

Lars Weimers & Lennart Harnefors, Power Systems – HVDC, Oslo, October 17, 2011

# A European DC Super Grid A Technology Providers View

# A European DC Super Grid Agenda



- Background
- Challenges
- Driving forces
- Technology
- Conclusion

# A European DC Super Grid Definition

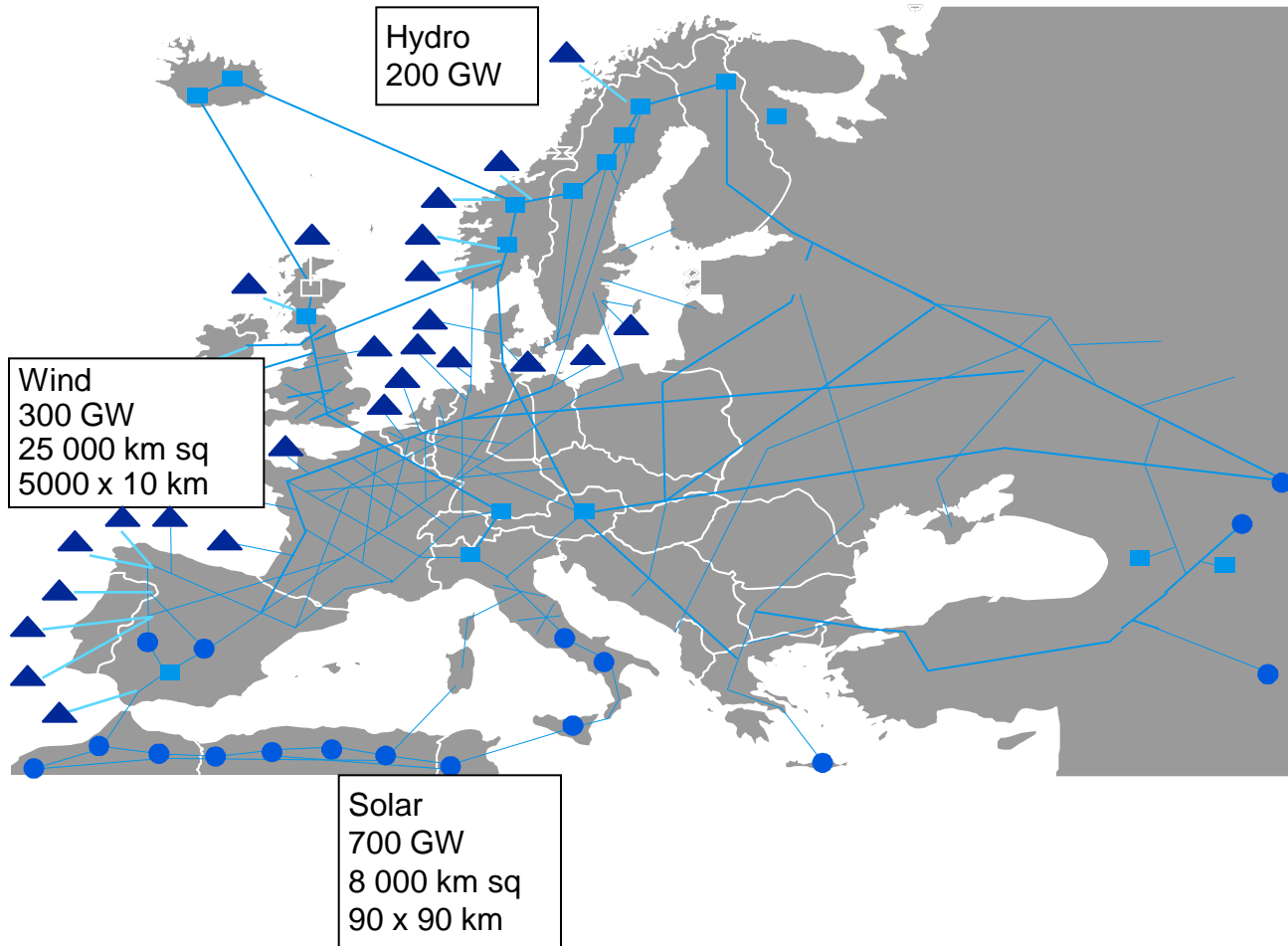
- Among other this is one
- The European lobbying group "Friends of the Supergrid" uses this definition:

"An electricity transmission system, mainly based on direct current, designed to facilitate large-scale sustainable power generation in remote areas for transmission to centers of consumption, one of whose fundamental attributes will be the enhancement of the market in electricity".

