POSITION PAPER

STAKEHOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
Type:	Position paper
Work Stream:	Technical
Topic:	T03 - Reactive Power Strategy
Filename:	ONL TTB-05416
Version:	2.0
Pages:	7 pages

QUALITY CONTROL	
Prepared:	AMO
Reviewed:	AMO / NLO-OD / BLIX
Approved:	Consultation Board
Release:	BLIX

Table of Contents

1. Background Material

LITERATURE USED:
• HVDC grid code: "COMMISSION REGULATION (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules"
• TenneT position paper: TTB-05417_T07_Voltage Level and Frequency v1.0
• TenneT position paper: TTB-05418_T08_Point of Common Coupling and Grid Connection Point v1.0

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.

This paper describes how TenneT, as the offshore grid connection owner, proposes to deal with the reactive power support of the offshore AC grid.

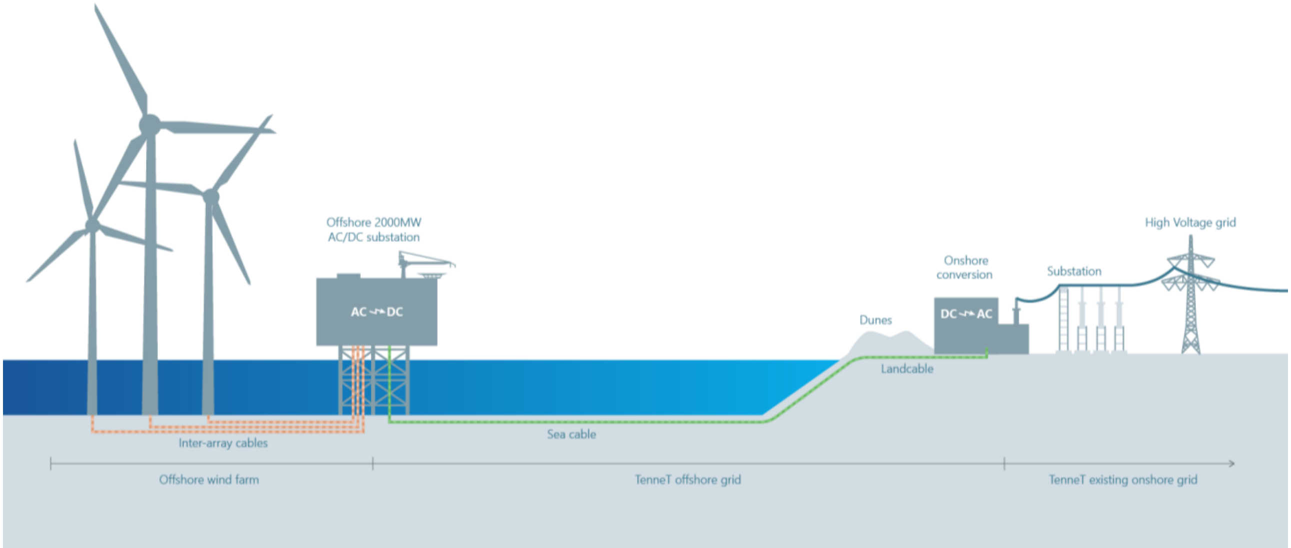

Figure 1 - HVDC grid connection concept

3. Reactive Power Strategy

The main objective for the overall design is to minimize the levelized cost of electricity over the asset lifetime, TenneT has evaluated several alternatives for the selection of the optimum reactive power support strategy. This section presents an overview of the arguments to establish TenneT's position.

3.1 Sources of Reactive Power at the Offshore AC Grid

3.1.1 Passive Components

The main sources of the passive capacitive reactive power (reactive power generation) at the offshore AC grid are the 66kV infield cables. For the IJmuiden Ver project, this is expected to be around 0.075 p.u. per wind farm, at the wind farm's power base. The amount of the generated reactive power is proportional to the square of the operating voltage magnitude of the offshore AC grid.

Due to the direct link concept, there is no additional transformer in the offshore AC grid besides the WTG transformers and the HVDC converter transformers. Therefore the leakage reactances of these elements form the main source of passive inductive reactive power (reactive power absorption). The amount of the reactive power absorption is proportional to the square of the current flow magnitude through the transformer.

3.1.2 Active Components

According to the HVDC grid code, from a compliance point of view, each offshore HVDC converter and each DC-connected power park module (PPM) shall be capable of providing the following voltage – reactive power profile:

- Capacitive reactive power between 0.0 – 0.14 p.u. in the voltage range of 0.9 – 1.05 p.u.
- Capacitive reactive power of 0.0 p.u. at the voltage of 1.1 p.u.
- Capacitive reactive power limited linearly between 0.0 – 0.14 p.u. in the voltage range of 1.05 – 1.1 p.u.
- Inductive reactive power between 0.0 – 0.14 p.u. in the voltage range of 0.95 – 1.1 p.u.
- Inductive reactive power of 0.0 p.u. at the voltage of 0.9 p.u.
- Inductive reactive power limited linearly between 0.0 – 0.14 p.u. in the voltage range of 0.9 – 0.95 p.u.

