POSITION PAPER

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1. Background Material

LITERATURE USED:

- [1] IEC 61400-27-1: Electric Simulation Models – Wind Turbines
- [2] Cigre B4.38: Modelling and Simulation Studies to be performed during the lifecycle of HVDC System
- [3] "HVDC compliance verification: Transmission connected demand facilities, transmission connected distribution facilities and distribution systems", version 0.1, valid from 8 September 2019, Netbeher Nederland, found in https://www.netbeheernederland.nl/dossiers/regulering-20/documenten

Field Code Changed

2. Scope and Considerations

For the roadmap offshore wind 2030 (routekaart windenergie op zee 2030) TenneT is tasked with the connection of several offshore wind farms up to 2030. The wind farm zones 'Hollandse kust West' and 'Ten Noorden van de Waddeneilanden' will be connected with TenneT's previously established and consulted standardized 700 MW grid connection concept. Due to its size and distance to shore, a new grid connection concept has been established for the wind farm zone IJmuiden Ver. The figure below shows a schematic cross-section of this new grid connection concept. Wind turbines are connected through 66 kV “inter-array” cables (in orange) to an offshore (HVDC) converter station. Using 2 GW high voltage (525 kV) export cables (in green) the electricity is transported to shore. TenneT will be responsible for the offshore grid, from the onshore substation up to and including, the offshore substation. TenneT intends to create a new standard HVDC grid connection concept for both connections to IJmuiden Ver and potential future far shore wind farms.

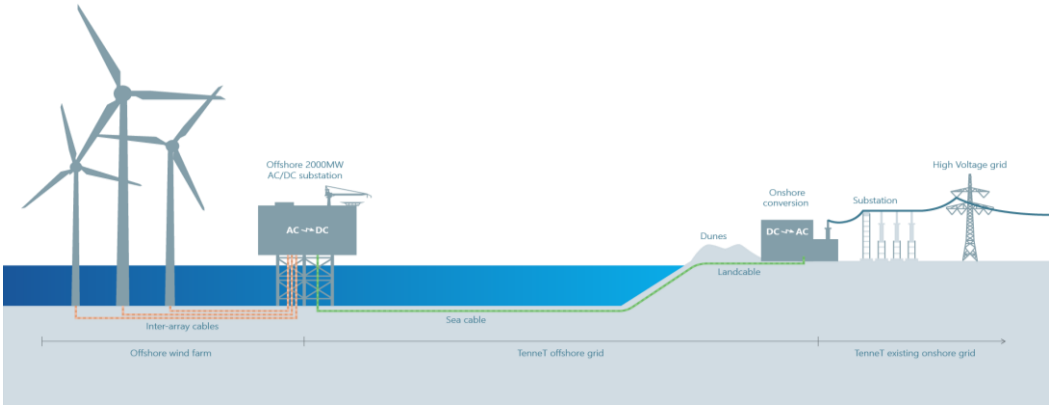

Figure 1 - HVDC grid connection concept

This paper describes how TenneT, as the offshore grid connection owner, proposes to deal with modelling of the Offshore Wind Farms to perform HVDC system studies.

3. OWF Modelling for HVDC System Studies

TenneT has the responsibility to provide relevant OWF data to the HVDC vendor(s) for performing various simulation studies during the engineering, verification and validation phases. This data includes (but is not limited to):

- Wind farm grid configuration and SLD, including:
  - Array cable parameters
  - Transformer parameters
  - Reactive power compensation equipment (if any)
- Wind turbine generators (WTG)
  - Type data and ratings
  - Functional description of the controllers
  - Protection settings
  - WTG simulation models

In case the necessary data is not available in a timely manner, the simulation models are constructed by the HVDC vendor(s), in accordance with the TenneT requirements, using international and national guidelines (IEC, Cigre etc.), generic WTG models, in-house experience and assumptions. Nevertheless, each project has unique features and both the wind farms and the grid connection systems are often tailor-made to optimize the assets. Hence, the correctness of the simulation models is critical.

The paragraphs below summarize the main phases in the construction of the HVDC infrastructure, along with required OWF data, whereas a preliminary planning for IJV-Alpha is given in Table 1. It should be noted that this planning is for indication purposes only and certainly does not imply contractual obligations. The exact dates will be subject to the commercial contracts (ATO/REA). The planning for IJV-Beta will be set accordingly.

