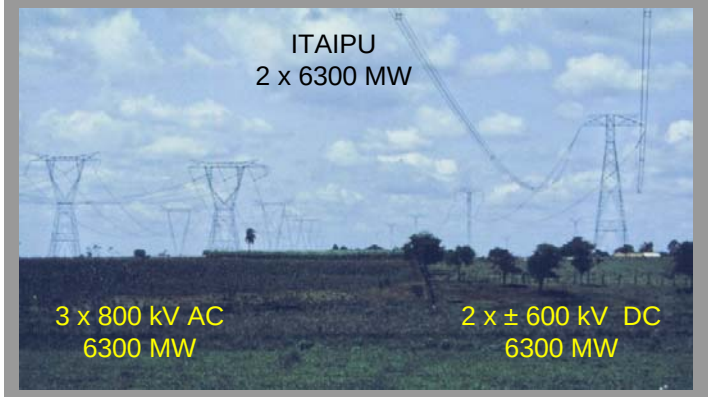
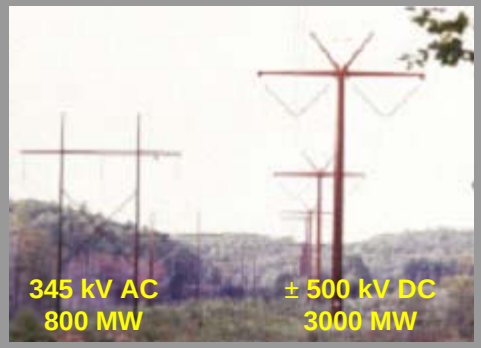
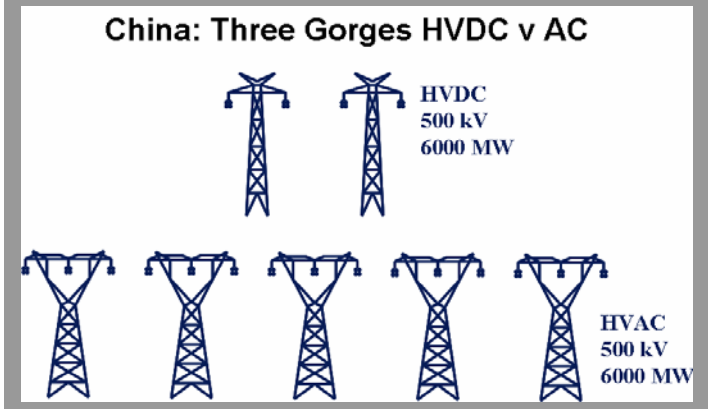
# Long-Distance Bulk Power Transmission



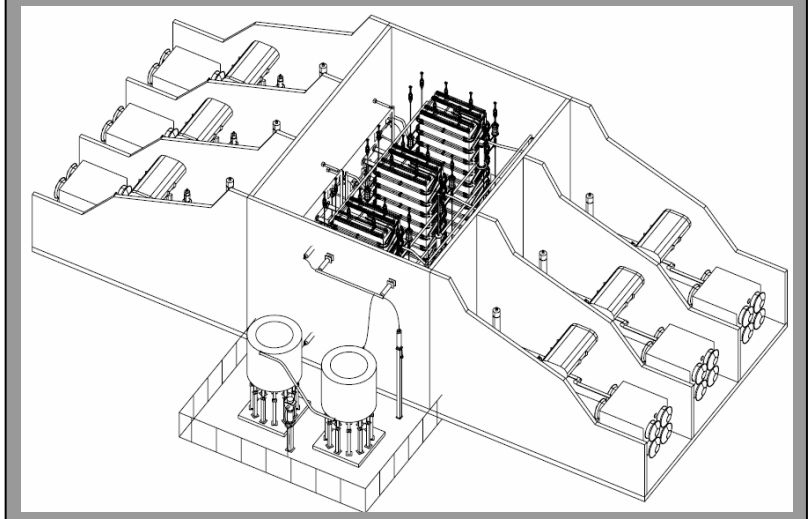

## Generator Outlet Transmission

- More power on fewer lines
- Improved stability
- Lower installed cost
- Reduced losses
- Double circuit (bipolar line)
- Reduced ROW
- Two lines vs. one – IPP, CU, Square Butte

## Interconnections

- Firm capacity
- Bypass congestion
- Avoid loop flow
- No limit due to parallel paths
- Interconnect diverse regions

