TenneT 2GW Program

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A moment for safety

Together we provide a safe working environment. We learn from mistakes and sharing ideas, concerns and asking questions are a matter of course.

We also draw attention to the following safety measures in case of evacuation of the premises

Follow the escape route as indicated

Use the stairs instead of the lift

Go to the assembly point

Follow the instructions of the in-company emergency responder

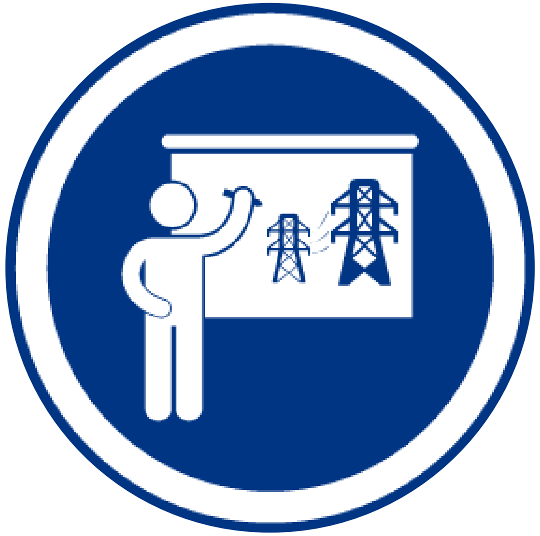
Outline

- Why → The Challenge
- How → 2 GW Program Background
  → Framework Tender
- What → Technical Aspects
  1. HVDC System
  2. DC Cable System
  3. Platform
  4. Landstation
  5. Multi-Terminal Readiness
- Questions & Discussion

Why → The Challenge

Vision offshore →Actively shaping the energy transition

EU climate targets: a fully climate neutral Europe by 2050



Offshore wind will play a **crucial role** in this energy transition

The North Sea as the **powerhouse** with international projects

Why → The Challenge

2 GW Program → Foundation for energy transition

Government

The Goal: Carbon neutrality in Europe until 2050

Netherlands: 21 GW by 2031, 70 GW by 2050 **Germany:** 30 GW by 2030, 70 GW by 2045