# A European DC Super Grid

## ABB's vision in 1999

- Hydro power
- Solar power
- ▲ Wind power
- DC transmission



# A European DC Super Grid

## This vision is now a shared vision

**Potential Common Electricity System**

- Population: 1.1 billion inhabitants
- Electricity Consumption: 4000 TWh/a
- Largest Distance: 800 km (Berlin - Athens) (Lyon - Barcelona)

**The pan-European grid: possible meshed HVDC North Sea**

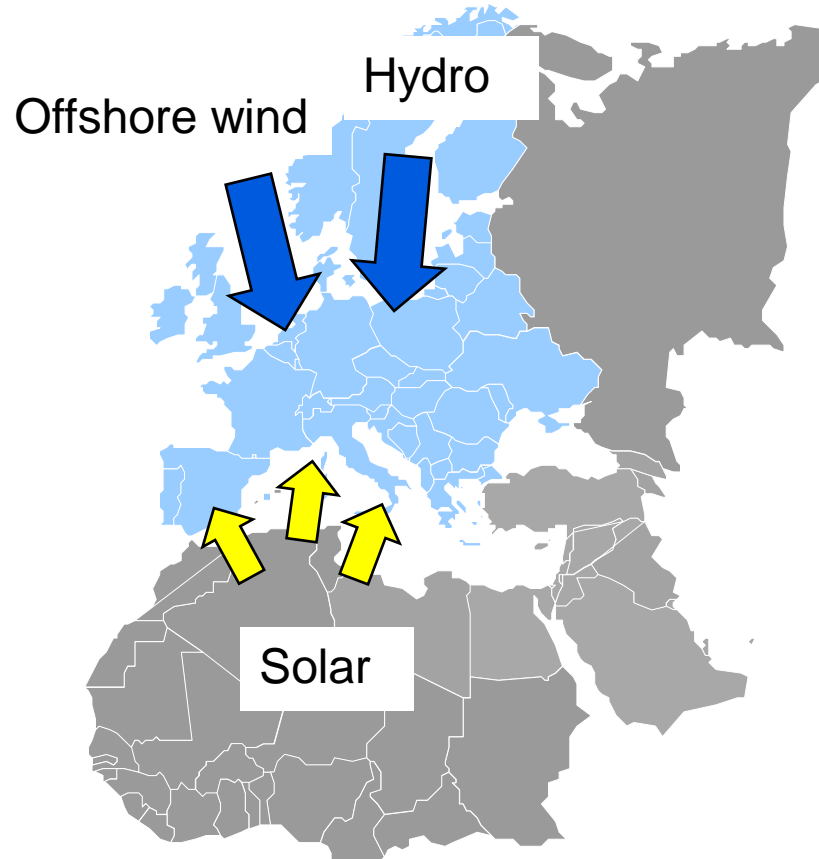
**An ocean grid for the North Sea**

**North Sea Power Wheel**

**Supergrid** is defined as "An electricity transmission system, mainly based on direct current, designed to facilitate large-scale sustainable power generation in remote areas for transmission to centres of consumption, one of whose fundamental attributes will be the enhancement of the market in electricity."