# Asynchronous Interconnections with HVDC



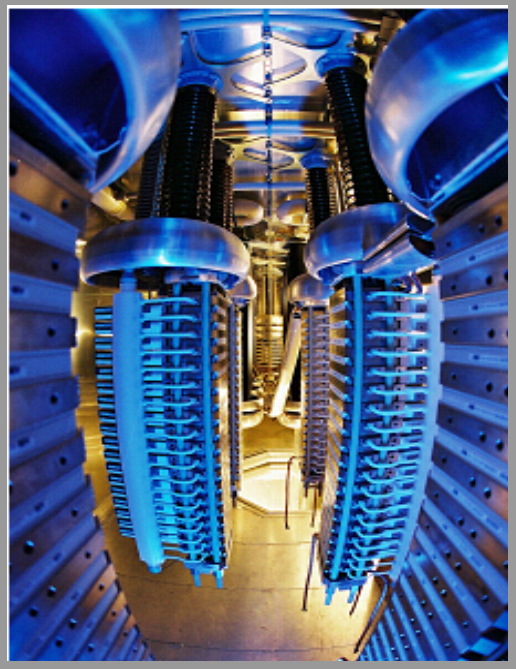
## Economic

- Firm transactions
- Shared reserves
- Increase diversity
- Economy energy trade
- Least costly, lowest losses

## Reliability

- Emergency power support
- Mutual assistance
- Isolate disturbances
- ‘Fire-wall’ against cascading outages
- Reserve sharing

# HVDC Light Transmission



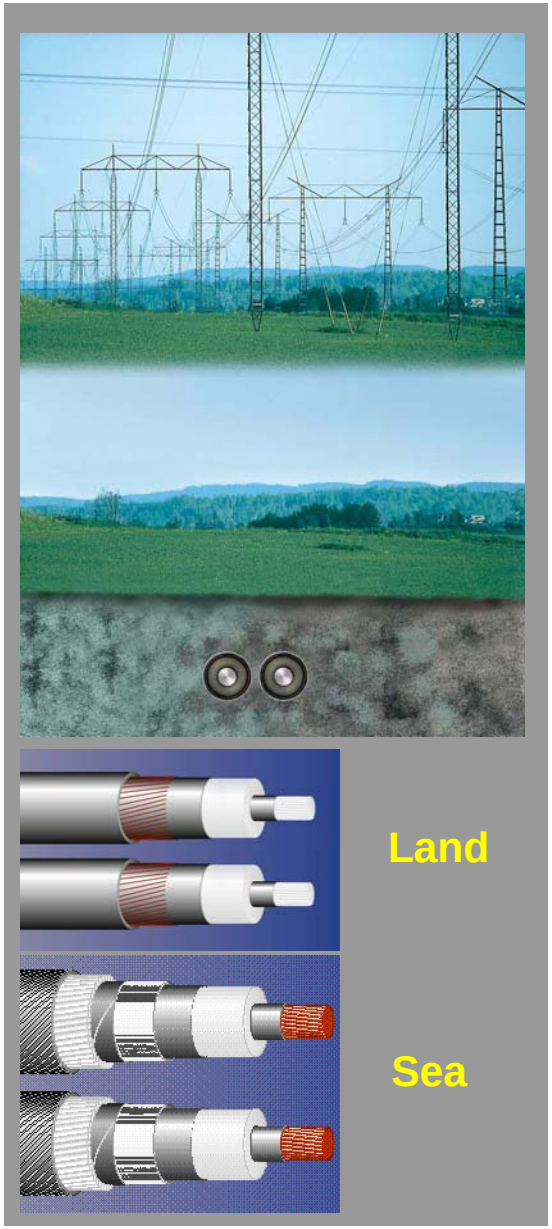
## Applications

- Off-shore - platforms, islands
- Urban in-feed
- Constrained ROW
- Virtual generator for replacement of RMR generation
- Integration of remote renewable generation
- Improved voltage stability

## Ratings

- Power range 50-1100 MW
- Voltages ± 80, ± 150 and ± 320 kV
- Extruded land or sea cables with molded joints

# Underground Cable Systems – HVDC Light




Economic

- No distance limitation
- Full utilization – no reactive power
- Two cables v three cables for AC
- Light, flexible and simpler design
- Timely permitting
- No induced circulating currents
- Lower losses than ac cables < 60%
- Easier transport and installation

Reliability

- No cable overloads possible
- Dynamic reactive power support
- Congestion relief
- Isolate disturbances
- Share ROW without increasing exposure
- Black-start capability