Esbjerg Declaration: Develop the North Sea as a Green Power Plant of Europe

65 GW by 2030, 150 GW by 2050 → >%50 **The Goal**

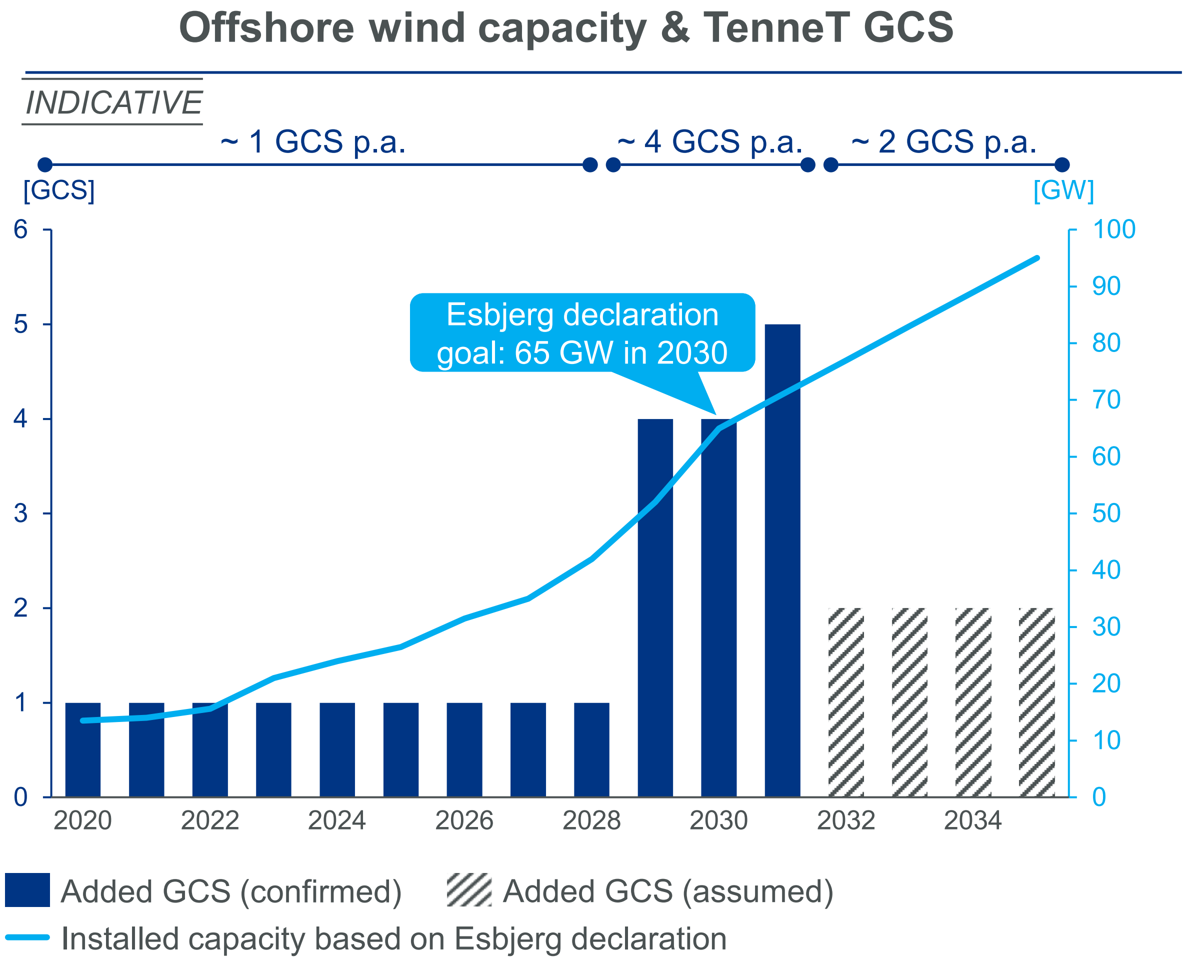
TenneT

2GW Program

It will help Europe to secure renewable energy supply today and tomorrow by delivering ...

- … **14 offshore projects** with **2 GW each** in GER and NL until 2031 + ~ 2 additional systems per year thereafter
- … green wind energy from the European powerhouse North Sea for up to **35 million households** by 2031
- … the **same amount of energy** with **less** than half as many **systems** compared to previous offshore grid systems
- EU: … **30%** (18 GW from nine systems) of **Europe´s offshore wind targets** for 2030
- NL: … more than >**75% of the Dutch** 2031 expansion **target**
- DEU: … **30% of the German** offshore **energy goal** for 2035 (currently confirmed systems)

Energy transition → Increase in Offshore wind → TenneT Leading role



GCS = Grid Connection System

How → A programmatic approach

2GW Program: a needed evolution

Key focus of the 2GW Program

- Safety and CSR
- Cost reduction (TOTEX)
- Standardization and Harmonisation
- Build on existing Knowledge
- Implementation of Lessons Learned
- Scale-up and Innovation
- Timely delivery

TenneT's view on benefits of **standardisation**:

- Shorter project duration and lower project execution cost
- Less operational cost
- Less risks for Contractors and TenneT
- Increasing confidence across supply chain
- Efficiently using TenneT's and suppliers (limited) resources
- Better incorporation of lessons learned

TenneT's 2 GW HVDC Grid Connection System Map

Netherlands

#	Project	Commissioning
1	IJmuiden Ver Beta	2029
2	IJmuiden Ver Alpha	2029
3	IJmuiden Ver Gamma	2029
4	Nederwiek 1	2030
5	Nederwiek 2	2030
6	Nederwiek 3	2031
7	Doordewind 1	2031
8	Doordewind 2	2031

