

# Operational challenges of HVDC Offshore Grids

A TSO's perspective

November 2016

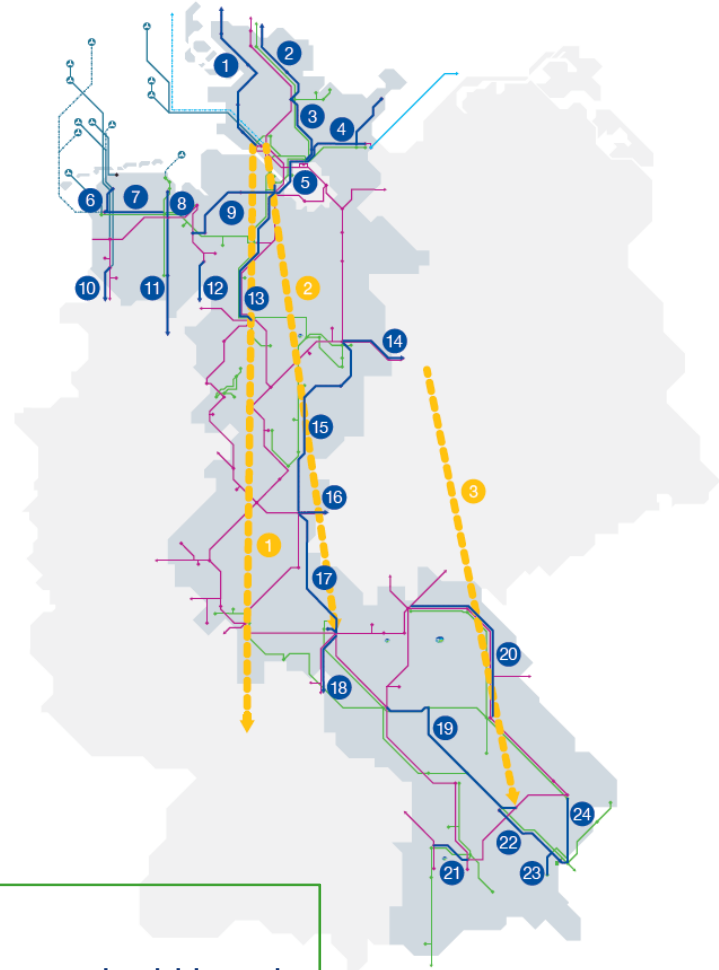
TenneT Offshore, AMO-GHC

# TenneT Offshore



## TenneT – The Company

- We supply 41 million end users with electricity
- Operation, maintenance and further development of (extra high-voltage) power grids in parts of Germany and the Netherlands
- Statutory mandate for grid expansion and safe operation on- and offshore



### TenneT

- Approx. **22,000 km** total grid length
- Grid availability **99.9975 %**
- Approx. **3,000** employees
- turnover of **EUR 3.3 billion**

# Establishing the concept



## Planning:

- Long term planning basis
- Uncertain development

## Technology:

- HVDC (LCC,VSC)
- HVAC (50 Hz, 16.7 Hz)
- GIL, HTSL...

## Framework:

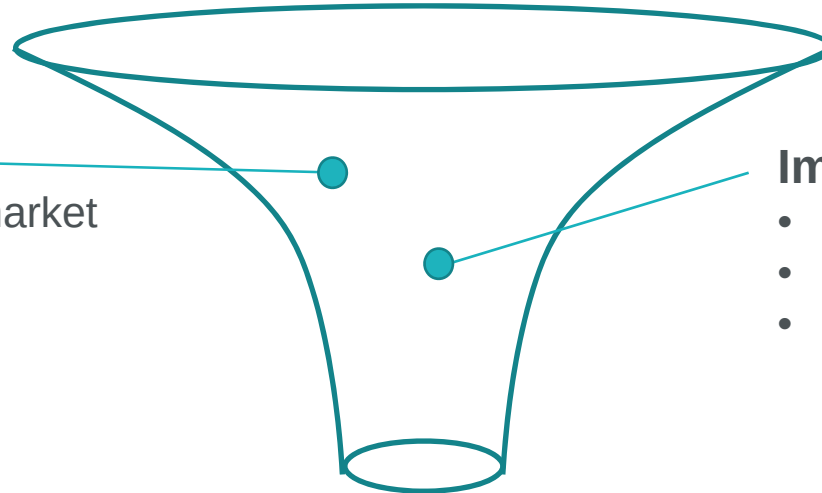
- Suitable
- No discrimination
- Efficient
- Nature