# Offshore Applications of HVDC Light

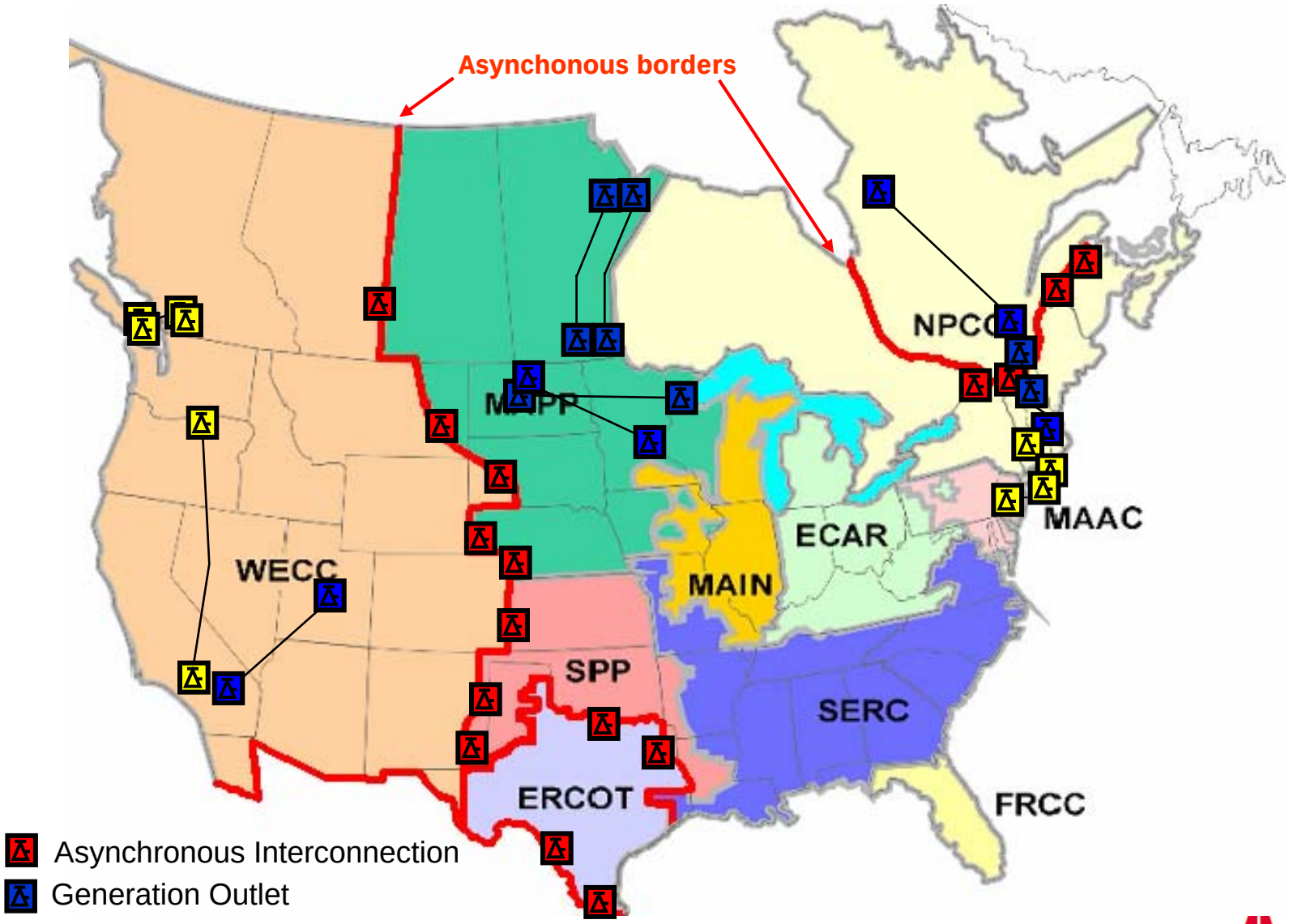
## Offshore Wind Farms

- Long cable transmission to shore
- Voltage regulation
- Wind generator excitation power
- Black start