Hitachi Energy Petrofac

GE/SEATRIUM

GE/McDermont

SIEMENS/Dragados

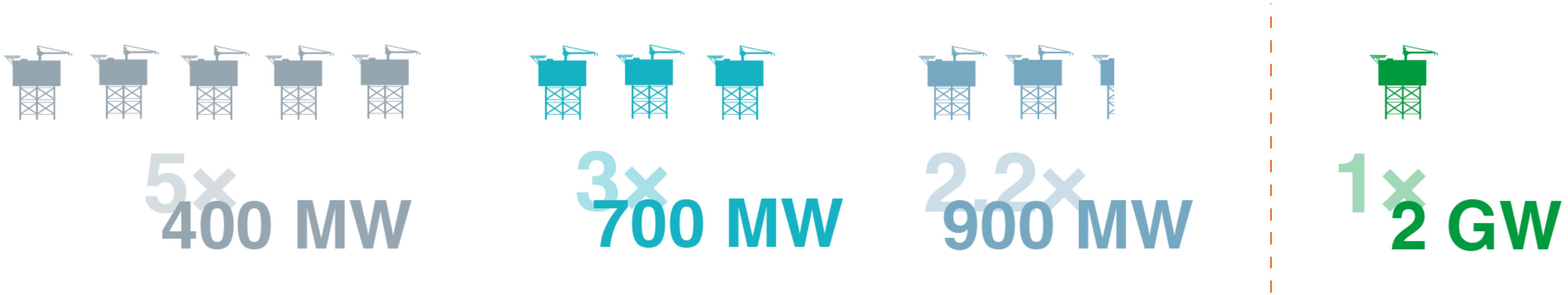
Germany

#	Project	Commissioning
9	BalWin3	2029
10	BalWin4	2029
11	LanWin1	2030
12	LanWin2	2030
13	LanWin4	2031
14	LanWin5	2031

What → Technical Solution

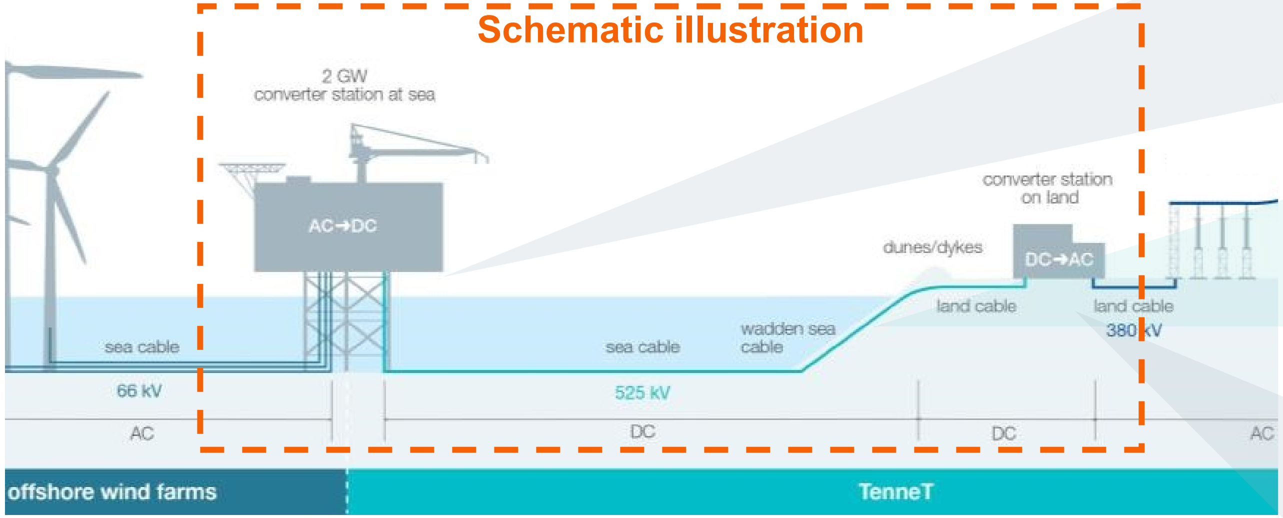
2GW Standard Program

- ❖ Standardized 2GW system and platform design with ±525 kV / 2 GW
- ❖ Achieve more with less:
  - ➢ Overall less resources needed than with 700 MW / 900 MW system equivalents
  - ➢ Design once, build many
  - ➢ Activate economy of scales
  - ➢ Standardized system and components reduces operational costs
- ❖ Partnership approach between TenneT and suppliers



TenneT's 2GW GCS are made of standardized assets

Technical scope of GCS



2GW Standard - Less assets - Less space - Less impact - Lower cost

Standardization Overview

HVDC Offshore Station:

- 66 kV AC to 525 kV DC
- Platform: Standardized layout and outer dimensions
- Jacket: Flexible design, depending on water depth / soil condition

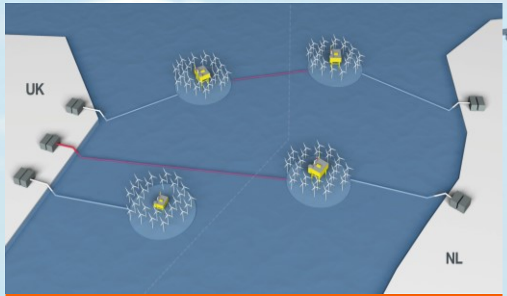
Cable:

- ±525 kV is currently highest voltage rating for offshore connections
- Dedicated metallic return cable
- Integrated fiber optic cable for communications

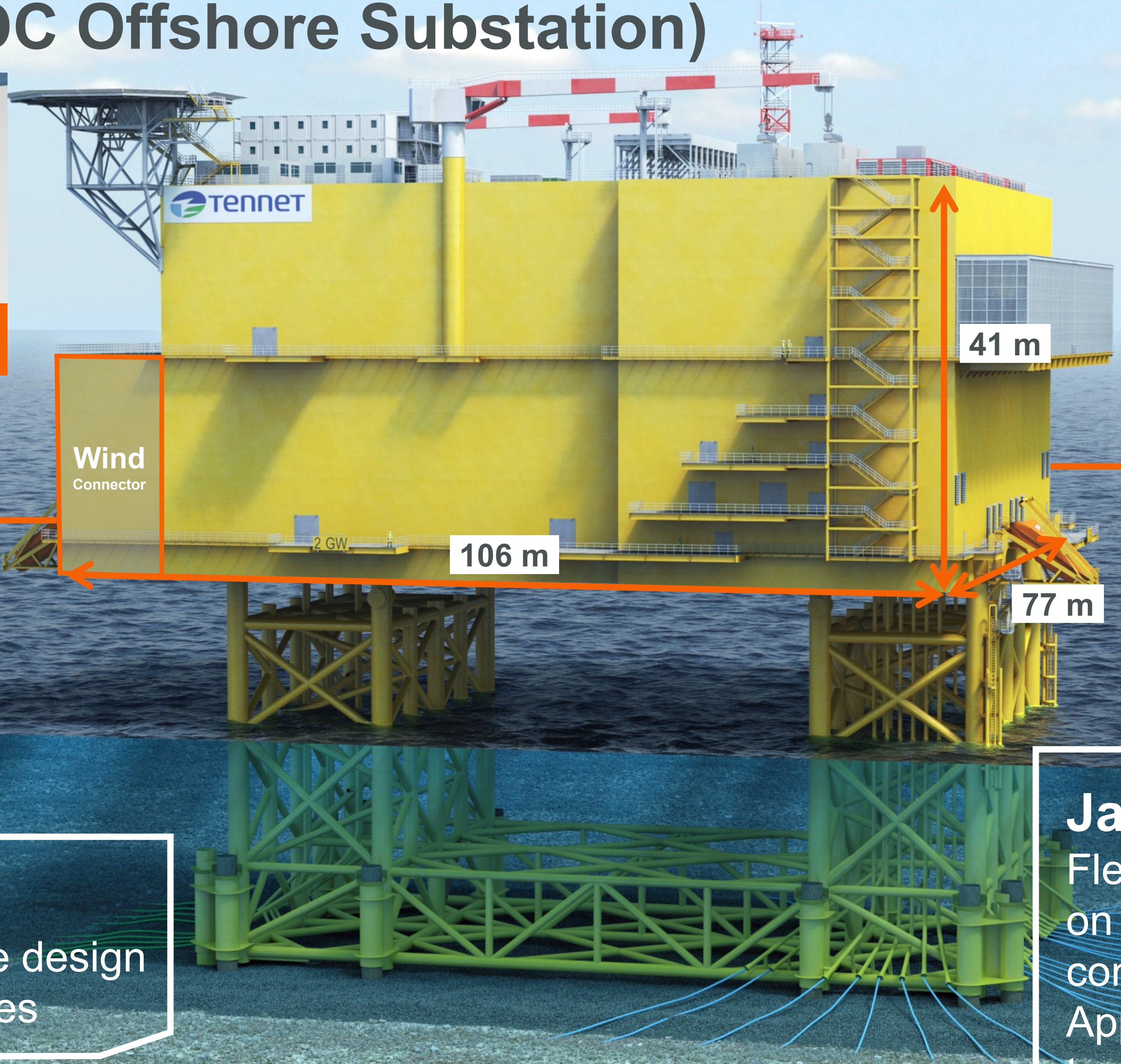
HVDC Onshore Station:

