POSITION PAPER

STAKE HOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
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QUALITY CONTROL		
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1. Background material

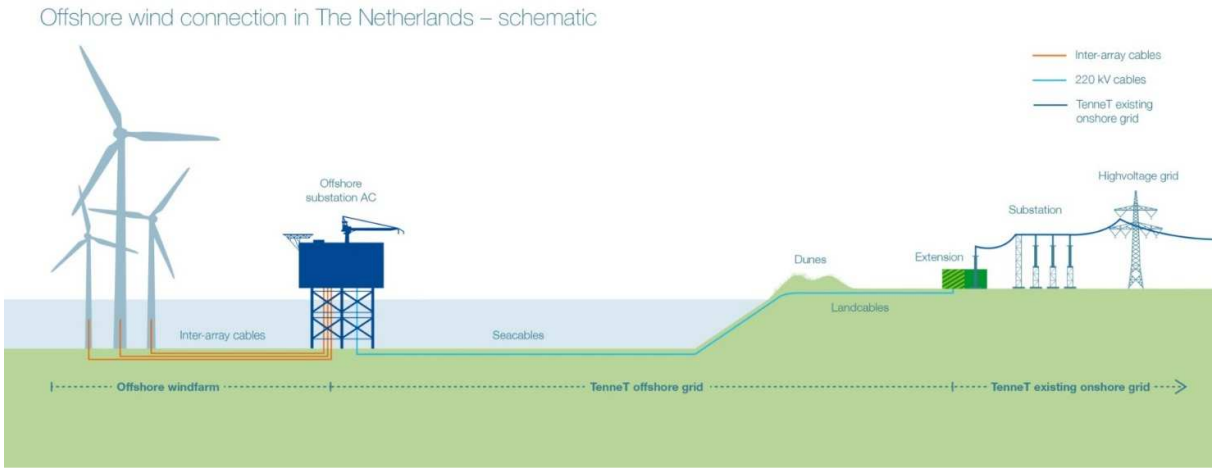
Literature used:
N.A.

2. Scope and considerations

The figure below 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 connection at the offshore substation of TenneT, is to be supplied and installed by the wind park operator (WPO).

Array cables shall be connected to wind turbines and the offshore substation. For supporting and protecting the cables between the bottom of the sea and the feed-in point at the platform J-tubes are applied. The J-tubes are connected to, and supported by, the foundation of the offshore substation or the wind turbine. For installation the array cables are pulled into the J-tubes. After having been pulled in at the offshore substation the cable ends are guided to and connected with the switch gears at the platform.

This paper describes options in the amount of J-tubes on the offshore substation to be taken into account for connecting the Power Park Module (PPM). Regarding this subject, the assumption is made that the voltage level of the PPM system is 33 kV or 66 kV. TenneT's position on voltage level is addressed to in a separate position paper.



Schematic of the offshore electrical grid. Source: TenneT

Technical

To connect the two 350MW wind areas to the platform with 66kV cables and the resulting amount of inter-

array cables per area, it is important to clear out several starting points for this case:

- Maximum nominal current per string: The maximum nominal current for each 66 kV string/bay is selected to be 630 A (= 72 MVA) to ensure the availability of suitable cables and switchgear.
- Maximum active power per string: since the offshore wind farms are expected to contribute to the grid stability with reactive power, it is not possible to connect 72 MW to one string/bay.

Implementation

Assuming contribution with a power factor of 0,9 the maximum active power that can be connected to one string/bay is around 64-66 MW. The actual rating of the wind turbines determines the actual connected active power per string. The tables below show an overview of some representative configurations. As can be seen, the minimum number of J-tubes is 6 per 350 MW system.

	Configuration: 8 MW per WTG @ cos phi = 0,89 44 WTG's = 352 MW		
# WTG's per string	Max. current per string	Max. active Power per string	Min. necessary J-tubes
5	393,6 A	40 MW	9
6	472,3 A	48 MW	8
7	551,0 A	56 MW	7
8	629,8 A	64 MW	6
9	708,5 A	72 MW	not feasible
10	787,2 A	80 MW	not feasible
11	865,9 A	88 MW	not feasible
12	944,6 A	96 MW	not feasible
13	1023,4 A	104 MW	not feasible

	Configuration: 6 MW per WTG @ cos phi = 0,92 59 WTG's = 354 MW		
# WTG's per string	Max. current per string	Max. active Power per string	Min. necessary J-tubes
7	400,7 A	42 MW	9
8	457,9 A	48 MW	8
9	515,1 A	54 MW	7
10	572,4 A	60 MW	6
11	629,6 A	66 MW	6
12	686,8 A	72 MW	not feasible
13	744,1 A	78 MW	not feasible
14	801,3 A	84 MW	not feasible
15	858,6 A	90 MW	not feasible

