POSITION
PAPER

STAKE HOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
Type:	Position paper
Work stream	Technical
Topic:	T.11 Overplanting
Filename	ONL 15-083-T11_Overplanting_PP_v1
Version	1 Public release
Pages	6

QUALITY CONTROL		
Prepared:	Team TenneT	
Reviewed:	Michiel Müller	08.04.2015
Approved:	Frank Wester	10.04.2015
Release		

Table of Contents

1. BACKGROUND MATERIAL **2**

2. SCOPE AND CONSIDERATIONS **2**

Overplanting *2*

3. ACTIVE POWER TRANSFER THROUGH THE TENNET OFFSHORE GRID **4**

3.1 Export cable design (220kV) 4

4. POSITION OF TENNET **5**

5. IMPACT ON COST **6**

6. TOPIC CONSULTATION **6**

1. Background material

Literature used:
• N.A.

2. Scope and considerations

The ***Figure 1*** below shows a schematic cross section of the connection of an offshore wind farm to the onshore electricity grid. Wind turbines are connected through “inter-array” cables (in orange) to the offshore Connection Point (CP)[1] at the offshore substation, from which electricity is transported to shore. TenneT is responsible for the grid connection up to, and including, the offshore substation and will take care for the supply and installation.

The wind park, including the wind turbines and the array cables, up to the offshore CP 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]).

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.

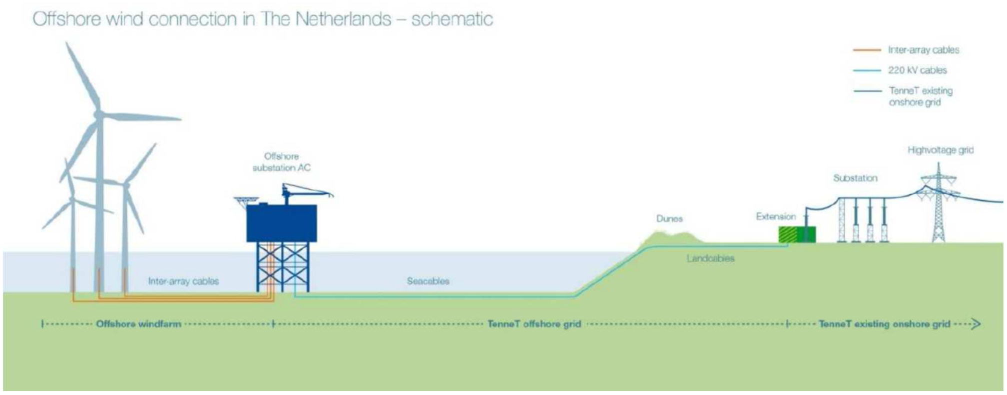

Figure 1 - Schematic of the offshore electrical grid. Source: TenneT

Overplanting

An important aspect in the design of an offshore wind farm, is to optimise the offshore wind farm capacity (type and number of wind turbine generators) to the fixed electrical infrastructure export capacity. This

[1] The connection point (CP) between the offshore power park module (PPM) and TenneT is specified [TenneT position paper ONL 15-061 T.3 Point of Common Coupling] at the cable termination of the inter-array cables and the switchgear installation on the platform.

[2] TenneT, position paper ONL 15-079 T.5 Operation of Bays

principle is also referred to as overplanting or overbooking since it usually leads to installing a (small) number of extra wind turbine generators compared to the grid connection capacity limit[3]. The "overplanted" power from these extra turbines will result in higher energy yield at lower wind speeds but will lead to a curtailed power at higher wind speeds as depicted in ***Figure 2***. Off course, the extra turbines will result in higher CAPEX, which should be balanced by extra revenues from the extra energy yield.