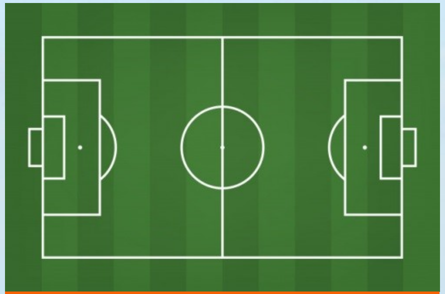
- 525 kV DC to 380 kV AC
- Standardized converter building layout with fixed outer dimensions
- Two-variations of plot size for site specific conditions

Platform (HVDC Offshore Substation)



MPI ready





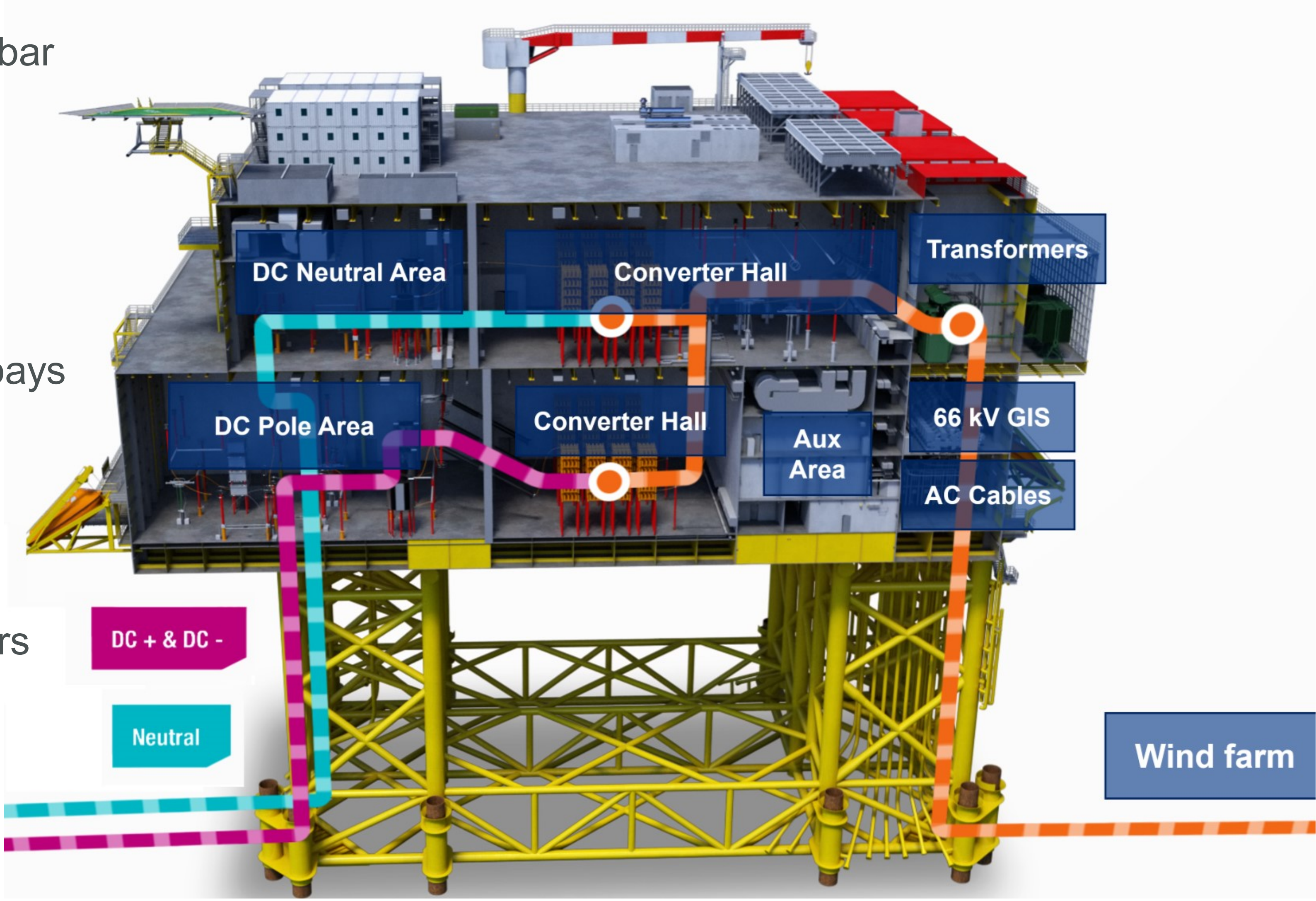
= size of a football field with ten floors!