# A European DC Super Grid

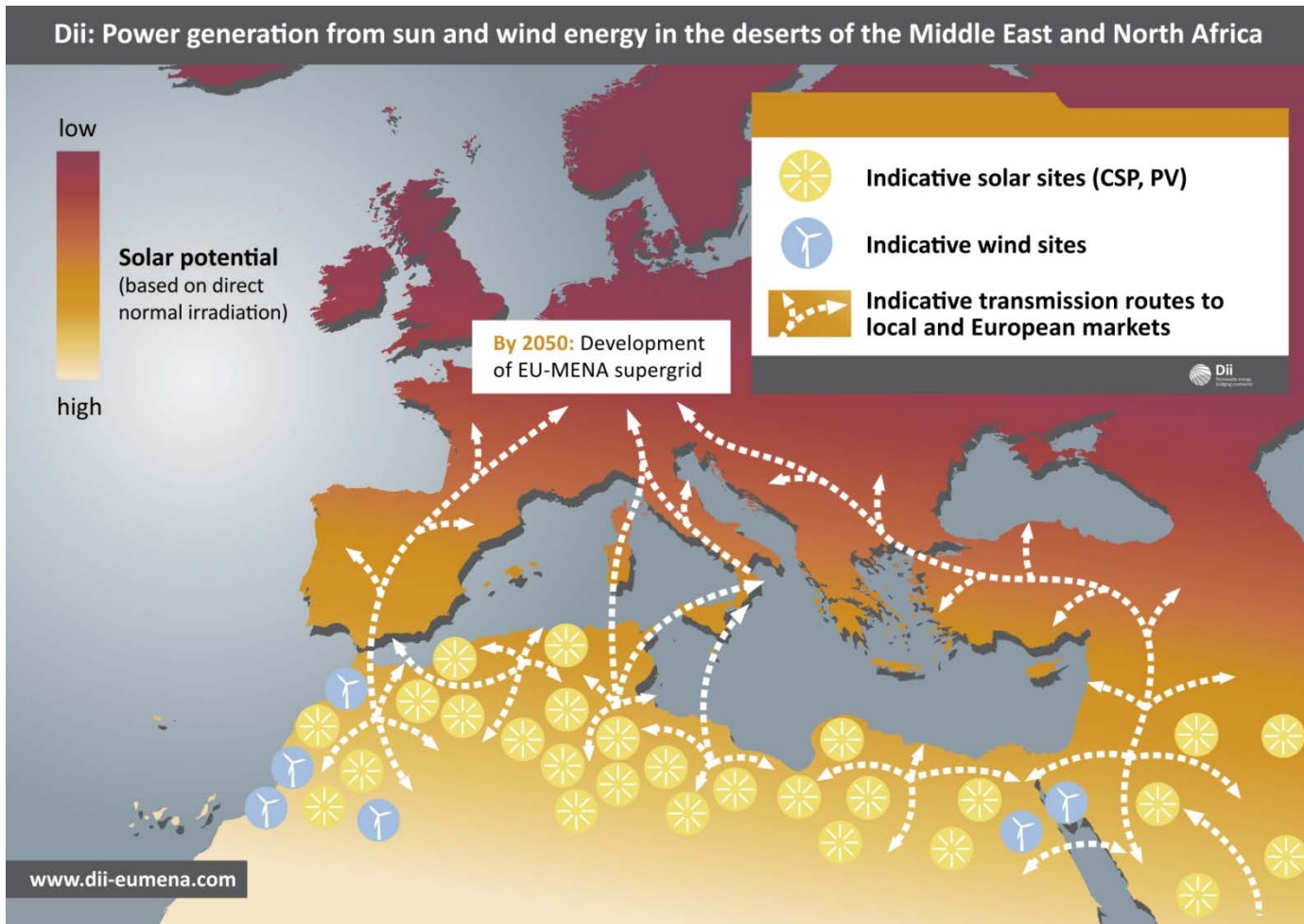
## More renewables to the European Grid



- Europe needs a new controllable transmission system:
  - Landing-point for offshore wind and solar power will be at the “out-skirts” of the grid
  - Changing generation patterns, e.g. the closing of German nuclear power
  - A wish for more interconnections and energy trade
- The transmission grid must be redesigned to meet the new transmission needs, such as
  - Long distance bulk power transmission
  - Low losses
  - Minimum environmental impact

# A European DC Super Grid

## Solar power



# A European DC Super Grid

## The Challenge



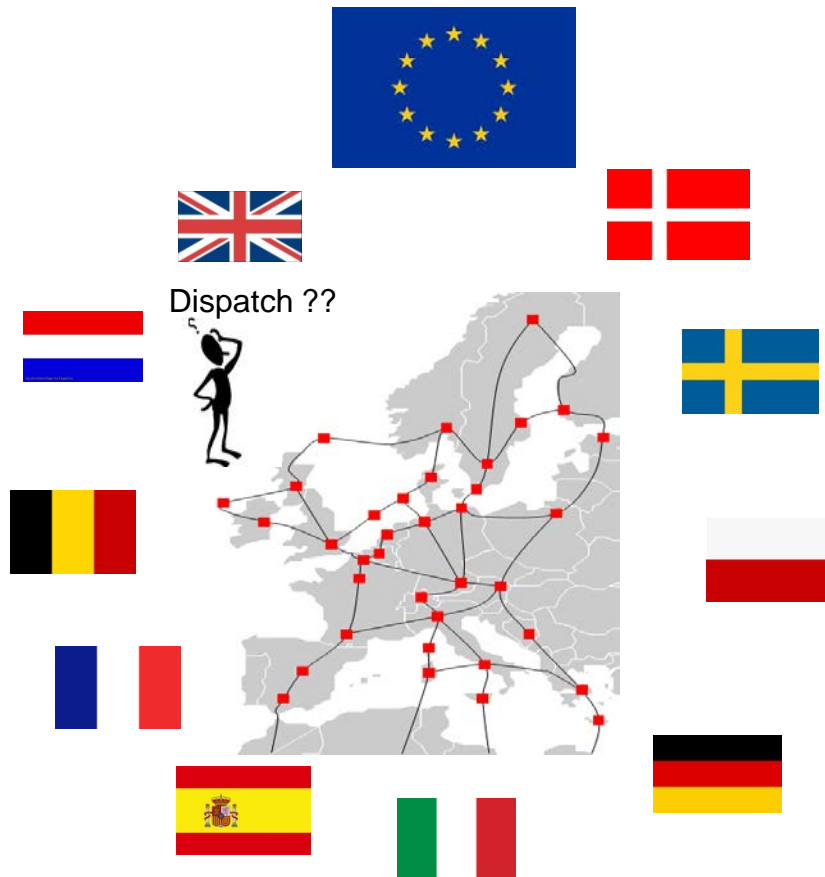
- The opening up of the European electricity markets requires :
  - A new regulatory framework
    - Harmonize the electricity market rules within EU
    - Unbundling generation and transmission
    - Open access to market information
  - Synchronize the feed-in tariffs for renewable energy
  - Close the technology gaps

The grids must become more flexible from both a structural as well as an operational point of view!



# A European DC Super Grid

## Challenges Regulatory frameworks



- Different support systems for green energy
- All markets are de-regulated, but differences remain
- Ownership of transmission system ?