## Oil and Gas Production

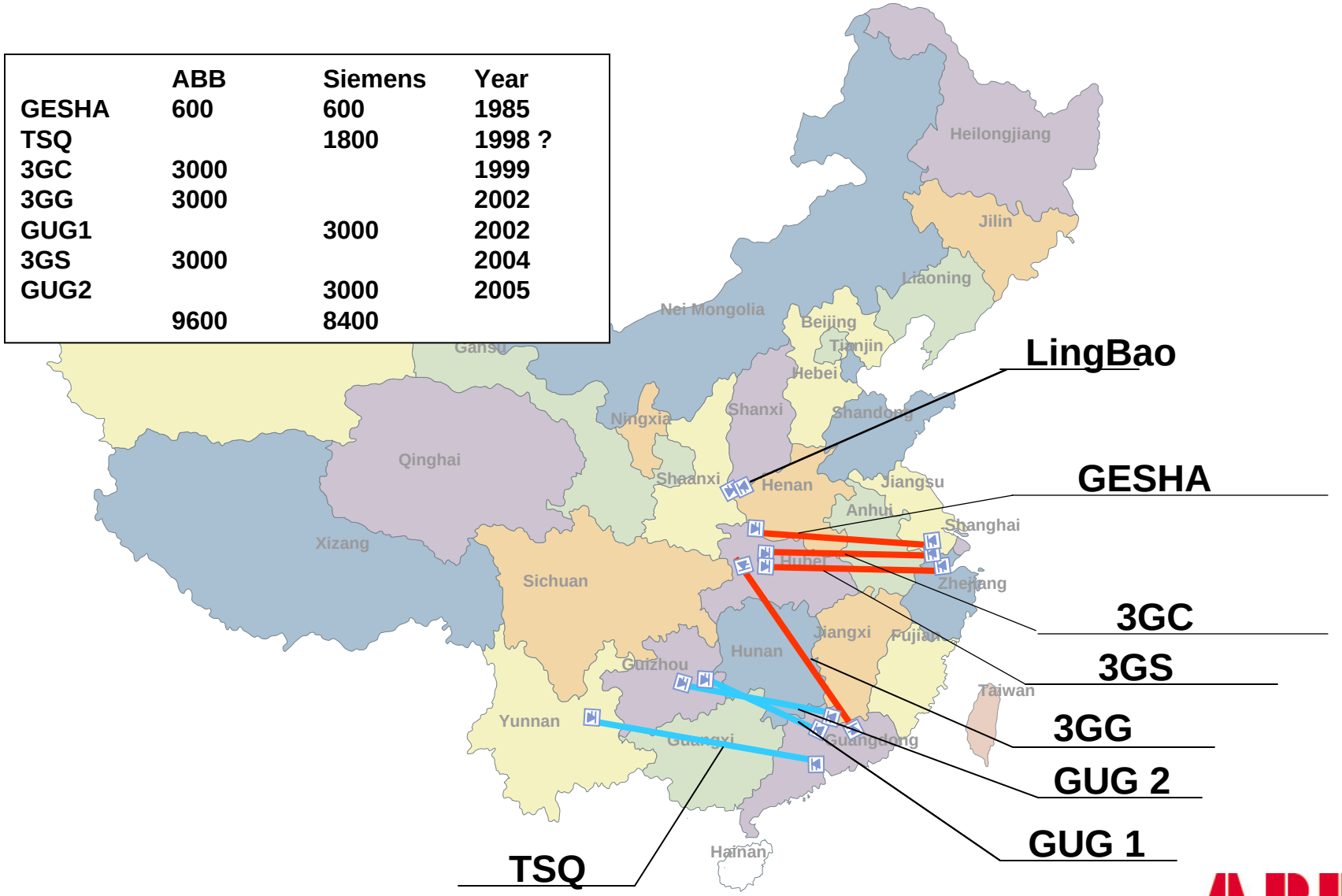
- Long cable transmission from shore
- Feed platform load
- Variable speed compressor drives
- Voltage regulation
- Reduced weight and volume
- Reduced emissions
- Greater efficiency

