TenneT
Taking power further

POSITION
PAPER

STAKE HOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
Type:	Position paper
Work stream	Technical
Topic:	T.12 Redundancy & availability
Filename	ONL 15-216-T12_Redudancy_availability_PP_v1
Version	1 - Public release
Pages	6

QUALITY CONTROL		
Prepared:	TenneT team	
Reviewed:	M. Müller	17.06.2015
Approved:	F. Wester	18.06.2015
Release	**Public**	

Table of Contents

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 transmission grid as much as possible for all five wind areas to be realised in the coming years in line with the Energy Agreement.

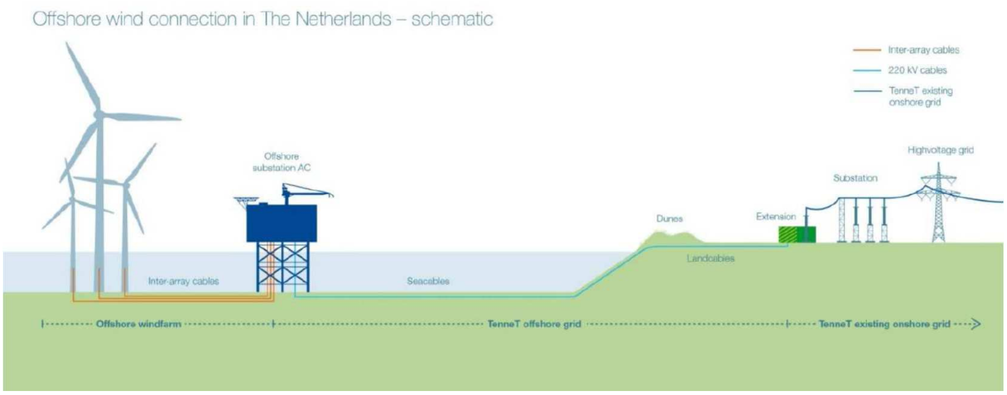

Figure 1 - Schematic of the offshore electrical grid. Source: TenneT

The standardisation process of the TenneT offshore grid included an assessment of various grid topologies where the level of redundancy was increased from the base case (no redundancy) to a topology with maximum redundancy. With the increase of redundancy both capital expenditures (CAPEX) as well as availability increases. The goal of the assessment was to find the optimal topology in this regard.

---

[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

This position paper gives a summary on this assessment and is structured as follows:

- Assessment structure and base assumptions
- Overview of assessed topologies
- Results of the comparison and position of TenneT

3. Assessment

3.1 Assessment structure and base assumptions

Assessment structure

At first the base case topology was determined on the minimum amount of required components and no redundancy at all. This leads to the lowest CAPEX but also to the lowest availability. This topology is shown in Figure 2.

Secondly, the other topologies were determined by adding or increasing:

- Coupling (at 33kV/66kV, offshore 220kV, onshore 220kV)
- Transformer capacity (50% versus 70% offshore and 100% onshore)
- # of offshore transformers (2 x 50% or 3 x 33%)

Finally for each topology the following was determined:

- the availability of the offshore grid (average time of outage per year) evaluating failure statistics of the major components;
- the net present value of the (average) loss of income due to loss of (half or the full) connection;
- the additional savings of the increase of redundancy (compared to the base case) and if these savings justify the additional CAPEX.

Base assumptions

Following assumptions have been used in the calculations of availability and loss of income:

- A typical offshore wind farm performance curve was used as input for the generated power with an overall increase of generated power of 20% to cater for future efficiency improvements;
- Failure rates of the grid components and MTTR rates were selected based on internal figures and literature (Cigré);
- Loss of income was determined with a price per MWh in a range of €20 - €120 which was used for a sensitivity analysis;
- For determining the net present value of the average loss of income, an interest rate of 5,6% (WACC or hurdle rate) over a period of 20 years was used;
- The amount of export cables is fixed (two export cables per platform with 50% steady state rating and possibility of dynamic temperature rating[3]);

[3] For the total active power which can be transferred by the offshore grid and in particular the export cables, reference is made to [TenneT, position paper ONL 15-083 T.11 Overplanting]

- The offshore grid which is being assessed consists of the 66 kV switchgear up to and including the 380 kV feeders at the onshore substation;
- A failure of one of the reactors will not lead to a decrease of the rating of the offshore grid and therefore the reactors were not taken into account in this assessment.

3.2 Topologies

In Figure 2 the base case topology is depicted. The offshore wind farms (OWF) are connected to four sections of 66kV switchgear which again are connected to two 220kV / 66kV transformers capable of transferring 50% of the total active power which can be transferred by the offshore grid[3].