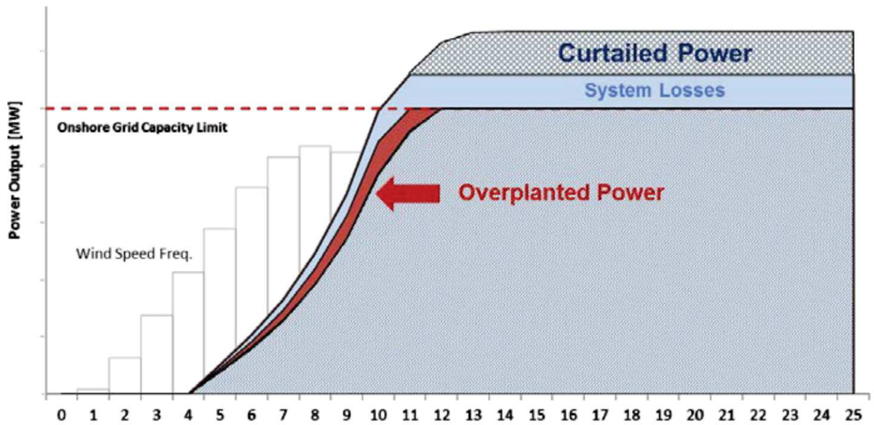

Figure 2 - Principal of Capacity Optimisation. Source: Global Offshore Wind Conference 2014.

To be able to further optimise the PPM lay-out (location, type and number of wind turbine generators), it is necessary for the PPM owner not only to know to what to extent the grid connection may be continuously loaded (e.g. the grid capacity limit) but also to what extent the grid connection may be (temporary) loaded above this capacity limit. In this way, the curtailed power is reduced and the energy yield is increased further.

This paper describes the position of TenneT with respect to the extent to which the offshore grid (see ***Figure 1***) may be loaded more than the rated power at CP and under which conditions. As the limiting factor in the offshore grid is the 220 kV export cable from the offshore substation up to and including the beach landing, this paper will mainly focus on these cables.

[3] Money does grow on turbines – Overplanting Offshore Windfarms, Andrew Henderson a.o., Global Offshore Wind Conference 2014

3. Active power transfer through the TenneT offshore grid

The offshore grid design will be based on the parameters as listed in ***Table 1***.

Table 1 - TenneT NL offshore grid parameters

Grid parameter	Value
Grid capacity per PPM at offshore CP:	350MW
Number of PPM per offshore platform:	2
Reactive power exchange at CP under normal conditions:	Max +/- 0,1 p.u. (+/- 35 Mvar)
Nominal voltage level onshore / offshore:	225 / 230kV +/- 1%

To determine if more than 700MW (2 * 350MW) of active power (P) can be transferred through the offshore grid, TenneT makes an assessment of the capability of the 220 kV export cables (next paragraph) based on the parameters shown above. If there is additional capacity found in the design which allows the 220 kV export cables to transfer more than 700MW of active power, TenneT will assure that other grid components will also be capable to transfer this extra power.

This is also applicable for land cables. It is assumed by TenneT at this moment that permissible dynamic loading conditions of the land cables will be similar or better than the loading conditions found for 220 kV export cables.

According to RfG, PPMs will be required to contribute to the primary voltage regulation with more reactive power than shown in ***Table 1***. It is assumed that these circumstances (Q > 35Mvar or Q < -35Mvar) will be limited in time and therefore will not significantly influence the thermal loading of the cables.

3.1 Export cable design (220kV)

A preliminary 220 kV export cable design study was commissioned by TenneT for a capacity of 700MW in steady state condition according to the IEC 60287. Although the exact soil conditions are not yet known, the results of this design show that under a wide range of the thermal resistivity of the soil, typical cable designs are available.

Furthermore, within this study dynamic load calculations on the 220 kV export cables have been performed using actual wind data over a measuring period of three and a half years. The calculations have been used to assess possibilities for optimisation of cable dimensioning. The calculations are based on various cable types (variation in conductor type and cross section), a range of thermal resistivity values of the soil and two different installation locations (near offshore platform at one meter under seabed and near shore at three meters under seabed).