Platform
Standardized topside design
Approx. 28.000 tonnes

Jacket
Flexible design, depending on water depth and soil condition
Approx. 8.000 – 11.000 tonnes

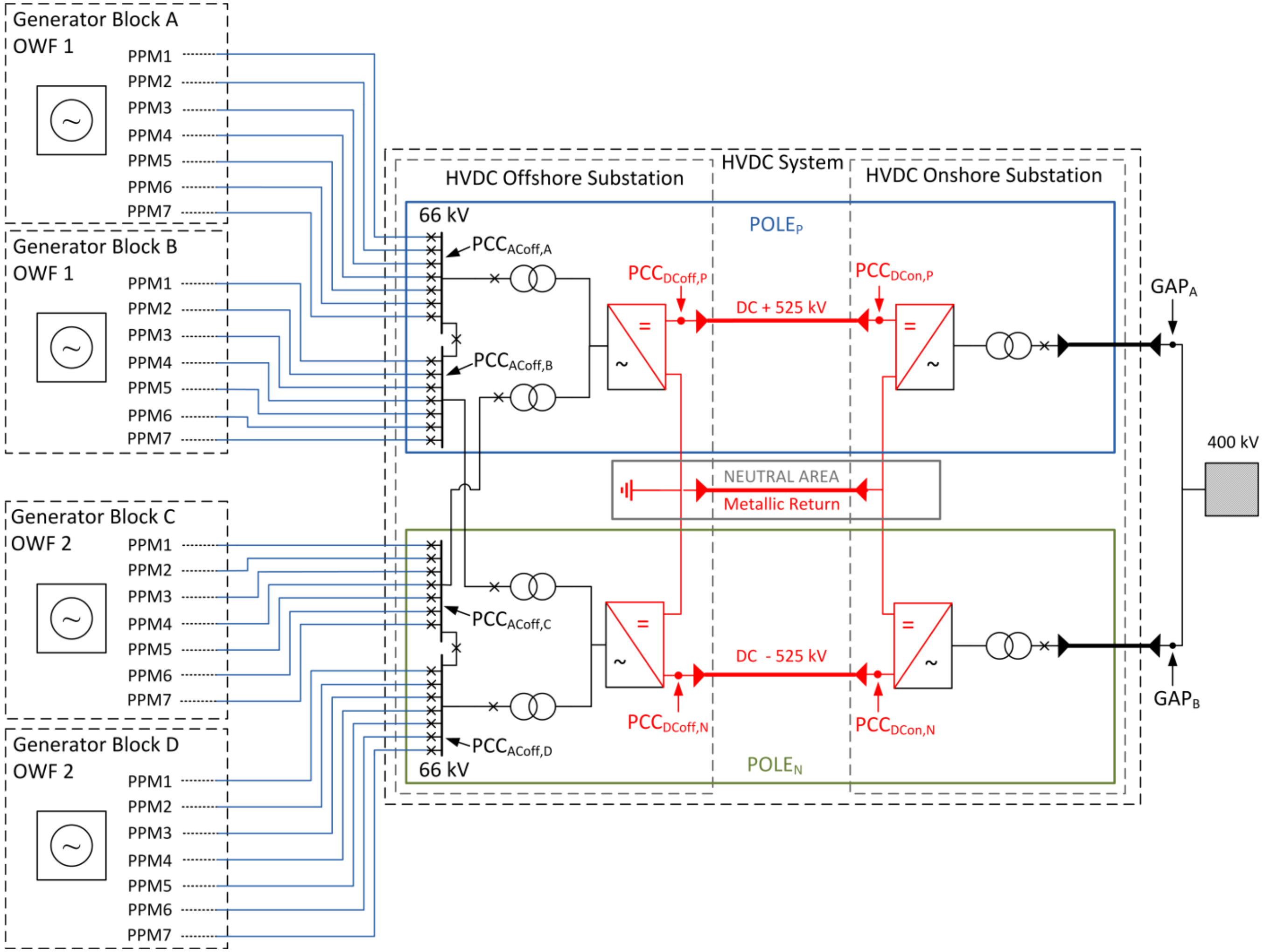
HVDC Offshore Substation

- SF6-free 145kV GIS with double-busbar arrangement
  - 4x6 OWF bays + 4 universal bays
  - 4x2 HVDC transformer bays
  - 2x2 sectionaliser bays
  - 4 AC filter & auxiliary transformer bays
- AIS equipment in all other areas
- ONAN HVDC transformers
- Standing converter valve towers
- Converter cooling based on air coolers
- DC switchyard design fit for MPI operation