# WTG's per string	Configuration: 5 MW per WTG @ cos phi = 0,90 70 WTG's = 350 MW Max. current per string	Max. active Power per string	Min. necessary J-tubes
8	387,5 A	40 MW	9
9	435,9 A	45 MW	8
10	484,4 A	50 MW	7
11	532,8 A	55 MW	7
12	581,2 A	60 MW	6
13	629,7 A	65 MW	6
14	678,1 A	70 MW	not feasible
15	726,6 A	75 MW	not feasible
16	775,0 A	80 MW	not feasible

- Flexibility of wind turbine distribution: For the offshore PPM, it is not always possible to have all turbines connected in such a way that the capacity of each string is fully and optimally utilised, e.g. due to the wind farm layout. For this reason, it is necessary to foresee some flexibility in the distribution of the wind turbines across the different strings. As a starting point the number of strings should be such that on average there is 20% spare capacity. See tables in the evaluation section (chapter 3) for the spare capacity of the strings. To allow for 20% of spare capacity, an extra J-tube shall be installed per 350 MW system.

3. Evaluation of options and scenarios

# strings	Configuration: 8 MW per WTG @ cos phi = 0,89 44 WTG's = 352 MW Max. 8 WTG's per string Max. # WTG's connectable	Spare positions for flexibility	
6	48	4	8%
7	56	12	21%
8	64	20	31%
9	72	28	39%

# strings	Configuration: 6 MW per WTG @ cos phi = 0,92 59 WTG's = 354 MW Max. 11 WTG's per string Max. # WTG's connectable	Spare positions for flexibility	
6	66	7	11%
7	77	18	23%
8	88	29	33%
9	99	40	40%

# strings	Configuration: 5 MW per WTG @ cos phi = 0,90 70 WTG's = 350 MW Max. 13 WTG's per string Max. # WTG's connectable	Spare positions for flexibility	
6	78	8	10%
7	91	21	23%
8	104	34	33%
9	117	47	40%

Next to the above amount of J-tubes to connect the wind farm, two additional J-tubes at 66kV level are foreseen. One for the connection of the platform to the neighbouring platforms at the same location (e.g. Borssele Alpha and Beta) and one J-tube for a possible testing field or spare.

4. Position TenneT

TenneT states that in case of **66 kV inter-array cables** (based on 64 MW per cable) a standard platform shall be equipped with 16 J-tubes:

- 2x 7 J-tubes for offshore PPM
- 1 J-tube installed for possible test purposes, or as spare
- 1 J-tube installed for the connection to the neighbouring platform

TenneT states that in case of **33 kV inter-array cables** (based on 35 MW per cable) a standard platform shall be equipped with 28 J-tubes:

- 2x 13 J-tubes for offshore PPM
- 1 J-tube installed for possible test purposes, or as spare
- 1 J-tube installed for the connection to the neighbouring platform

For dimensioning of the J-tubes, the diameter of the 66 kV cable is estimated to be 160 mm. The inner diameter of the J-tube shall be at least 2,5 times the diameter of the cable, resulting in at least 400 mm.

5. Impact on cost

To determine the impact on cost the 66 kV infield cable scenario is compared to an equivalent 33 kV cable scenario below. The cost of J-tubes (and all associated electrical equipment) on the offshore substation are within TenneT's scope only. The option of connecting one or more extra array cables to the offshore substation also requires the availability of other provisions at the offshore substation, such as cable supports, extra switch gear bays, extension of the bus bar and space at the offshore substation (i.e. steel structure). These costs need to be considered for comparison with a possible cost reduction for the WPO.

In the table below a summary is presented of the impact - both quantitatively on cost and qualitatively - of moving from a standard 33 kV infield configuration to a 66 kV infield configuration.

Adding two additional J-tubes for innovation or spare, and for a possible redundancy cable, results in a small increase of cost (negligible LCoE impact), while it is expected to have a positive reducing impact on LCoE when required for used for a redundancy cable, ensuring availability and/or facilitating innovation.

Cost impact: high level breakdown

Quantitative	LCoE Impact	Uncertainty	Comment
Cost element TenneT			
Substation: Connection	0.0%	Low	Increase in costs by increase in number of bays (from 28 for 33 kV or 16 for 66 kV), but LCoE impact is insignificant (1).
Substation: J-tubes	0.0%	Low	Increase in costs by increase in number of J-tubes (from 28 for 33 kV or 16 for 66 kV), but LCoE impact is insignificant (1).
Society			
Borssele Alpha LCoE impact	0.0%	Medium	Summation of the LCoE impact from separate items above (3).
Impact future years	0.0%	Medium	Price for 66 kV equipment expected to decrease by 10% - 20% in the coming years (1). LCoE impact estimate (3).

Referenties: Ecofys internal (1)

6. Topic consultation

The expert meeting of March 18, 2014 gives TenneT the opportunity to get feedback from developers on their position regarding the number of J-tubes/bays on the offshore platform. 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.