3.1 Development Phase

The development phase is defined as the period until the HVDC contract is awarded, which is foreseen to be Q3-2022. The goals of the development phase are to determine the design basis as well as the basic design including the main circuit parameters, operation modes and the basic control functions. It is unlikely that detailed offshore wind farm models will be available during the pre-engineering phase of the project. Therefore, generic OWF models (grid compliant) are used to perform the relevant HVDC studies.

3.2 Detailed Engineering Phase

The detailed engineering phase is defined as the period between the contract award and the off-site commissioning tests, which is expected to take place between Q3-2022 and Q4-2025. During the detailed engineering phase, the HVDC system design is completed and the design parameters of each component

are finalized. The detailed control and protection functions are also determined. In doing so, several studies such as insulation coordination, energization studies, dynamic performance tests, transient stability tests etc. are performed. It is optimal to have an envelope of OWF data available for these tests. If not, boundary conditions such as shortest/longest array cables should be available. This period coincides with the selection of the OWF developer for IJmuiden Ver I and II (OWF tender foreseen in Q4 2023).[1]

3.3 Off-Site Commissioning Tests

In order to verify and validate the proper design and operation of the HVDC system, the full control hardware and software is tested in a real-time simulation environment on the premises of the HVDC vendor, before shipping the equipment to the site. This activity is also known as Factory Acceptance Tests (FAT) and is foreseen to range from Q1-2026 to Q4-2026. It is essential that these tests are performed using the exact OWF data in order to ensure there are no undesired interactions between the HVDC system and the offshore wind farms. Failure to provide the necessary data in a timely manner may lead to re-engineering efforts, potentially delaying the commissioning of the HVDC system.

3.4 On-Site Commissioning Tests

The simulation studies are also performed to support the on-site commissioning tests, also known as Site Acceptance Tests (SAT), in order to determine the appropriate conditions for the tests. In this period, which is expected to take place between Q1-2027 and Q3-2027, the models delivered by the OWFs are compared to the actual conditions on site. Fine-tuning of the models might be required, or even modification of the converter system in case it shows that the models used in the studies and design differ too much from the actual design. Therefore, it is crucial that any deviations in wind farm design are provided in a timely manner.

4. Position TenneT

Above considerations lead TenneT to the following position. However, it must be highlighted that due to the very recent publication of the "HVDC Compliance Verification" policy by Netbeheer Nederland, there may be contradictory descriptions between this position paper and the compliance policy. In that case, the policy shall of course prevail in the relevant parts.

TenneT will not require detailed OWF data to be made available for the studies to be performed during the development phase.

TenneT will require an envelope of the OWF data to be made available for the studies to be performed during the detailed engineering phase.

TenneT will require the detailed OWF data to be made available for the off-site commissioning tests of the HVDC system commences.

[1] Minister of Economic Affairs and Climate, Voortgang uitvoering routekaart 2030, 5 April 2019

TenneT will require the OWF data to be maintained and updated actively during the on-site commissioning tests.

TenneT will add this topic to a list with topics that will require consultation after this round.

5. Appendix

Table 1: Preliminary planning of HVDC system activities and the required OWF Data for IJV-Alpha

Activity	2019				2020				2021				2022				2023				2024				2025				2026				2027			
HVDC Tender													Q1			Q3																				
OWF Tender																				Q4			Q2													
Required OWF Data																																				
Development Phase	Q1												Q2																							
Generic OWF Models (No specific OWF data)																																				
Detailed Engineering - Phase 1															Q3								Q2													
Generic OWF Models (No specific OWF data)																																				
Detailed Engineering - Phase 2																						Q3							Q4							
Preliminary single line diagram (SLD)																																				
Envelope of electrical data																																				
Envelope of ratings of the main components																																				
Preliminary protection concept																																				
Preliminary auxiliary power concept																																				
Concept for realizing automatic system functions																																				
Off-Site Commissioning																													Q1			Q4				
Detailed single line diagram (SLD)																																				
Detailed electrical data																																				
Ratings of the main components																																				
Detailed protection design																																				
Detaled auxiliary power design																																				
Detailed design of automatic system functions																																				
Dynamic behaviour																																				
Harmonic behaviour																																				
On-Site Commissioning																																	Q1		Q3	
Actual single line diagram																																				
Actual electical data																																				
Actual ratings of the main components																																				
Actual protection design and parameters																																				
Actual auxiliary power system																																				
Actual parameters of automatic system functions																																				
Actual harmonic behaviour																																				