HVDC System

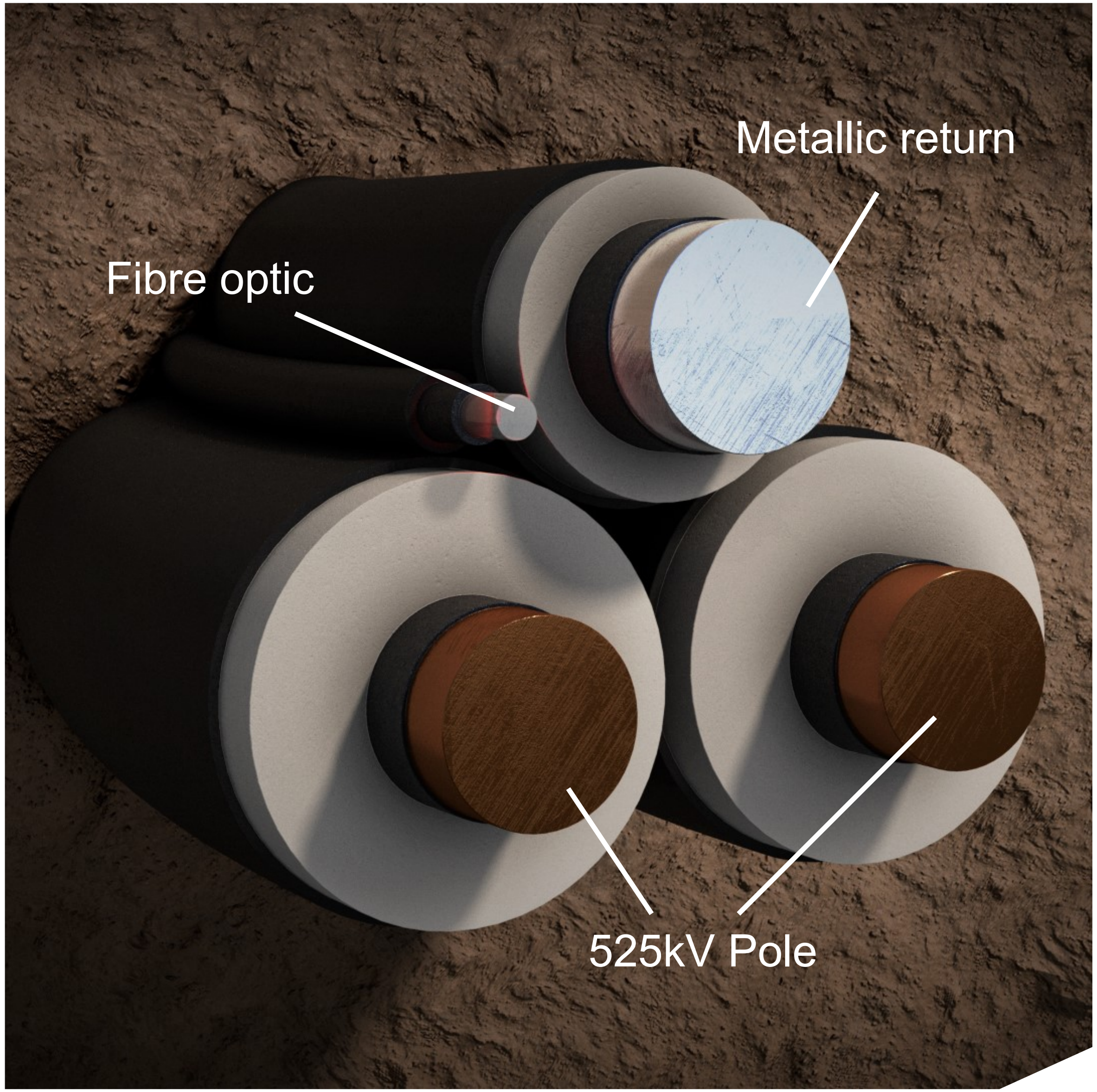
- Bipole with metallic return configuration
- 525 kV nominal voltage
- 4 OWF generator blocks, of 500MW → 2GW transmission
- 4 HVDC offshore transformers
- Offshore AC cross-coupling
- Onshore grid forming features
- Multi-terminal ready (MPI 1.0) with blackstart functionality
- Sophisticated automation system for unmanned operation & remote control