# HVDC in North America

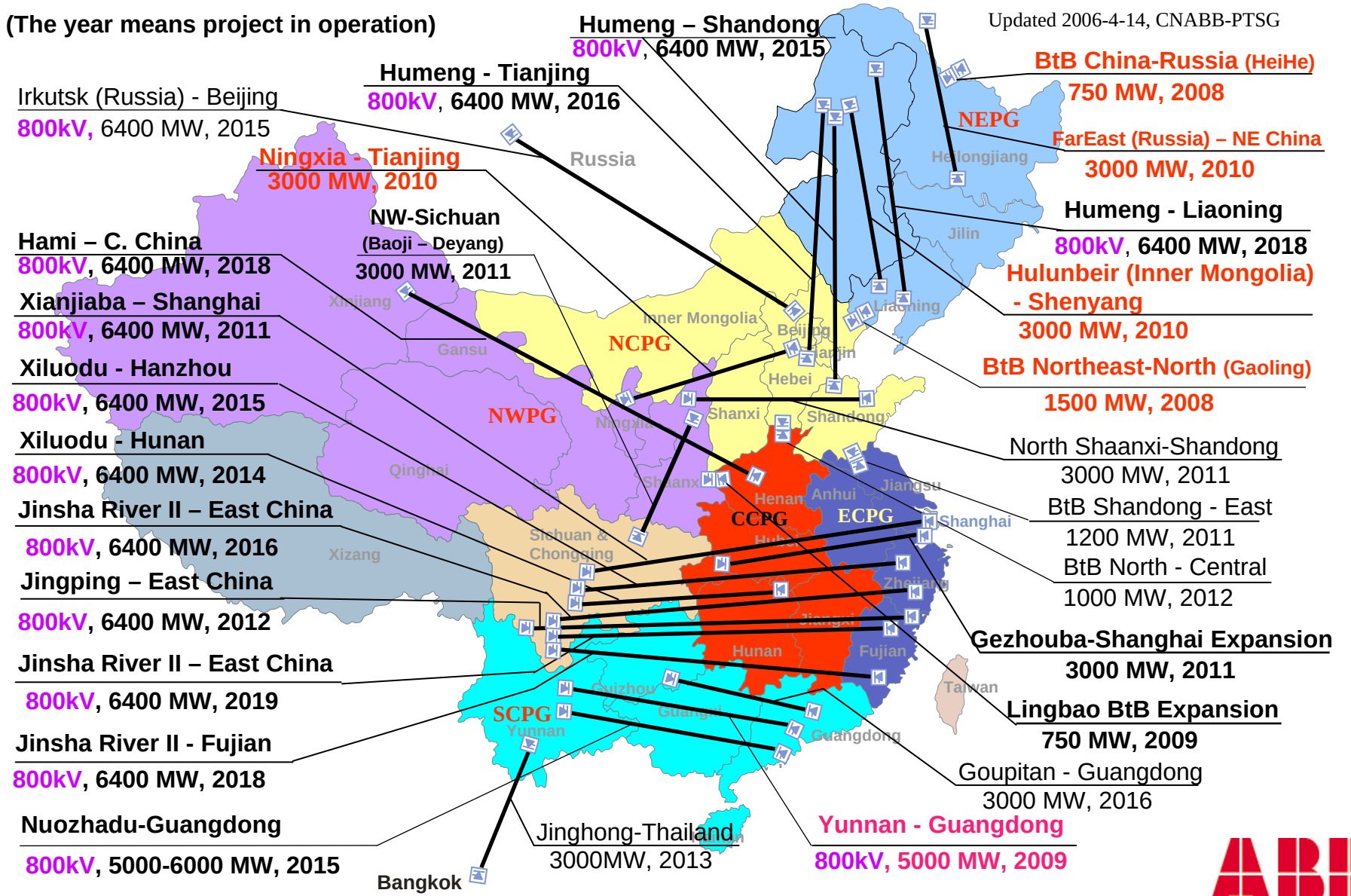


# Existing HVDC Projects in China

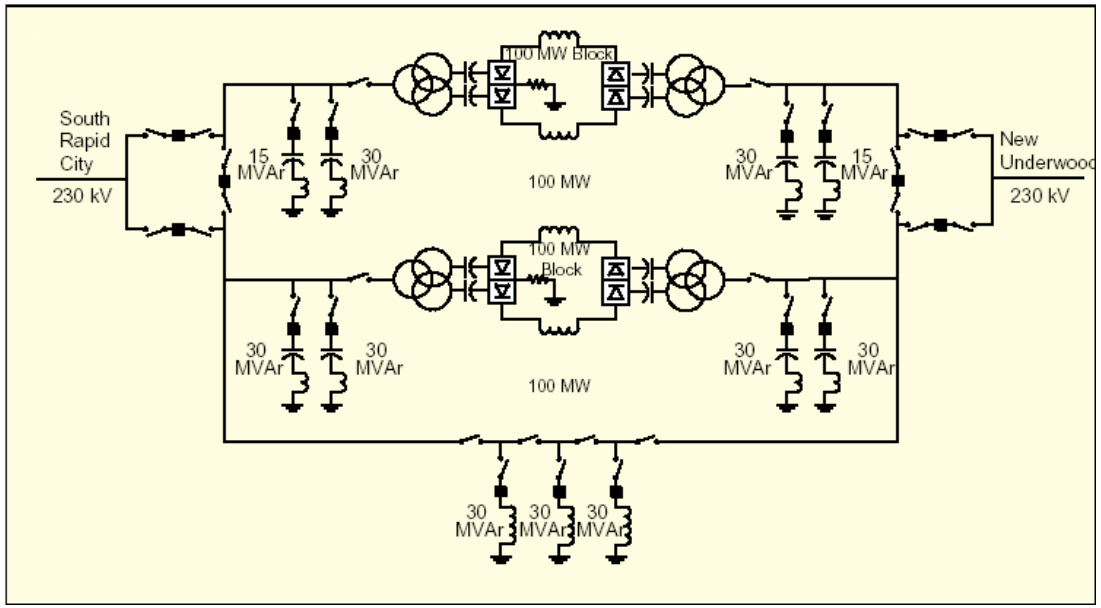
| | ABB | Siemens | Year |
|---|---|---|---|
| GESHA | 600 | 600 | 1985 |
| TSQ | | 1800 | 1998 ? |
| 3GC | 3000 | | 1999 |
| 3GG | 3000 | | 2002 |
| GUG1 | | 3000 | 2002 |
| 3GS | 3000 | | 2004 |
| GUG2 | | 3000 | 2005 |
| | 9600 | 8400 | |