## Market:

- Availability on the market
- Standards
- Supply chain

## Implementation:

- Investment
- Operational exp.
- Viability



## Concept

- Grid Codes
- Standard
- Principles



# Security of supply







# Planning principle (n-1)

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The failure of a single component

- Overhead line circuit
- Cable
- Transformer
- Reactive power compensation device
- Bus bar
- Generation unit

will not endanger the

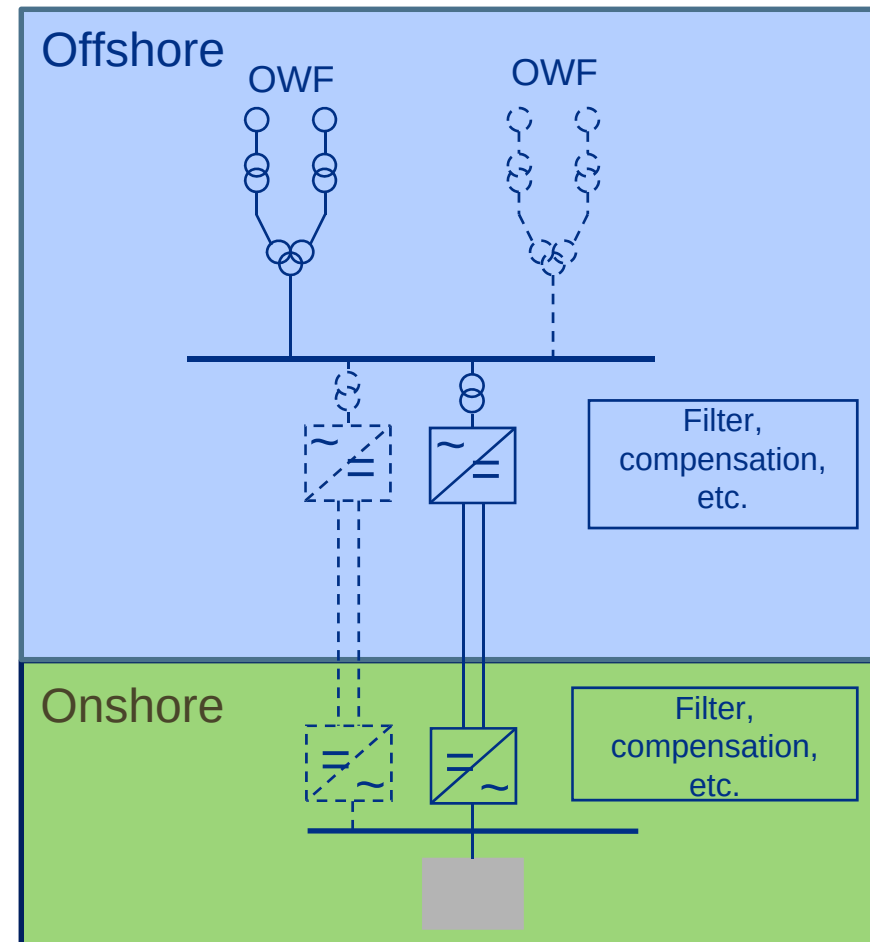
- horizontal or
- vertical

transport of electrical energy.



