3 terminals	Simple, no limitations

Technology trend in DC transmission



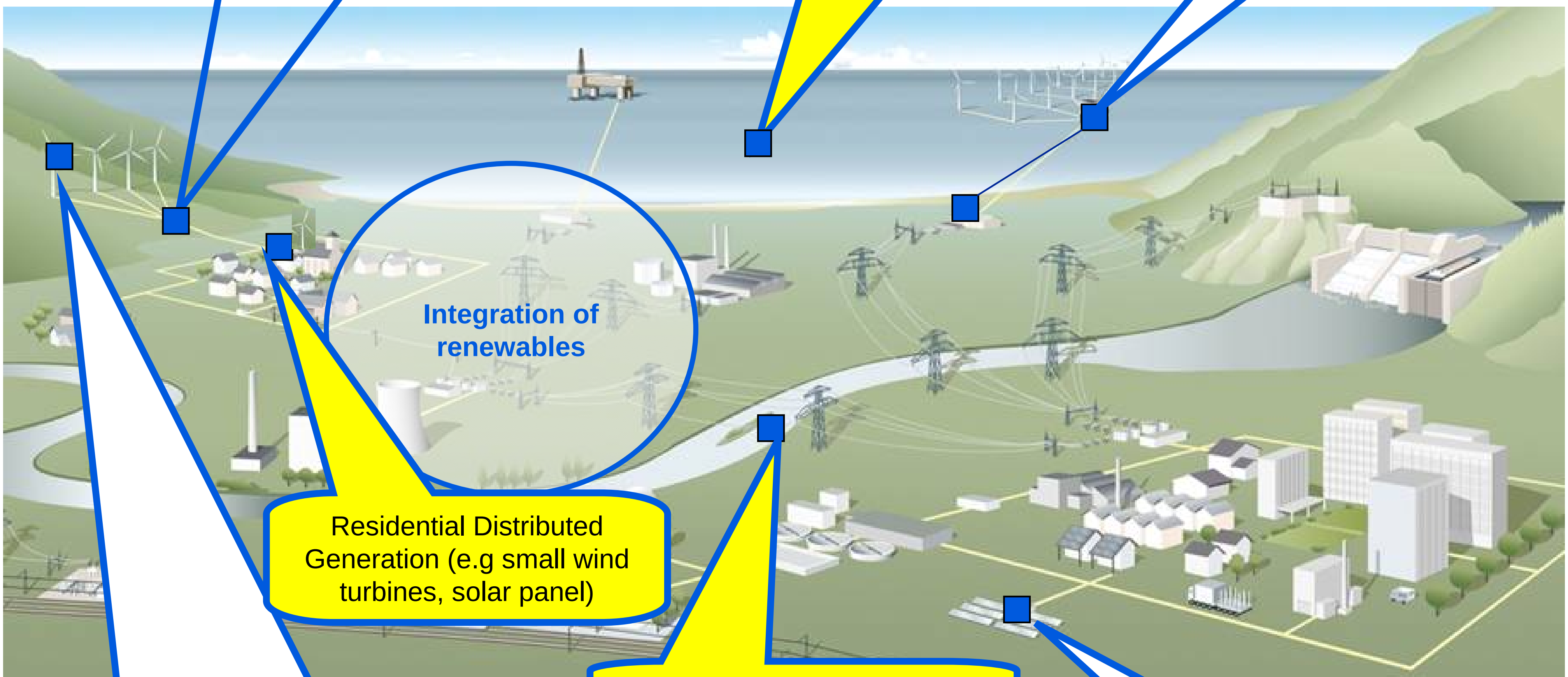
Technology leaps significantly increase transmission capacity



Power ↑ , Losses ↓

Bulk power transmission

Power Electronics in Smart Grids
Integration of renewables



Technology Challenges

- **Fault protection and handling**
- **Voltage level transformation**
- **Efficiency**
- **Reliability**
- **Direct Connection**

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