# Planned HVDC Projects by 2020 in China



# Rapid City DC Tie  Project



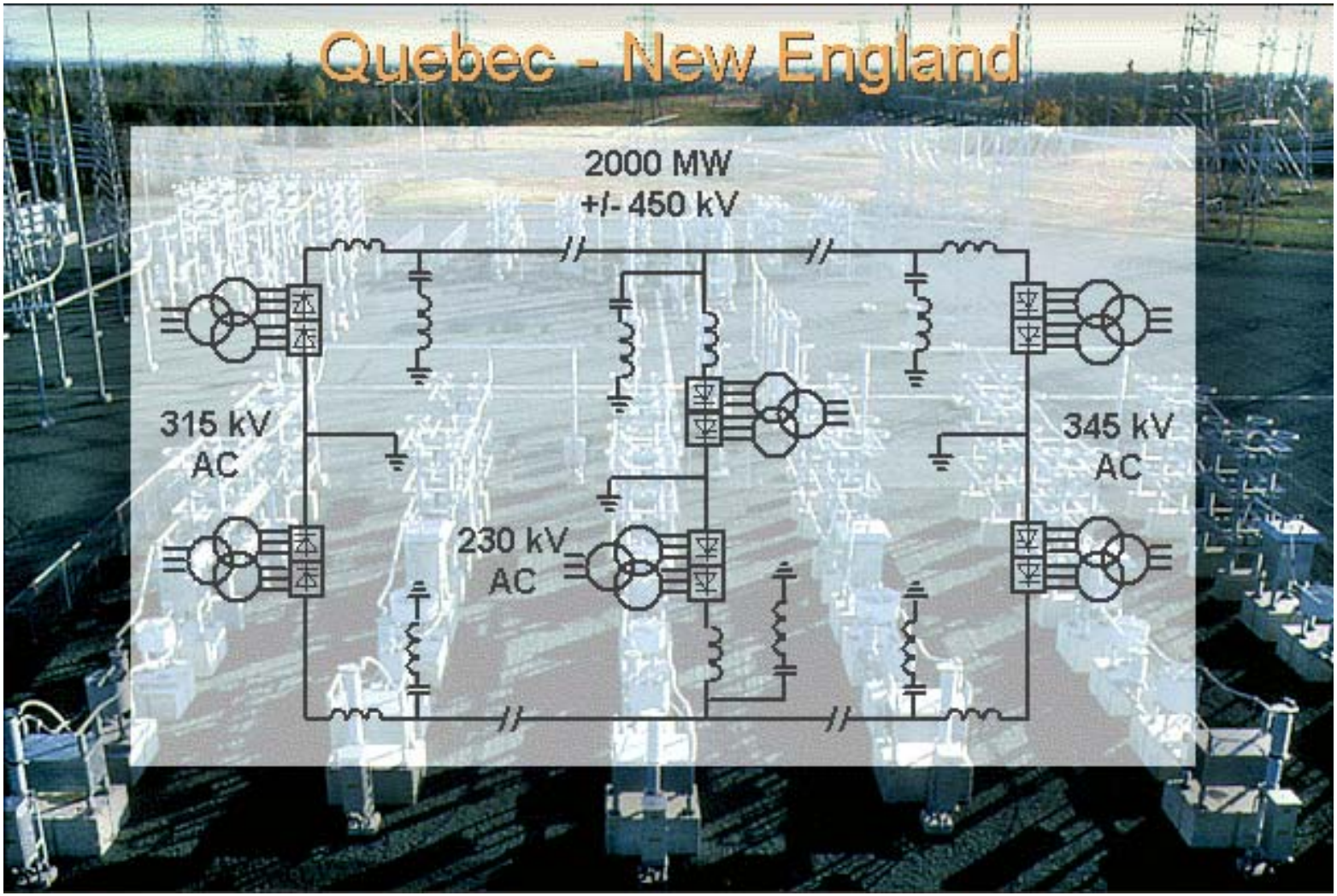

- Rated power: 2x100 MW
- DC voltage: ±13 kV
- Transmission: Back-to-Back
- In operation: 2003
- Project duration: 19 months
- Asynchronous
- CCC due to weak network

# Estlink – HVDC Light between Estonia & Finland



| | |
|---|---|
| **Client:** | Nordic Energy Link, Estonia |
| **Contract signed:** | April 2005 |
| **In service:** | November 2006 |
| **Project duration:** | 19 months |
| **Capacity:** | 350 MW, 365 MW low ambient |
| **AC voltage:** | 330 kV at Harku |
| | 400 kV at Espoo |
| **DC voltage:** | ±150 kV |
| **DC cable length:** | 2 x 105 km (31 km land) |
| **Converters:** | 2 level, OPWM |
| **Special features:** | Black start Estonia, no diesel |
| **Rationale:** | Electricity trade |
| | Asynchronous Tie |
| | Long cable crossing |
| | Dynamic voltage support |
| | Black start |

# Multi-Terminal HVDC

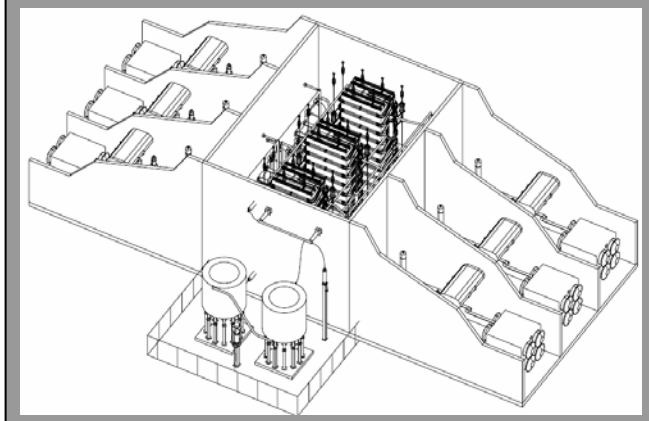



**Radisson**
**±500 kV**
**2250 MW**

**Nicolet**
**±475 kV**
**2138 MW**

**Sandy Pond**
**±450 kV**
**2000 MW**

# Outaouais Asynchronous Tie- Summary

Scope

- 1250 MW HVDC B t B Interconnection Québec-Ontario
- Two independent converters of 625 MVA
- Includes 14 x 250 MVA 1-phase converter transformers