# Security of supply for offshore GCS

- Individual GCS is build mainly following (n-0) philosophy
- Mother – daughter concept is established
- Build-in redundancy for auxillary systems



# Challenge Power Electronics



# Challenges

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## Electrical point of view

- Offshore grids differ a lot from strong onshore AC grids
  - Low short circuit capacity
  - High amount of power electronic devices (interaction between controls)
  - Various number of switching configurations
  - Classical control strategies not always applicable to offshore grids
- Long cables lead to high capacitive currents and low resonance frequencies
- Missing loads cause low damping in the grid
  - Resonances reach very high/low values
  - Excellent conditions for problems with steady state harmonics/harmonic instability
  - Sympathetic transformer interaction





# Steady state harmonics

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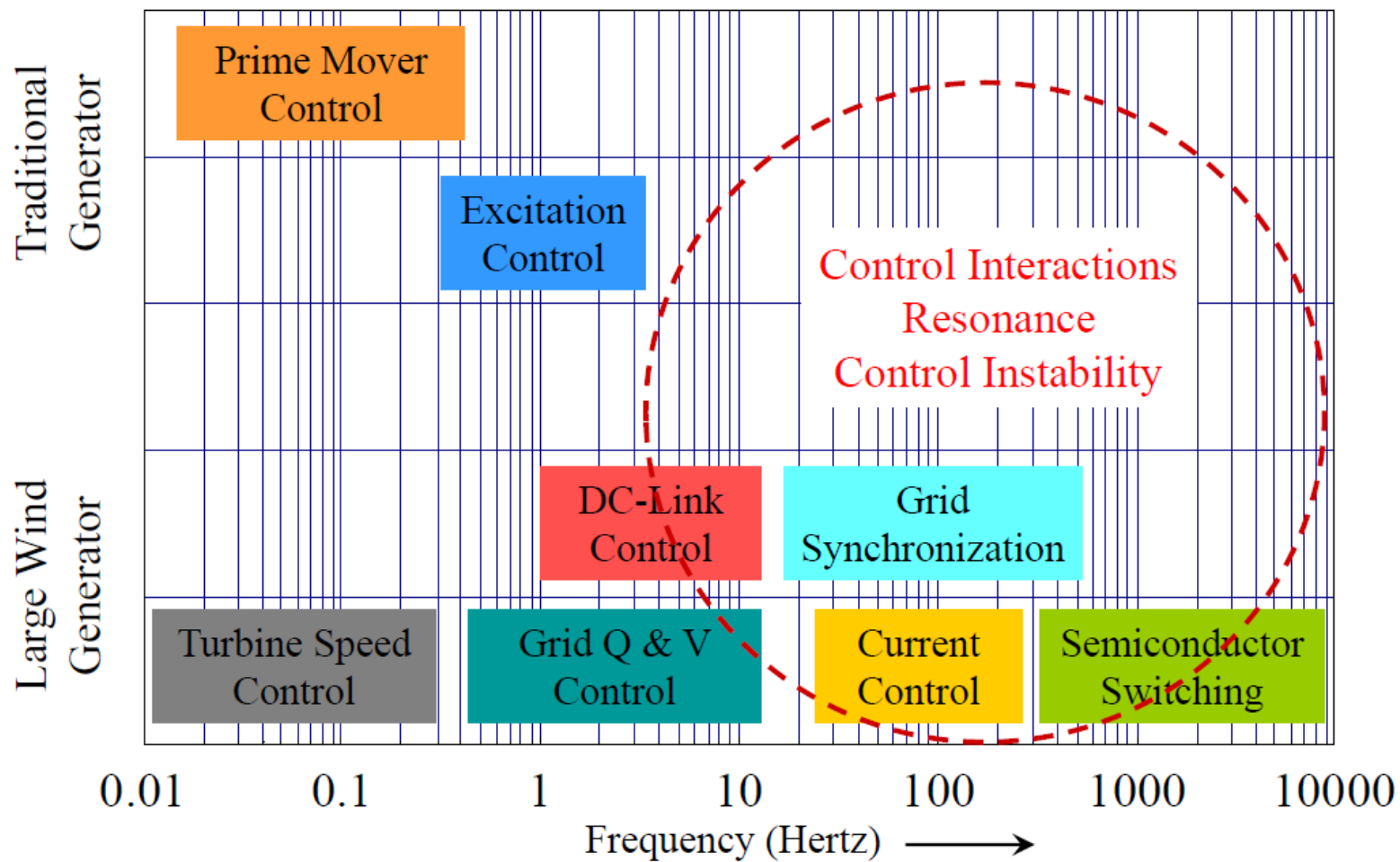
- Resonances can reach very low values of below 5 Ohm
- Resonances can occur at 200 Hz, 250 Hz or at lower frequencies
- Strong dependency of resonance frequency to the switching topology; a (dis)connection of one string of wind turbines is sufficient to shift the resonance to a critical frequency
- Even MMC converters are able to feed in a significant amount of current, which causes problems, if the resonance has the „right“ frequency