For the offshore HVDC converters, above requirements shall be fulfilled at the point of common coupling (PCC). For the PPMs, above requirements shall be fulfilled at the grid connection point (GCP). The definitions of PCC and GCP are stated in the position paper *"T08 - Point of Common Coupling and Grid Connection Point".* The visual representation of the voltage – reactive power profile is given in Figure 2.

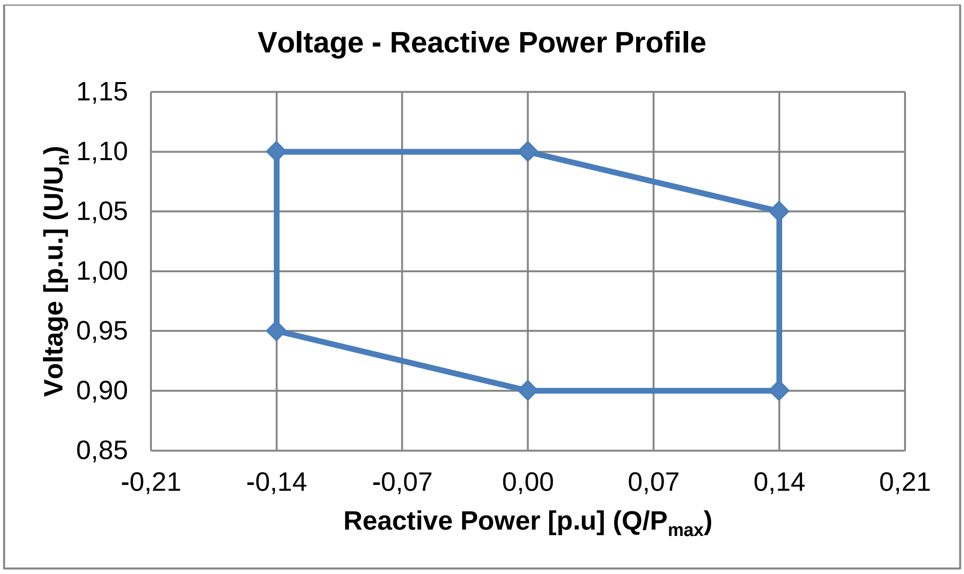

Figure 2: Voltage – reactive power profile according to the HVDC grid code

3.2 Options for Reactive Power Compensation

This section describes the operational strategy only. The compliance activities shall be based on the HVDC grid code.

3.2.1 Full Compensation by the HVDC Converters

This strategy requires the HVDC converters to fully compensate the reactive power of the offshore AC grid. It means that the HVDC converters will operate at a higher current duty compared to the other options, hence increasing the transmission losses in the grid connection system. Thereby, this approach results in additional operational costs to TenneT.

It is intended that the WTGs shall operate at zero reactive power exchange at their own terminals within this strategy. WTGs shall not generate or absorb reactive power in order to optimize the grid losses, unless ordered by TenneT.

3.2.2 Zero Reactive Power Exchange at the GCPs

This strategy requires the PPMs to achieve zero reactive power exchange at their GCPs. As a consequence, the reactive power exchange at the PCC is also zero and there is no burden on the HVDC converter. On the other hand, this strategy puts stringent requirements on the string level and does not provide any room for optimization and co-ordination between the individual strings.

3.2.3 Zero Reactive Power Exchange at the PCCs

This strategy requires the PPMs to achieve zero reactive power exchange at the PCC that they are connected to. In other words, the reactive power exchanges at the GCPs may be non-zero, but their summation at the 66 kV PCC should be zero. Thereby the HVDC converters will also provide zero reactive power at the PCC.

Through flexibility and coordination between the individual strings, this strategy allows the wind farm operators to optimize their assets and operations without incurring extra costs to TenneT. Nevertheless, this strategy requires a breakdown of the reactive power orders to the GCP level in case there are multiple entities connected to the same PCC. This can be achieved by the exemplary control structure given in Figure 3.