Project Basis

- Customer: Hydro-Québec (HQ)
- Project to export power from Québec to Ontario (Hydro Québec and Hydro One)
- Ontario gets access to clean hydroelectric power during peak times and decreases dependency on coal from US
- HQ sells at peak and buys at low (pump storage)
- Provides stability and reliability to both grids

# Sharyland Mission 150 MW HVDC Tie, ERCOT - CFE

Scope

- 150 MW HVDC back-to-back Interconnection ERCOT – CFE, Mexico

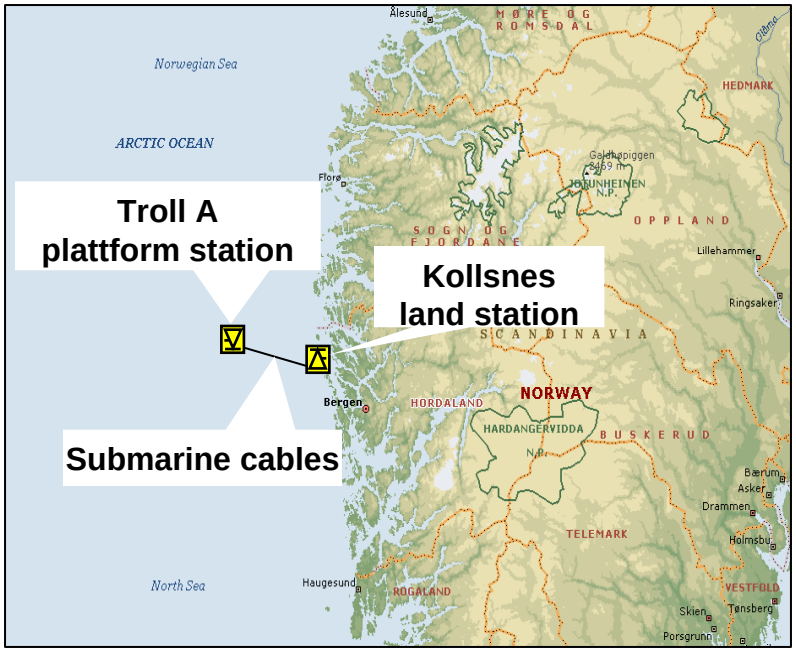
Project Basis

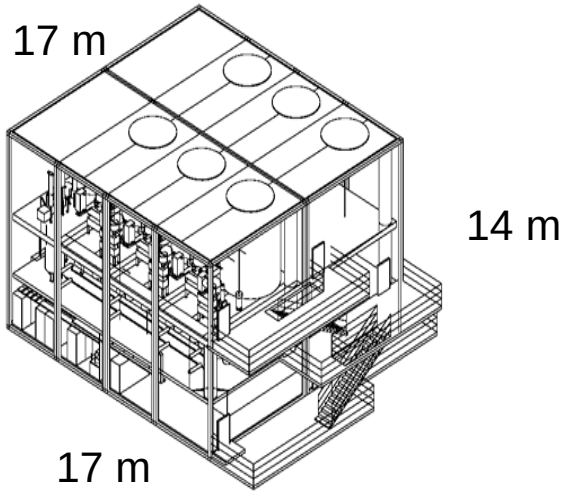
- Customer: Sharyland Utilities
- Energy Trade – Primary Driver
- RMR Generation at Bates – Savings Potential
- System Reliability – Secondary Driver
- Existing 138kV Transmission Thermally Limited
- CFE Network along the Border is Stronger than ERCOT
- Asset in Transmission Tariff Rate Base
- Black Start with bypass