The results of the dynamic load calculations show that for an optimized cable design (at 700MW design capacity), the transmission of 10% additional active power is allowable, but not guaranteed, provided the following conditions are met:

- Voltage at nominal voltage as defined in ***Table 1***;
- Soil resistivity over the whole trajectory 0,7 K.m/W as a maximum

Simulation results show that on a few occasions the maximum allowable conductor temperature would be exceeded and curtailment is necessary (provided that all wind turbine generators are in operation). These results are shown in ***Figure 3***. Further analysis of these results show that from the 30.000 simulated hours, the conductor temperature is 643 hours above 90 °C (2,14%).

A more detailed forecast on risk of curtailment will be made by TenneT when soil conditions are known and the basic design of the cable is available.

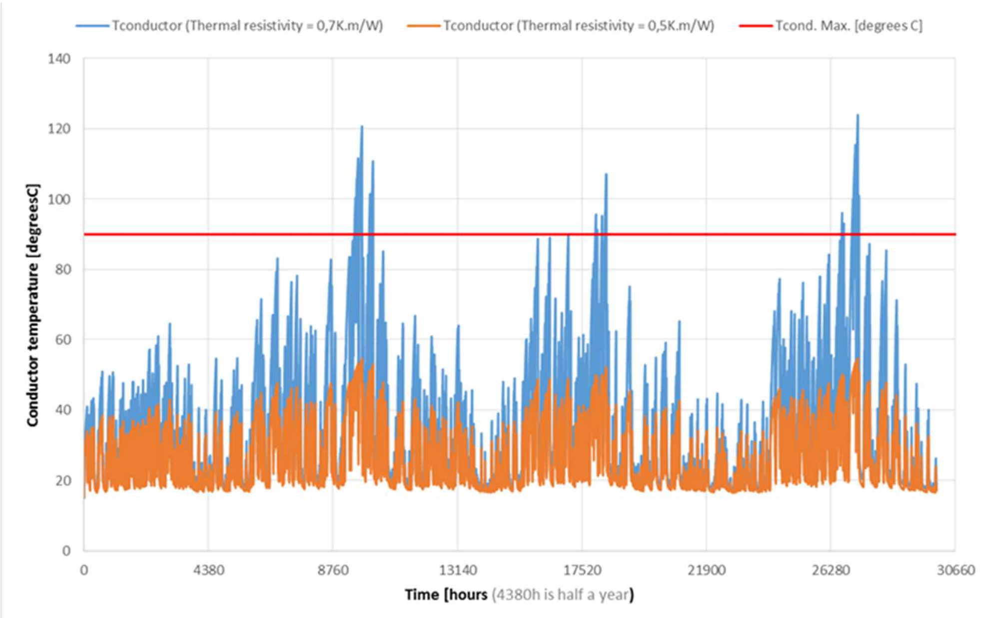

Figure 3 - Thermal behaviour of one of the 220 kV export cables (preliminary design) at two thermal resistivity values at the beach with a wind farm installed power of 770MW.

4. Position of TenneT

Above considerations lead TenneT to the following position:

TenneT is inclined towards allowing the PPMs to transmit 10% above their rated power (350MW), which is 35MW extra, with the requirement for PPM's to curtail their produced power, in case the 220 kV export cables reach their maximum allowable temperature limits[4]. Details on curtailment of the PPMs will be addressed to in the 'Customer Connection Agreements (ATO)'.

[4] Operational limits of sea and land cables will be monitored continuously by temperature sensing systems.

5. Impact on cost

At this point in time the impact on costs cannot be analysed quantitatively, as this requires detailed knowledge (assumptions) on both wind farm layout, turbine choice and dynamic loading strategies.

6. Topic consultation

The expert meeting of 15-16 April, 2015 gives TenneT the opportunity to get feedback from developers on their position regarding overplanting. The main goal of this meeting will be to assess whether TenneT's views as documented within this position paper, and background data above, are shared by the industry.