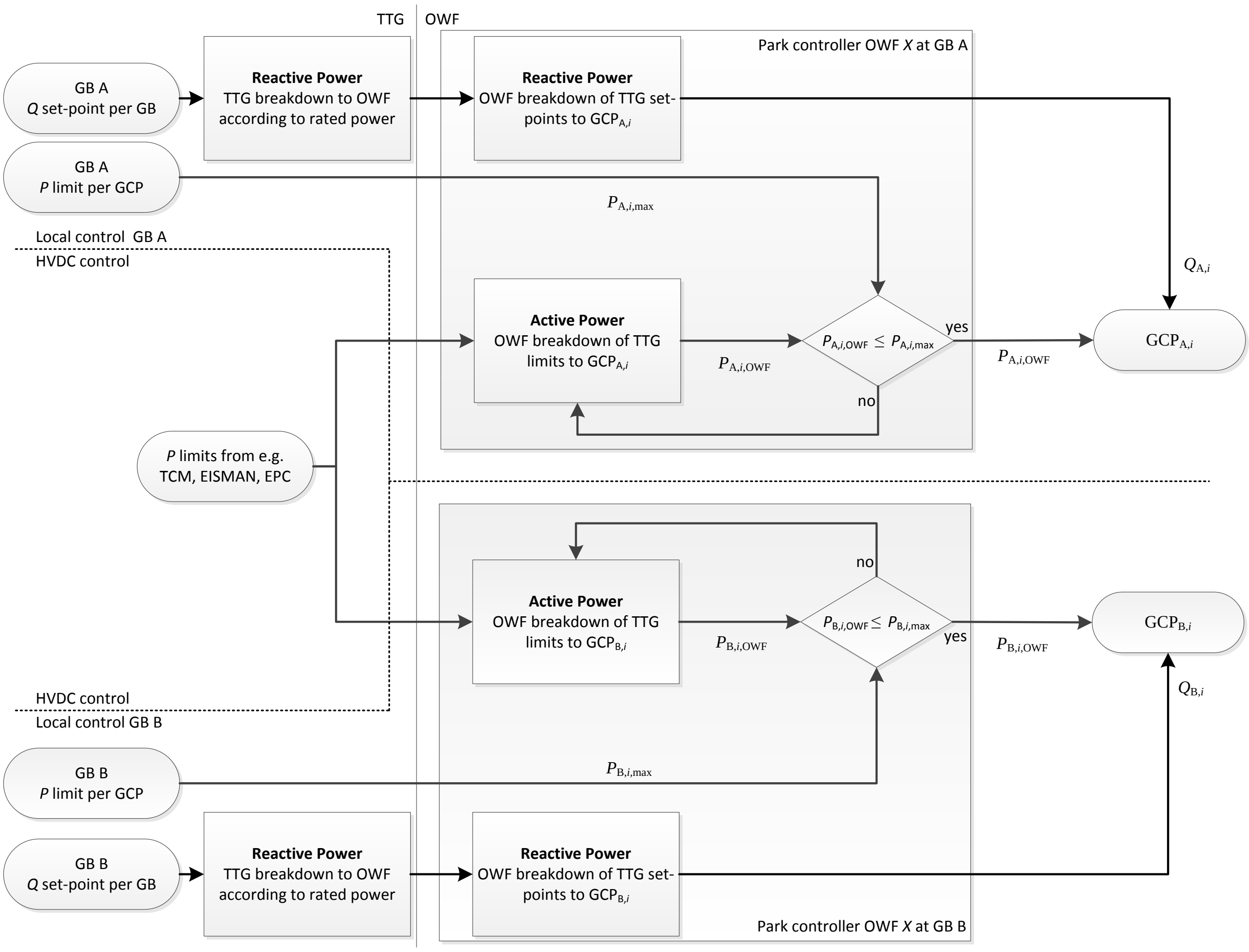

Figure 3: Control structure for the breakdown of the reactive power orders

3.3 Reactive Power Compensation during No Wind Production

When there is no wind production, the active power losses of the offshore grid are supplied by the HVDC system. Although the WTGs may still be able to provide reactive power, from a loss perspective this may not be the optimum solution in terms of the LCoE. As a result, the HVDC converters can take the responsibility of compensation of the offshore reactive power within their capabilities. Given the reactive power sources at the offshore grid, it is intended that the wind farms will be allowed to exchange reactive power up to 10% (between -0.1 p.u. and 0.1 p.u.) of the agreed connection capacity with regards to the active power. The allowance will be applied at the PCCs. In case there are multiple entities connected to the same PCC, the breakdown of the allowance will be proportional to the active power capacity.

3.4 Reactive Power (Voltage) Control Modes

According to the HVDC grid code, the requirements applicable to offshore power park modules under Articles 13 to 22 of Regulation (EU) 2016/631 shall apply to DC-connected power park modules subject to specific requirements provided for in Articles 41 to 45 of the HVDC grid code. Consequently, type D power park modules shall be capable of providing reactive power automatically by either voltage control mode, reactive power control mode or power factor control mode. The voltage control mode is further elaborated as being capable of exchanging reactive power at the connection point via set point value within the continuous operating voltage range supplemented with a counter-intuitive droop value, which may also be known as "Dynamic Voltage Control".

Although the wind farms need to demonstrate such capability for the compliance purposes, TenneT will use the capability of the offshore HVDC converters to exclusively control the offshore AC voltage. Hence, TenneT will not exercise the voltage control mode or the power factor control mode. TenneT will only exercise the reactive power control mode.

4. Position TenneT

Above considerations lead TenneT to the following position:

TenneT intends to reserve reactive power compensation capability for the offshore grid using only the inherent capabilities of the converters.

TenneT does not intend to install any additional equipment on the offshore grid or to allow PPMs to install their own equipment on the platform for the reactive power compensation purposes.

TenneT intends to select the *"Zero Reactive Power Exchange at the PCCs"* option for the offshore reactive power strategy.

TenneT intends to allow reactive power exchange up 10% (between -0.1 p.u. and 0.1 p.u.) of the agreed connection capacity with regards to the active power, at the PCCs, in case there is no wind production.

TenneT intends to exercise only the "Reactive power control mode" functionality by the wind farms.
