POSITION PAPER

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1. Background material

Literature used:
• "Harmonic emission limits for system users connected to the onshore and the offshore transmission system of TenneT"

2. Scope and considerations

Figure 1 shows the connection of an offshore wind farm to the onshore electricity grid. TenneT will supply and install the grid connection up to, and including, the offshore substation. The wind park, including the wind turbines and the array cables, up to the offshore Connection Point (CP)[1] at the switchgear installation on the offshore substation of TenneT, is to be supplied and installed by the owner of the Power Park Module (PPM[2]).

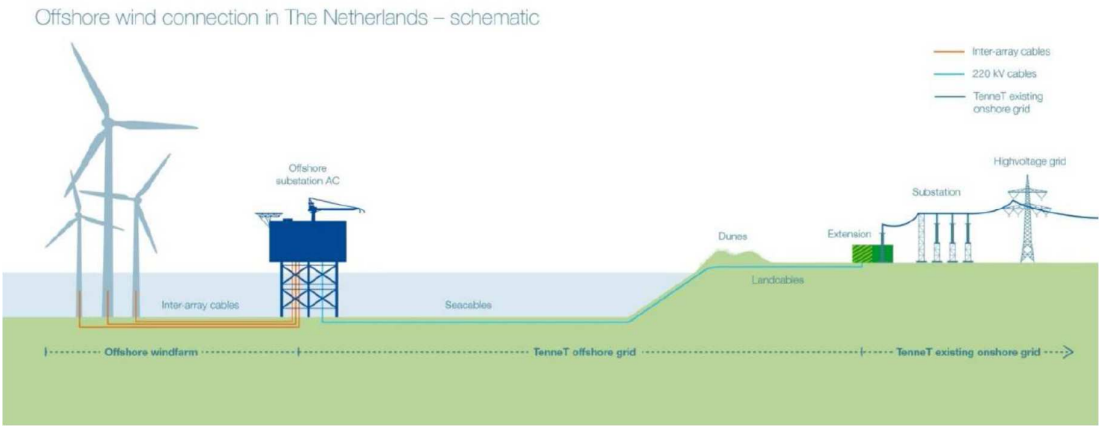

Figure 1 - Schematic of the offshore electrical grid. Source: TenneT

Each inter array cable string connects a number of turbines of a PPM to the offshore substation. TenneT intends to standardise the offshore substations as much as possible for all five wind areas to be realised in the coming years in line with the Energy Agreement. This paper describes the harmonic emission limits for connected Power Park Modules connected to TenneT offshore grid.

General

The Energy Agreement requires a 40% cost reduction for offshore wind to be realised over the period 2014-2024. Realisation of this cost reduction is expected to require a combination of measures[3], including - but not

[1] The connection point (CP) between the offshore power park module (PPM) and TenneT is specified [Ref: position paper T3] at the cable termination of the inter-array cables and the switchgear installation on the platform.
[2] Ref: position paper T3
[3] http://tki-windopzee.nl/files/2015-01/20141124_TKI_Roadmap.2015-2020_EZU_F%20(1).pdf

limited to standardisation of the offshore electrical infrastructure and larger capacity wind turbines within larger wind farms. TenneT contributes to this overall cost reduction target, through a strategic long term vision on the development of the offshore grid, focussing on the initial investments, but certainly also on operational expenses during the lifetime of its grid connections.

Technical

This position paper focuses on the requirements for connection of PPMs to the TenneT offshore substation with respect to the harmonic emission limits. To ensure a proper operation of the PPM and the TenneT offshore and onshore grid, attention shall be paid to the following topics:

1) The offshore PPM shall not exceed the harmonic emission limits as specified by TenneT
2) The connection of the TenneT offshore grid, including the offshore installation of the PPMs, to the onshore grid shall have no impact on the harmonic amplification.

At first instance TenneT will define the planning levels of the harmonic current emission limits at 66 kV level, which will be further appointed to the individual connected parties based on their rated power of the offshore connection. The connected parties shall respect the defined acceptable Total Harmonic Distortion level at their 66 kV grid connection. All connected parties shall in principle take measures to fulfil the requirements.

However, there is no possibility to install additional equipment at the platform of TenneT, needed to the improve the harmonic performance of the OWF installation, it is proposed to install the necessary measures (for instance active filter equipment) at the onshore substation at 33 kV level (tertiary winding 380/220/33 kV transformer). This implies that the PQ performance of the OWF will also be assessed onshore.

The second issue, regarding the harmonic amplification will be dealt with by TenneT. TenneT will take the responsibility to undo the impact of the total offshore grid (export cabling and inter array cabling) to the onshore grid with respect to the harmonic amplification.

Studies

To investigate the impact of the total offshore installation to the onshore grid, and to investigate the impact of the export installation to the emitted harmonics at 66 kV, further detailed analysis is needed.

However, at this moment there is insufficient detailed information available to perform these studies to the harmonic system performance, with sufficient profundity, which can be used to determine the necessity and specifications of any needed measures to reach the harmonic acceptance level.

In general, each OWF is connected to the onshore grid via a separate transformer, which simplifies the analysis and assessment of the harmonic distortion. During outage of an onshore transformer, OWFs might be connected offshore and behave differently (detuned) with respect to the harmonic distortion. The impact and possible solutions shall be investigated.

Because the Offshore PPM installation consists of several physical cable connections, the harmonic

distortion caused by the OWF will be evaluated and assessed for different grid topologies.

It shall be acknowledged by all parties that necessary information for these studies shall be made available and shared without restrictions.

3. Position TenneT on Harmonic emission limits

Above considerations lead TenneT to the following position:

It is the responsibility of each connected party to fulfil the requirements with respect to the harmonic distortion. TenneT will specify the maximum allowed harmonic distortion (for instance by specifying the maximum emission level of individual harmonic currents) at the 66 kV level and the maximum allowed impact on the onshore grid. If more than one OWF is connected to one single 66 kV bus bar, the emission planning level will be distributed proportional to the rated power of each connected party.

The necessary measures to be taken by the OWF to fulfil the requirements with respect to the harmonic distortion, are the responsibility of the OWF. Regarding the thoughts of lowest LCOE, at first instance, measures to fulfil the requirements shall be installed onshore instead of offshore.

TenneT will take the responsibility to investigate and specify the needed measures to make sure that at the onshore connection point there is no harmonic amplification caused by the offshore installation of TenneT and the installation of all connected OWFs.

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4. Topic consultation

The expert meeting of 25 September 2015 gives TenneT the opportunity to get feedback from developers on their position regarding "Harmonic emission limits".