# A European DC Super Grid

## Challenges Regulatory frameworks

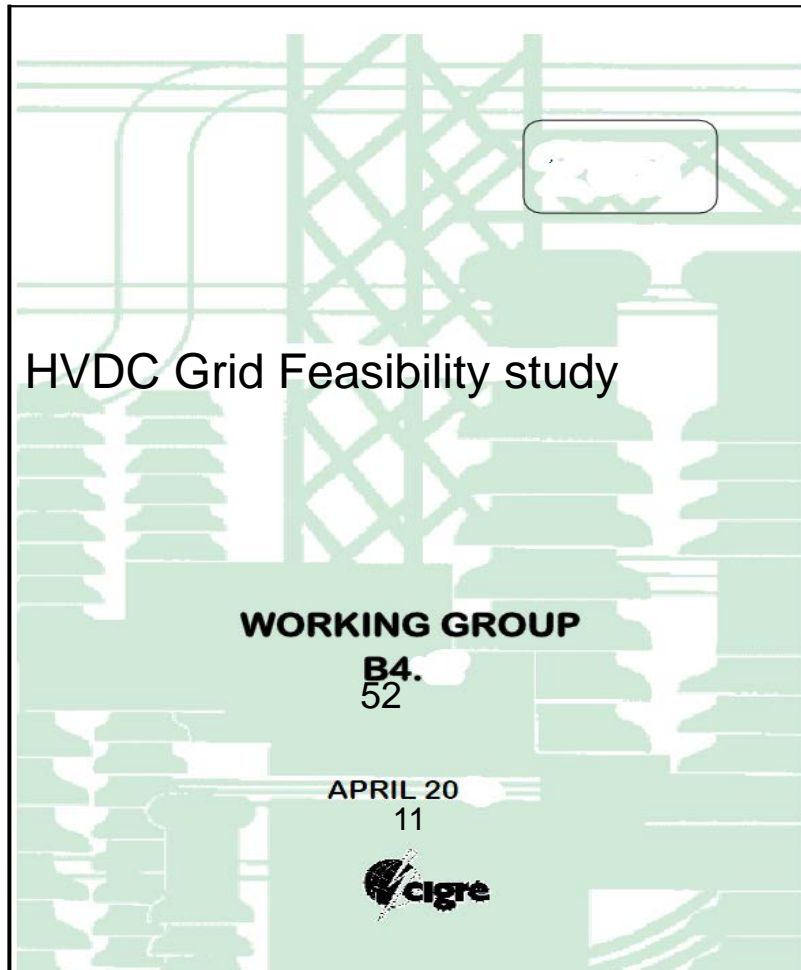


- The regulatory aspects of offshore grid development pose huge challenges and work on addressing these is in its infancy.
- It will be important to share findings between the different forums undertaking work in this area.
- There must be continued involvement at Ministerial level in the North Seas Countries' Offshore Grid Initiative and in bilateral negotiations.
- In the meantime, we believe that progress can be made through an evolutionary "bottom up" approach, that would allow ongoing development in the offshore sector while further work on regulation proceeded.

Source: Energy and Climate Change - Seventh Report, A European Supergrid [www. parliament.uk](http://www.parliament.uk)

# A European DC Super Grid

## Cigré WG B4.52 "HVDC Grid Feasibility Study"



- The security and reliability
- The costs
- The grid configurations – radial and meshed grids
- Power flow control
- Identifying the necessary breaking current capabilities and times
- Converter station design for DC Grids
- The possibility of recommending interface standards for DC Grids
- Technical brochure 2012