# Harmonic stability

## Operating range of controllers

Source: Jian Sun, RPI



# Challenge Offshore

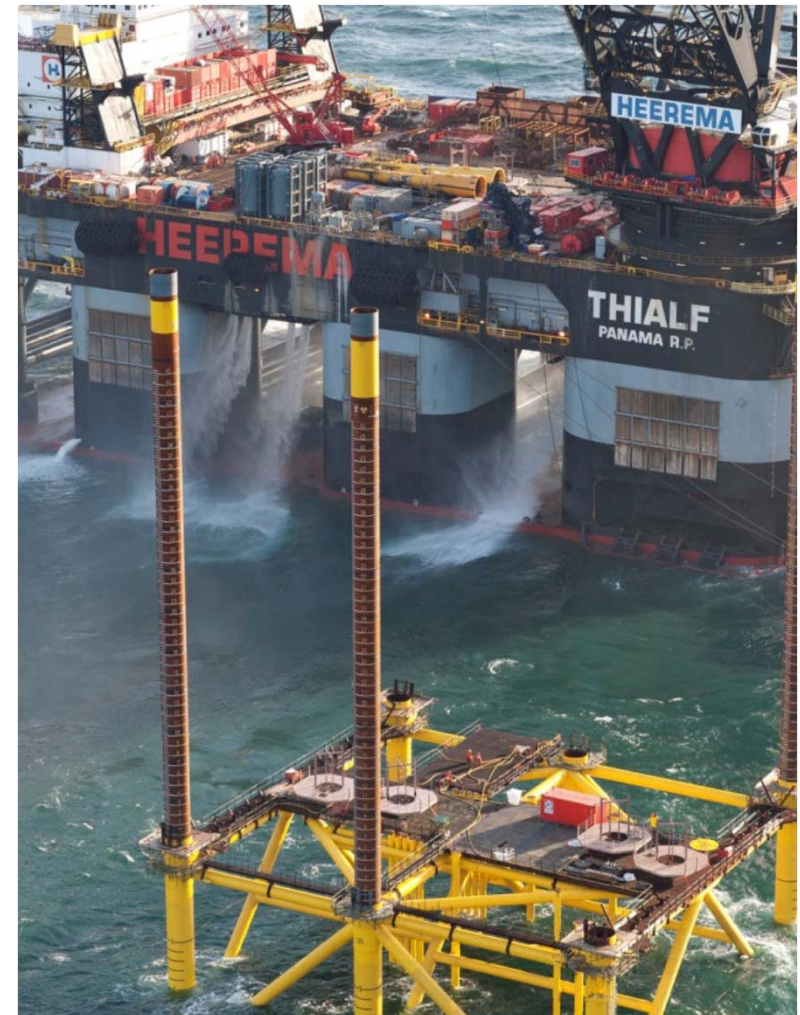




# Technology



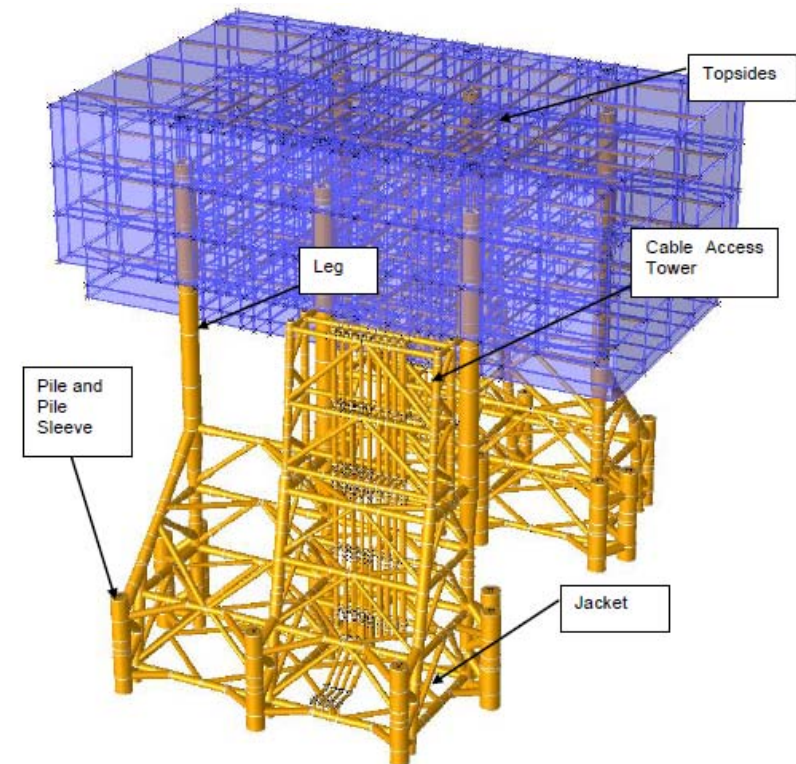
- Limited experience worldwide with the operation of HVDC grid connections for offshore wind farms
- Complex technology must be able to withstand the harsh conditions of the North Sea for 30 years



# Capacities



- The supplier market is tight and there is only little infrastructure available for the construction (cable laying vessels, etc.)
- Availability of offshore experts is rather limited in the German labour market
- Almost every project has to be custom built and is considered a prototype
- For work offshore a multi-day construction period is necessary



# Safety



- The working environment poses numerous risks
- Emergency responses take a long time, because of the long distance to the coast
- All TenneT offshore personnel has completed a wide range of training, including that of a special first responder
- TenneT contracted the development of safety gear, which meets the requirements to work offshore and with high voltage power





# Ordnance finds



- It has been estimated that 1,3 million tons of ordnance are still lost in the North Sea
- Ordnance areas are clearly marked on maps, but actually the ordnance contaminated areas have spread all across the sea, because of ocean currents
- The protection of man and environment must always be of highest priority
- When the Riffgat cable was laid, 30 tons of ordnance were recovered and cleared



# Environmental protection

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- Much of the work at sea and in the wadden sea has to be done under tight time constraints, because of environmental restrictions
- Construction may only proceed in the wadden seas outside of the birds' nesting period later than July
- Cables may only be laid during temperatures of minimum 5°C, which usually excludes the winter months
- In addition, work out at sea has to meet strict conditions; Such as noise-abatement measures which have to be applied during the installation of a converter platform



# Grid Expansion is a big task

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With innovative approaches and enormous capital spending such kind of grid expansion is possible. An appropriate framework is obligatory to start these efforts:

- **Realistic expansion goals** for the grid and offshore generation and consumption, in order to avoid over capacities and idle costs
- **Secure investing** and appropriate returns for the TSO, the investor and the OWF
- **Political backing** for the authorities during planning and conflict management on site



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**Taking power further**