HVDC Cable System

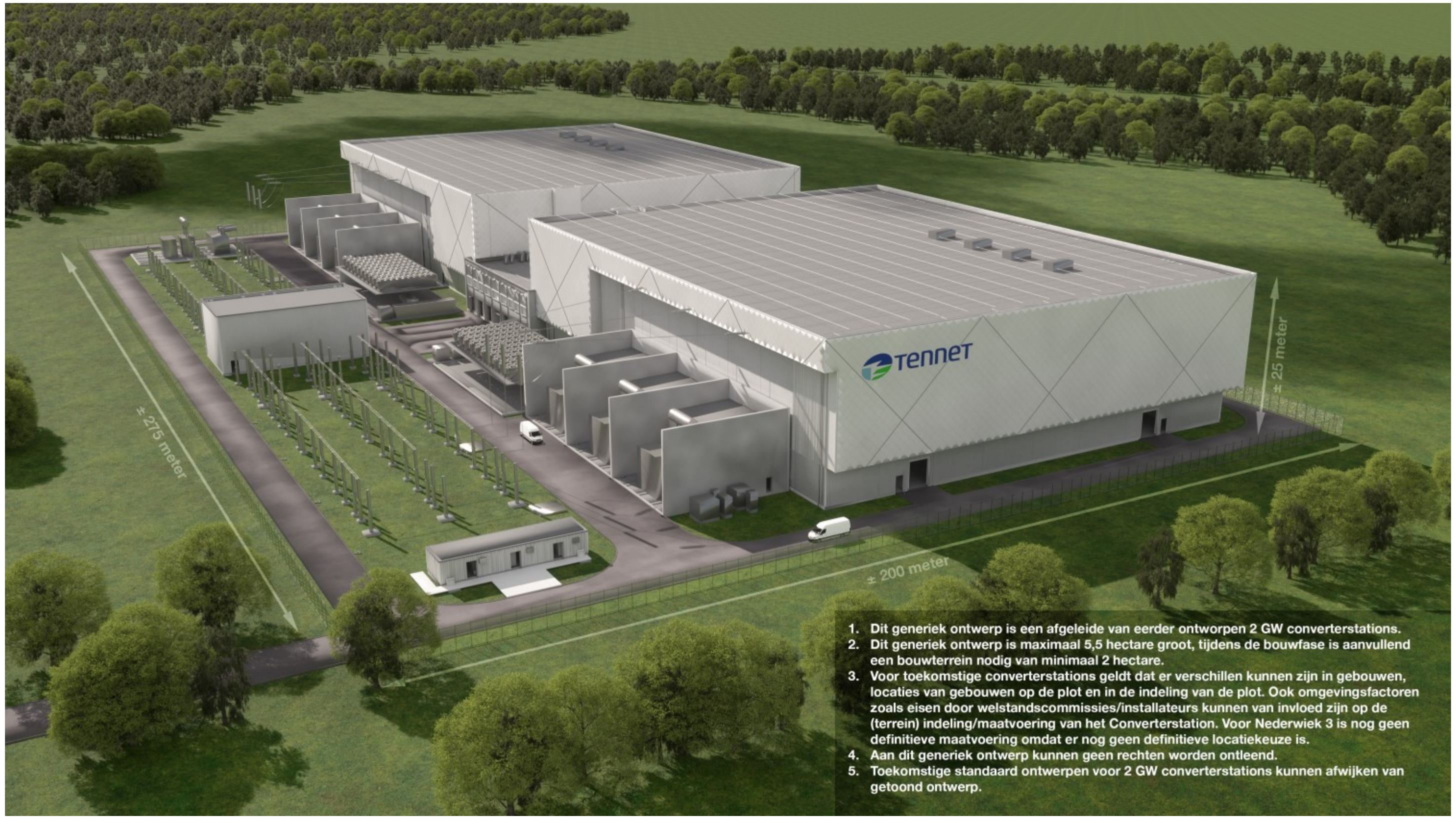
Consists of a bundle of four cables

- 2 X525 kV DC (± poles)
- Dedicated metallic return cable
- Fibre optic cable
- Route lengths 150 – 300 km (excluding MPI)
- Various cross sections depending on location and supplier
  - 2300 mm2 Cu
  - 2500 mm2 Cu
  - 3100 mm2 Al



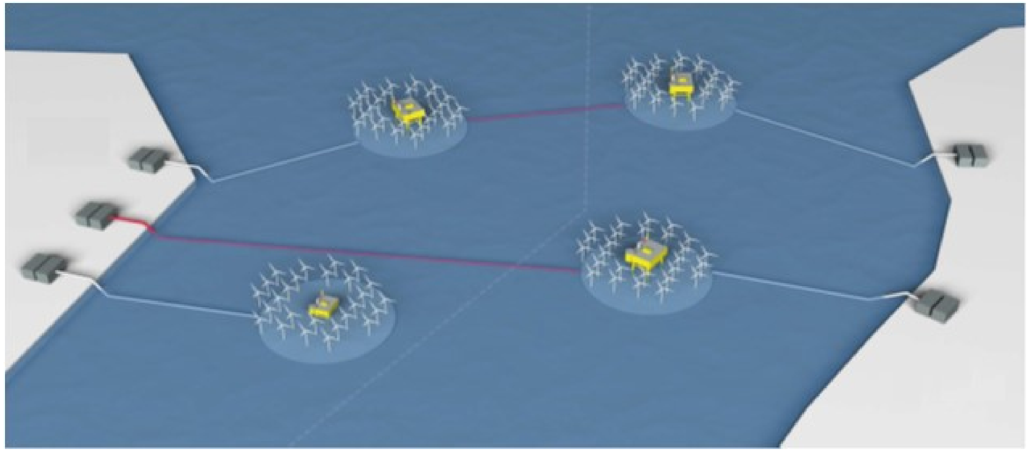
Landstation (HVDC Onshore Substation)

- 2x3 single-phase HVDC transformers + 1 spare
  - Transformer bushings penetrating through converter building walls (docked arrangement)
  - ONAN cooling
- AC Yard outdoor
  - Switchgear & measurement
  - AC cable terminations
  - AC filters
- DC Equipment indoor
  - Converter valves
  - Dynamic braking system
  - Converter reactors
  - DC yard
  - Neutral yard
- Roof-top PV panels as part of Auxiliary Power System