# A European DC Supergrid

## ABB is a R&D front-runner



Gotland 1  
Control Room  
20 MW  
mercury  
valves



Skagerrak 1-2  
500 MW  
thyristor valves



Gotland Light  
50 MW IGBT  
+ Plastic cable



Troll power from  
shore  
84 MW IGBT



BorWin1  
Offshore Light  
400 MW



Xiangjiaba - Shanghai  
800 kV Classic  
6 400 MW

1950

1970

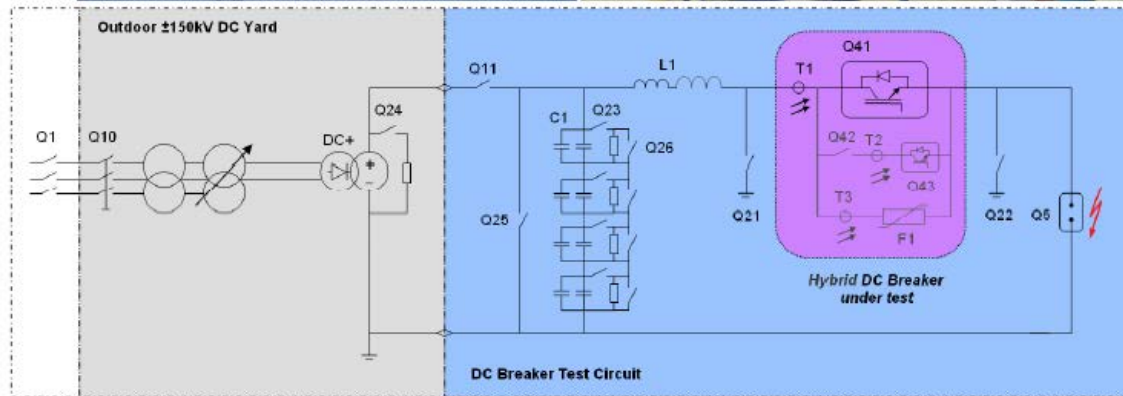
1990

2010

2030

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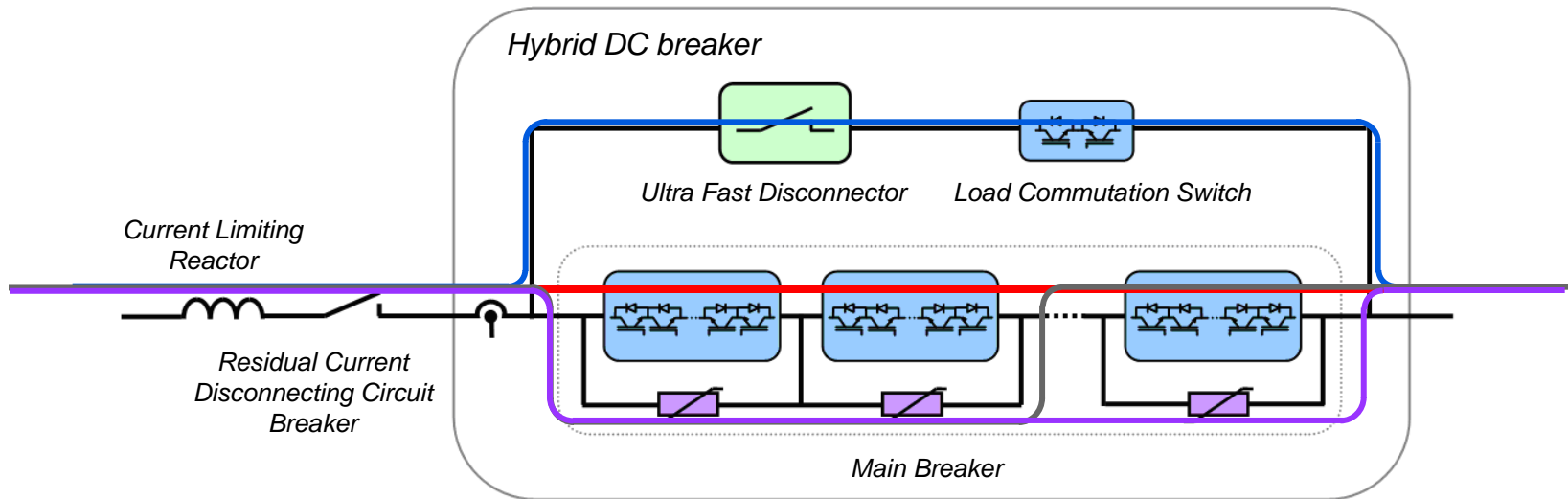
## The first DC breaker launched September 2011



At Cigré meeting in Bologna ABB released a paper:  
"Proactive Hybrid HVDC Breakers - A key innovation for reliable HVDC grids"

# A European DC Super Grid

## Hybrid DC Breaker Basic Functionality



**Normal operation:** Current flows in low-loss bypass

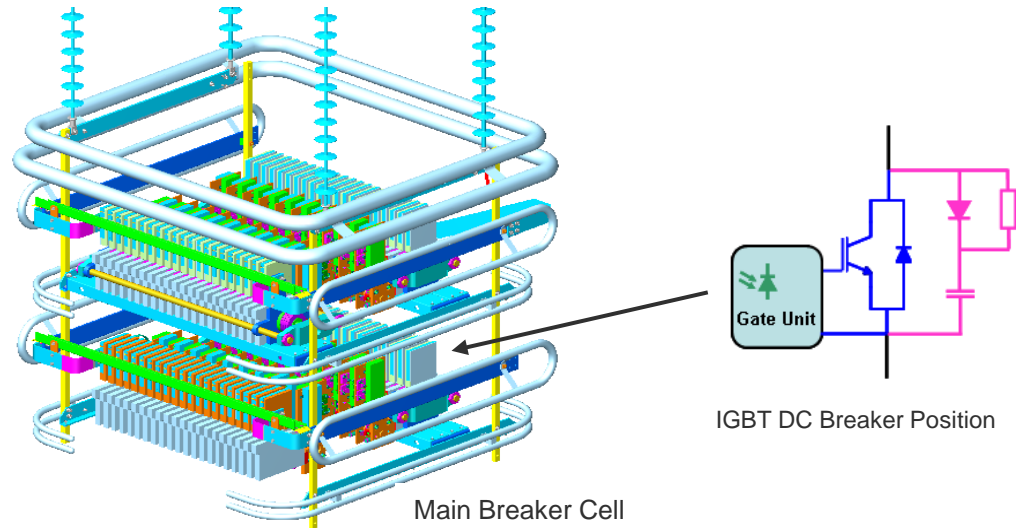
**Proactive control:** Load Commutation Switch opens and commutates current into Main Breaker; the Ultra Fast Disconnecter opens with very low voltage and current stress

*Current limitation:* Suitable number of Main Breaker Modules open and commutate fault current into corresponding arrester banks