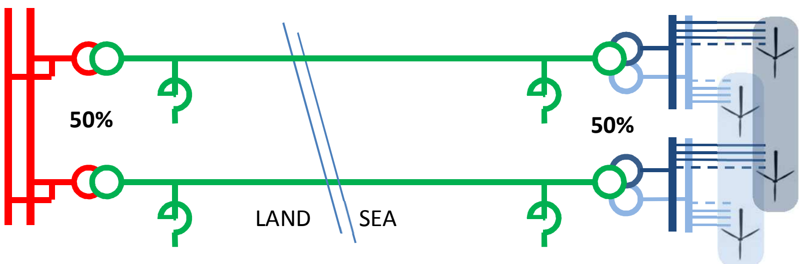

Figure 2 - Base case topology with no coupling

The other topologies are shown in Figure 3 where for each consecutive topology, redundancy is further increased except for option 5, which is similar to option 3, but with three transformers (with a single 66 kV winding) on the offshore platform instead of two transformers (with a double 66 kV winding).

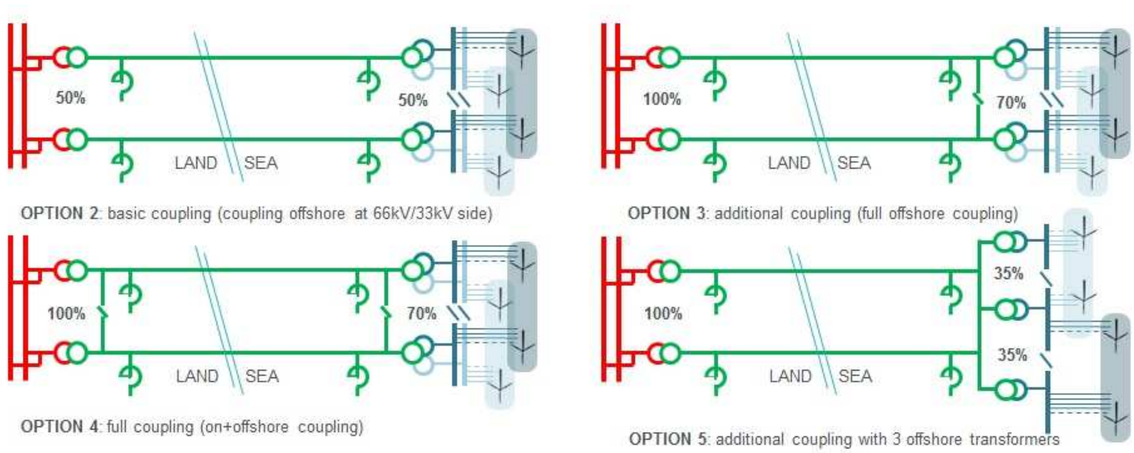

Figure 3 - Topologies with increased redundancy: options 2 to 5

3.3 Results

The base case topology leads to an average availability of energy at the 380 kV onshore grid of 98,7%[4]. The components which have a significant impact on this figure are the offshore transformers, export cables and onshore transformers.

Option 2 (adding coupling at 66kV side) leads to an increase of availability of 0,4% to 99,1%. Due to the coupling, production of the OWF up to 50% will not be affected by an outage of one of the offshore grid components. This increase of availability leads to significant cost savings over the 20 years of operation which justifies the additional CAPEX of the 66 kV coupling.

Options 3 to 5 lead to a further increase of availability of 0,1% to 0,3%. However, in TenneT's assessment, the cost savings over the 20 years of operation of this increase does not weigh up to the additional CAPEX of 220 kV coupling and increase of the rating or numbers of transformers.

This assessment has been summarized in the following table where all values have been normalized on the additional CAPEX of option 2 (basic coupling). Options 2 has the highest NPV and is positive even when a low price per kWh is assumed.

Topology	CAPEX	NPV[5] of combined CAPEX and cost savings over 20 years	
		high price / kWh	low price / kWh
Base case	0	0	0
Option 2 - 66kV coupling	+1	+6	+1
Option 3 - additional coupling, higher transformer capacity	+6	+3	-4
Option 4 - full coupling	+8	+4	-5
Option 5 - additional coupling with 3x35% transformers	+5	+3	-3

4. Position of TenneT

Above considerations lead TenneT to the following position:

TenneT intends to select the topology "option 2: basic coupling" with coupling at 66 kV level as a basis of design for the offshore grid infrastructure.

[4] As an average, 98,7% of the total amount of energy which could have been delivered to the 380 kV onshore grid over one year will actually be delivered.
[5] NPV: Net Present Value calculation (normalized) with base assumptions as described in this paper and all CAPEX in the first year.

5. Topic consultation

The expert meeting of 2-3 July, 2015 gives TenneT the opportunity to get feedback from developers on their position regarding "SCADA, communication interface and data links for offshore PPMs". 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.