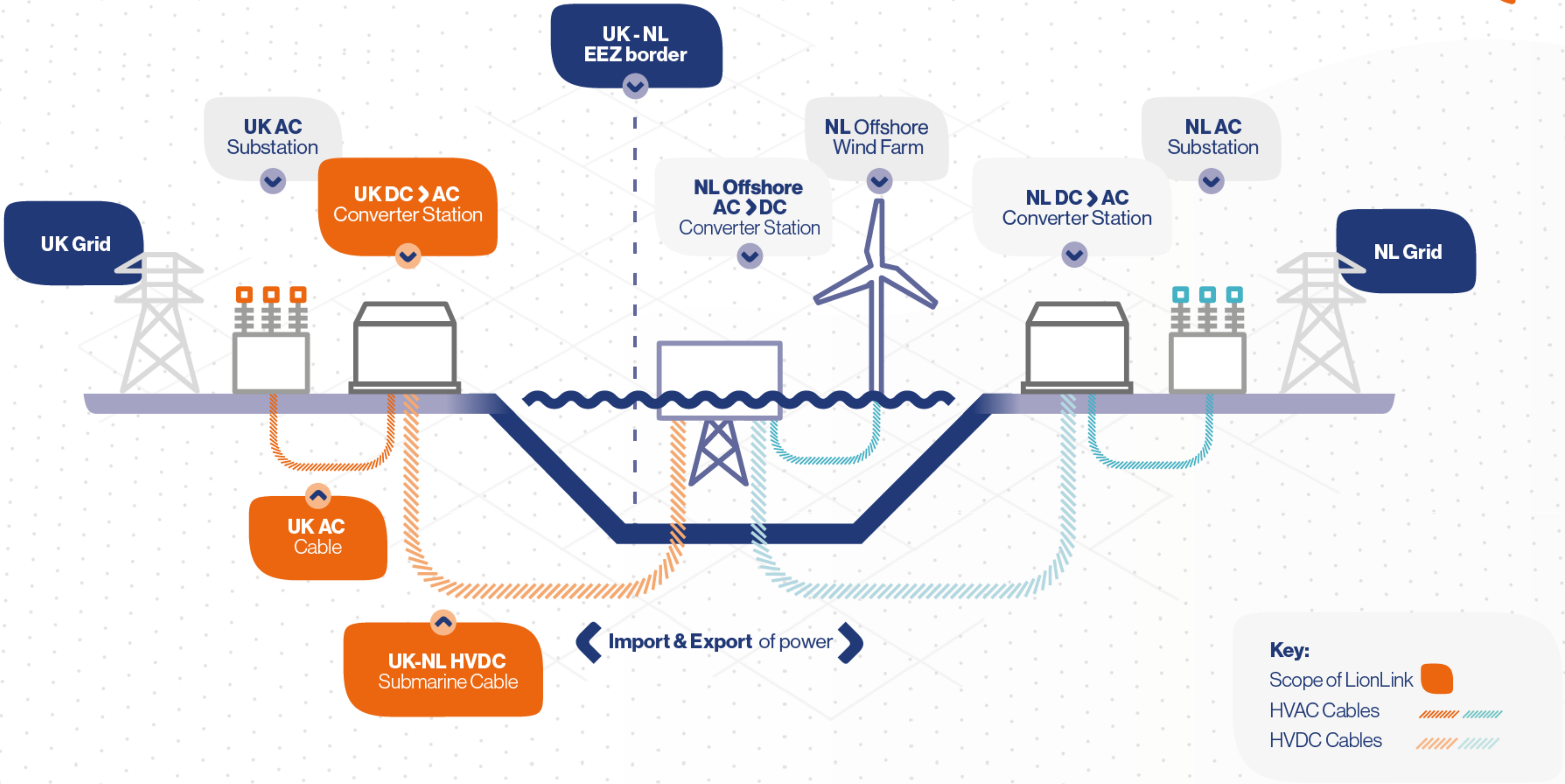
Multi-Terminal Readiness → MPI 1.0

- **M**ulti-**P**urpose **I**nterconnector (MPI) → has the following duties:
  a) Connect synchronous areas or control areas
  b) Connect power park modules to the transmission network
  c) Interface embedded HVDC Systems within one control area
- **MPI 1.0 -** combine duties a) and b); up to 4-terminals



- Impact in project's Design and Testing activities:
  - HVDC Substation design (e.g. space reservation)
  - DC connection requirements
  - MTDC Control functions – Development and testing
  - Black start capabilities

LionLink as first application of MPI 1.0



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TenneT is a leading European grid operator (Transmission System Operator (TSO). We design, build, maintain and operate the high-voltage electricity grid in the Netherlands and large parts of Germany and facilitate the European energy market. We are committed to providing a secure and reliable supply of electricity, today and in the future, 24 hours a day, 365 days a year and to playing our role in driving the energy transition. We transport electricity over a network of approximately 23,500 kilometres of high-voltage connections, from wherever and however it's generated, to over 42 million end-users while keeping electricity supply and demand balanced at all times. With close to 5,000 employees, we achieve a turnover of 4.1 billion euros and a total asset value of EUR 23 billion. TenneT is one of the largest investors in national and international onshore and offshore electricity grids. TenneT makes every effort to meet the needs of society. This will require us all to take ownership, show courage and connect with each other.

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