**Fault clearance:** Remaining Main Breaker Modules open and commutate fault current into corresponding arrester banks

# A European DC Super Grid

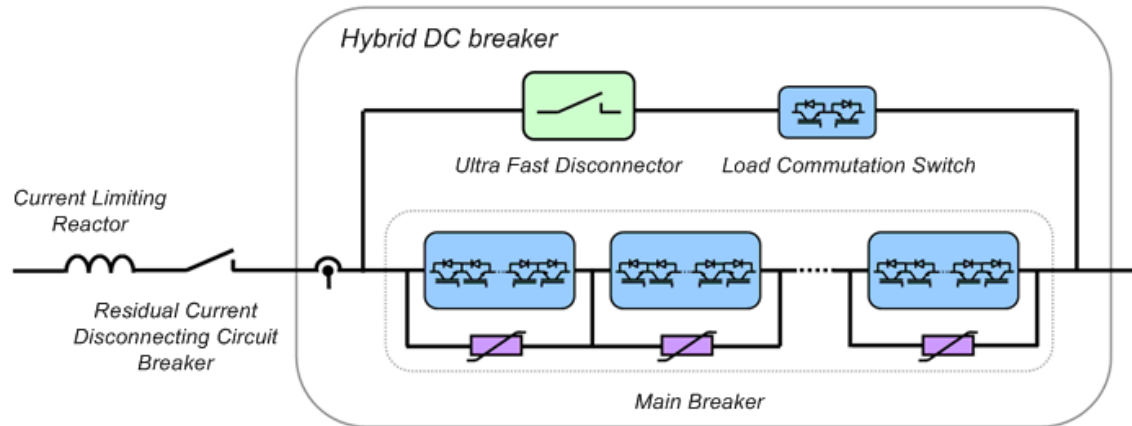
## Hybrid DC Breaker Main Breaker Cell



- 80 kV IGBT DC breaker cell consists of four IGBT stacks, two stacks required to break fault current in either current direction
- Compact design using reliable 4.5 kV Press-pack IGBTs
- Resistor-Capacitor-Diode snubbers ensure equal voltage distribution
- Optically powered gate units for independent DC breaker operation

# A European DC Super Grid

## Hybrid DC Breaker is well suited for HVDC grids



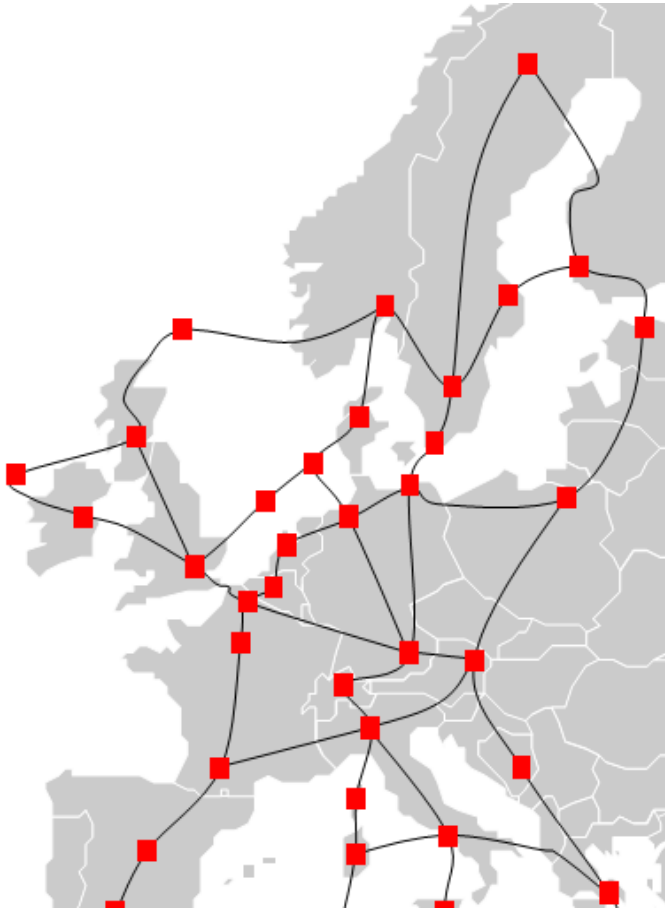
- Fast: Breaking times of less than 2ms
- Powerful: Current breaking capability of 16kA
- Efficient: Transfer losses are less than 0.01%
- Modular : Easily adapted to actual voltage & current ratings
- Reliable: Protective current limitation, functional check while in service
- Proven: Power electronic design similar to converter technology

DC Breakers are no longer a showstopper for large HVDC grids



# A European DC Super Grid

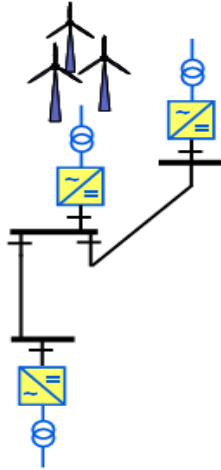
## What is needed to build future DC Grids?



- DC grids should be able to operate during different states in the connected AC systems as well as in the DC system, i.e.
  - Normal operation
  - Alert state
  - Emergency state
  - Failure state
- DC grids can be divided into
  - Regional DC grids
  - Interregional DC grids

# A European DC Super Grid

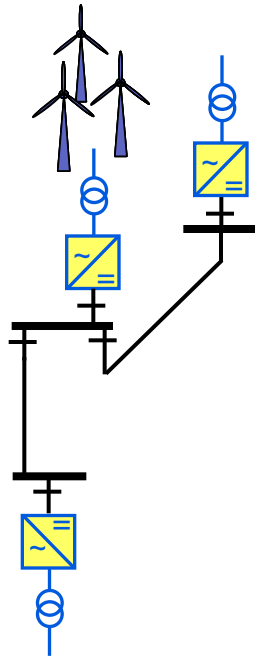
## Regional and interregional HVDC grids



- Regional HVDC grids, having one DC protection zone for DC earth faults
- An interregional HVDC grid is defined as a system that needs several protection zones for DC earth faults, has the same voltage level and very high power rating