# Troll A Pre-compression EDS Project, Norway

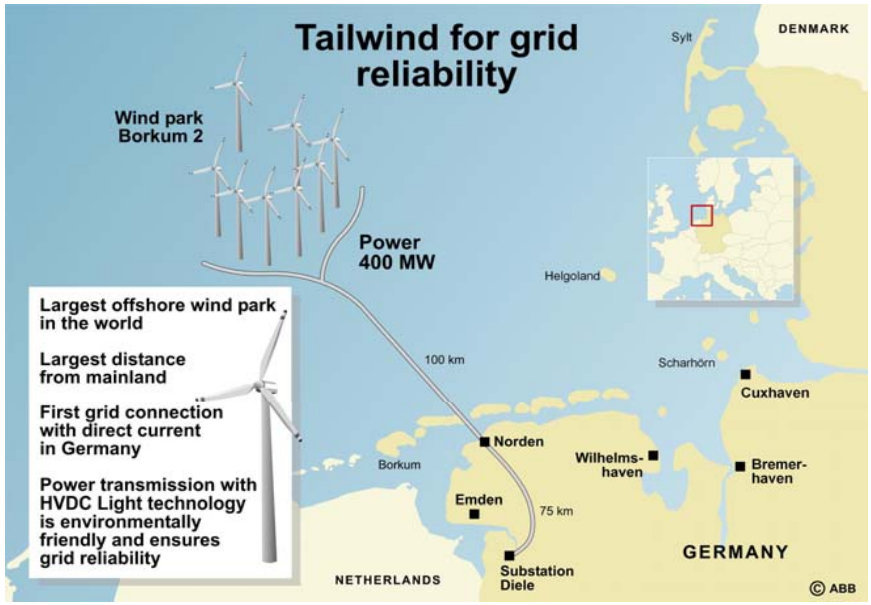
Key data

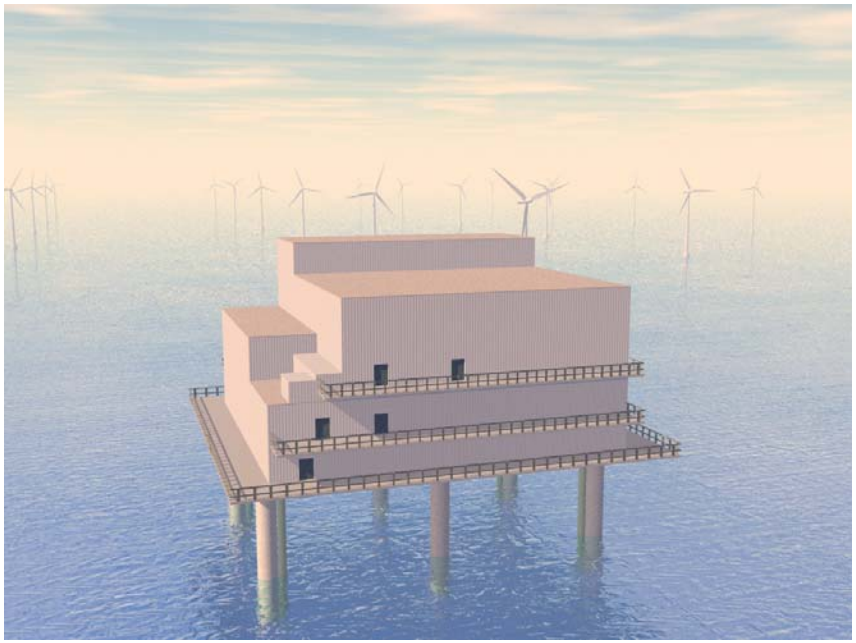
- Two HVDC Light transmissions
- 2 x 40 MW nominal mechanical output on Motorformer shaft
- ± 60 kV DC
- 67 km submarine cable
- HVDC Light inverter placed on existing Troll A gas platform



# Borkum 2, E.ON Netz



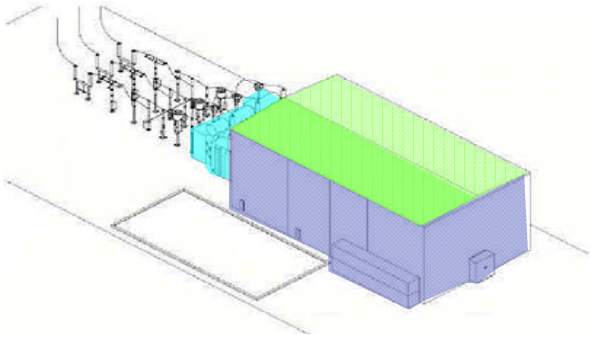
## Scope

- 400 MW HVDC Light Offshore Wind, North Sea - Germany
- ±150 kV HVDC Light Cables (route = 130 km by sea + 75 km by land)
- Serves 80 x 5 MW offshore wind turbine generators

## Project Basis

- Customer: E.ON Netz GmbH
- Project serves 80 x 5 MW offshore wind turbine generators
- Germany gets gets access to clean wind power with higher capacity factor than land based wind generation
- Provides stability and reliability to receiving system

# Southlink, Swedish National Grid Company

Customer need

- Improved security of the electricity supply in South and Central Sweden
- Distance 250 miles

Alternatives

- 400 kV overhead transmission line
- Turnkey 700 MW ±300 kV underground HVDC Light system

Customer benefits with HVDC

- Shorter project time due to easier permitting ( 2 – 3 years )
- Increased power transfer existing a.c. lines ( approx 200 MW)
- Voltage and reactive power control

Project status

- Final evaluation ongoing. Decision 2007