# A European DC Super Grid

## What is a regional HVDC grid?



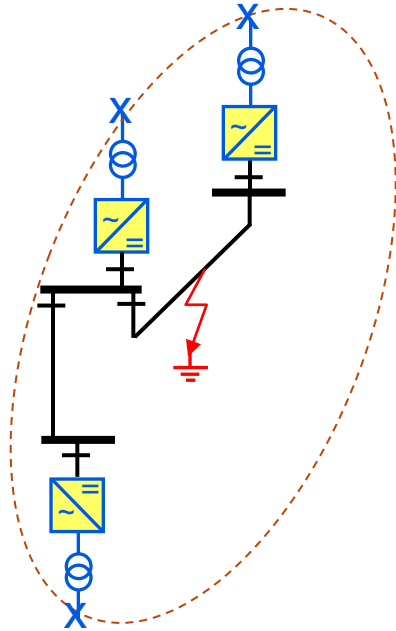
Regional HVDC grid with optimized voltage level

- A system that constitutes of one protection zone for DC earth faults
- Temporarily loss of the whole HVDC system has a limited impact on the overall power system.
- Quick restart of the faultless part of the system
- HVDC grid breakers are not needed
- Normally radial or star network configurations
- Limited power rating

Are built today with proven technology

# A European DC Super Grid

## Regional DC Grid line fault handling at DC earth faults

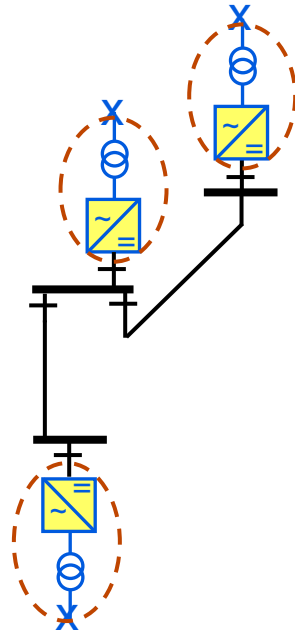


- All AC-breakers (X) opens at a DC line fault
- DC switches (-) opens and isolates the faulty part
- Start-up of none-faulty part

One protection zone  
for DC earth faults.

# A European DC Super Grid

## Other faults than DC earth faults

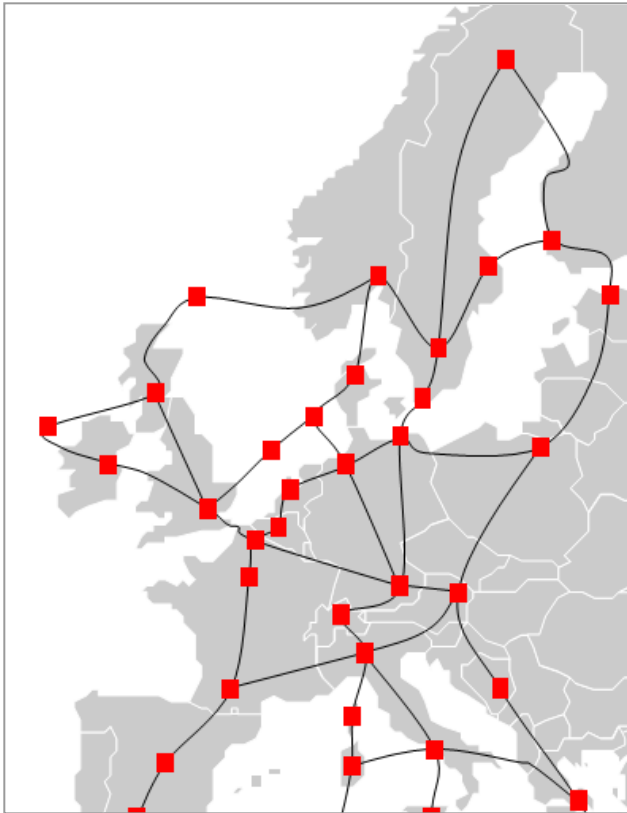
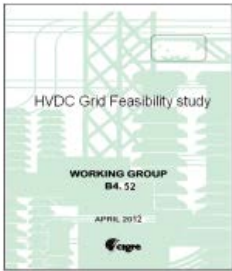


Several protection zones for faults in controls, cooling, filters etc.

- Faults in controls, cooling, filters etc cause a trip of the converter:
  - The rest of the system continues operation without any interruption
  - Does not require DC grid breakers
  - Applies to point-to-point transmission, regional HVDC grids and interregional HVDC grids

# A European DC Super Grid

## What is an interregional DC grid?

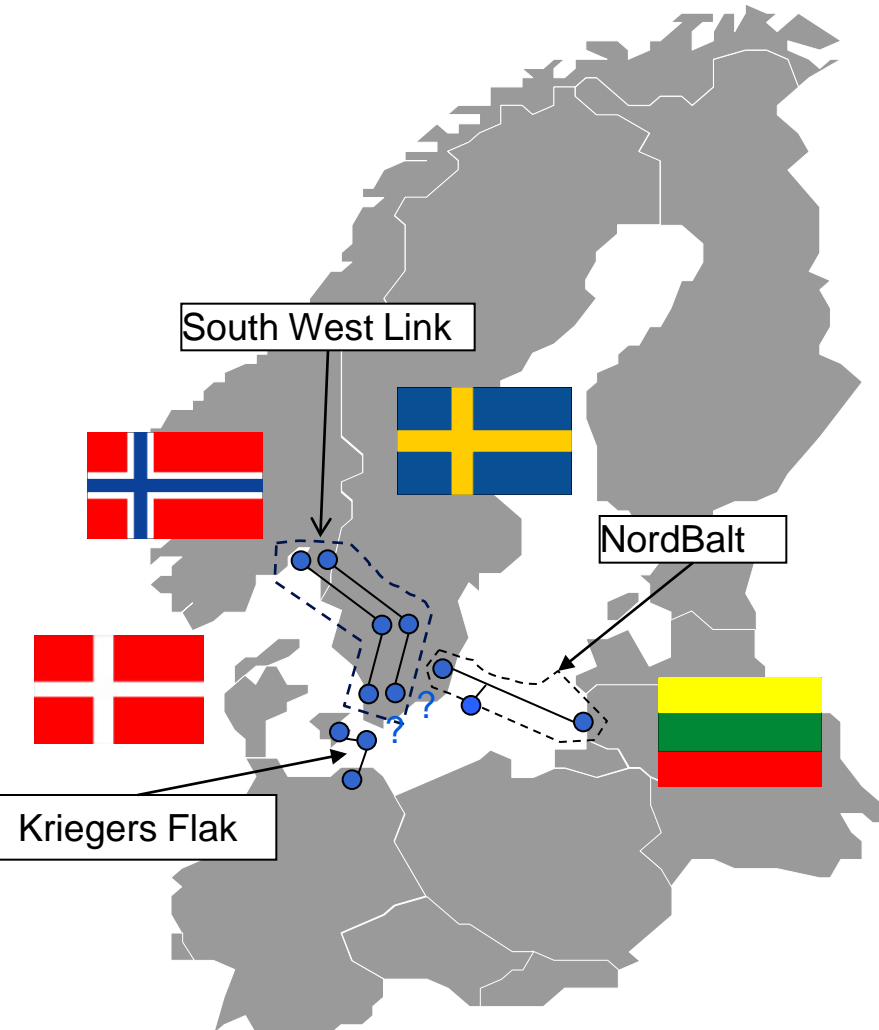


Regulatory issues such as how to manage such new grids need to be solved

- An interregional HVDC grid is defined as a system that needs several protection zones for DC earth faults, has the same voltage level and very high power rating
- New developments needed, e.g.:
  - HVDC grid breakers
  - Grid power flow control
- Long-term development, e.g.
  - High voltage DC/DC converters for connecting different regional systems
  - On-going Cigré WG B4.52 "HVDC Grid Feasibility study".

# A European DC Super Grid

## One of the first regional DC Grids ?



### South West Link

1'st stage: 2 terminals á 2 x 700 MW  
2'nd stage: 3 terminals á 2 x 700 MW

### NordBalt

1'st stage: 2 terminals á 700 MW  
2'nd stage: 3 terminals á 700 MW

### Kriegers Flak

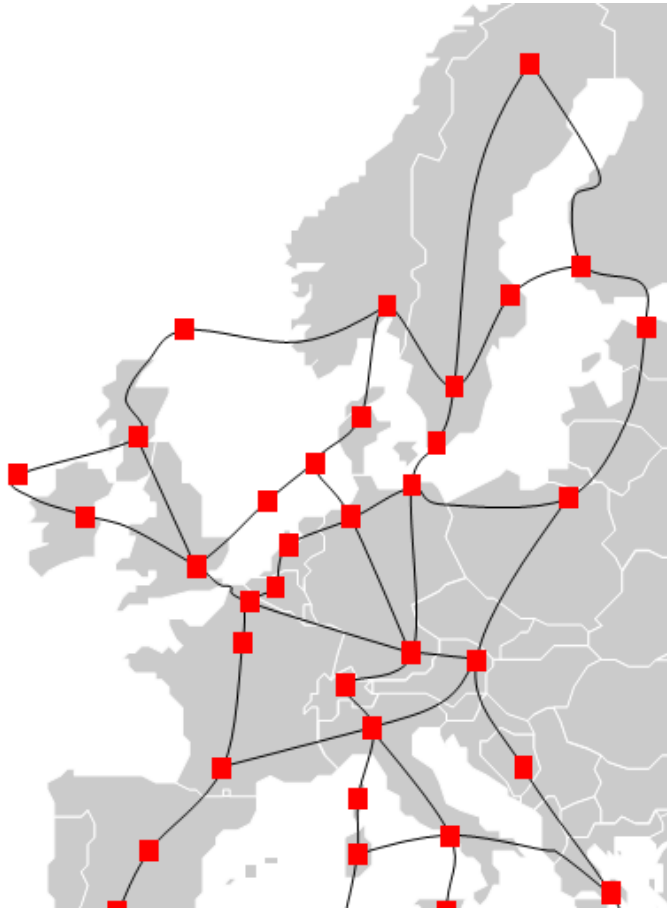
1's stage: 3 terminals á 600 MW

### Future DC Grid

9 terminals @ 300 kV

# A European DC Super Grid

## Conclusion: It is a reality, but not yet



- Technology gaps will be closed
  - ABB DC breaker is available
  - Higher ratings will come
- Regulatory issues will be coordinated but regional differences will remain
- A European DC Super Grid will be realized because
  - Strong political commitment
  - Environmental reasons
- Step by step evolution of the grid
  - 1'st: regional grids are built
  - 2'nd: regional grids evolves into “limited” interregional grids
- The European DC Super Grid is a reality, but it will take time



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