POSITION PAPER

STAKE HOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
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1. Background material

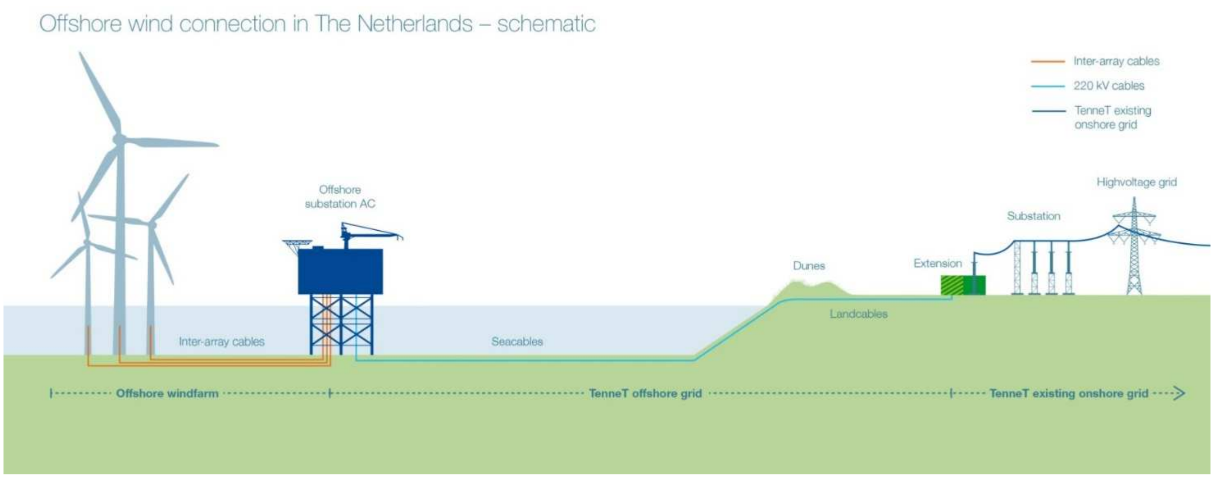
Literature used:
N.A.

2. Scope and considerations

The figure underneath 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 Power Park Module (PPM).

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 to 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 voltage level of the PPM system is considered to be either 33 or 66 kV. TenneT's position with respect to this voltage level position is covered 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 either 33 or 66 kV cables and the resulting amount of inter-array cables per area, it is important to set the maximum transmission capacity of the infield cable. Regarding the determination of the number of J-tubes, TenneT starts from a conservative estimate of the maximum load of the infield cables. Taking into account the general available cable types and a power factor of 0.9, the maximum transmission capacities are set to 35 MW for a 33 kV infield cable and 70 MW for a 66 kV infield cable. For the 66kV cables, the calculations for the amount of J-tubes are performed with 64MW per infield cable, giving extra margin.

Minimum number of strings/J-tubes

Depending on turbine capacity and infield cable voltage the bare minimum number of strings/J-tubes is calculated:

Scenario 1: Base case - 350 MW

Total	350	MW
Max capacity 33 kV	35	MW

Total	350	MW
Max capacity 66 kV	64	MW

Wind turbine capacity	**8**	**MW**
Number turbines per string	Capacity per string	# J-tubes
2	16	22
3	24	15
4	32	11
5	40	9
6	48	8
7	56	7
8	64	6

Wind turbine capacity	**8**	**MW**
Number turbines per string	Capacity per string	# J-tubes
4	32	11
5	40	9
6	48	8
7	56	7
8	64	6
9	72	5
10	80	5

Wind turbine capacity	**6**	**MW**
Number turbines per string	Capacity per string	# J-tubes
2	12	30
3	18	20
4	24	15
5	30	12
6	36	10
7	42	9
8	48	8
9	54	7

Wind turbine capacity	**6**	**MW**
Number turbines per string	Capacity per string	# J-tubes
5	30	12
6	36	10
7	42	9
8	48	8
9	54	7
10	60	6
11	66	6
12	72	5

Wind turbine capacity	**5**	**MW**
Number turbines per string	Capacity per string	# J-tubes
3	15	24
4	20	18
5	25	14
6	30	12
7	35	10
8	40	9
9	45	8
10	50	7

Wind turbine capacity	**5**	**MW**
Number turbines per string	Capacity per string	# J-tubes
7	35	10
8	40	9
9	45	8
10	50	7
11	55	7
12	60	6
13	65	6
14	70	5

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. In addition, the NL government has indicated that it will allow a 380 MW as the maximum installed capacity per wind farm. TenneT therefore uses as starting point that the number of strings should be such that on average there is 20% spare capacity, on top of the 380 MW installed. To allow for 20% of spare capacity, 4 additional J-tubes (16 in total) are required at 33 kV and 2 additional J-tubes (8 in total) are required at 66 kV per 350 MW system.

Scenario 2: 380 MW (350 MW + overplanting) + 20% spare capacity

Total	456 MW
Max capacity 33 kV	35 MW

Total	456 MW
Max capacity 66 kV	64 MW

Wind turbine capacity	**8 MW**	
Number turbines per string	Capacity per string	# J-tubes
2	16	29
3	24	19
4	32	15
5	40	12
6	48	10
7	56	9
8	64	8

Wind turbine capacity	**8 MW**	
Number turbines per string	Capacity per string	# J-tubes
4	32	15
5	40	12
6	48	10
7	56	9
8	64	8
9	72	7
10	80	6

Wind turbine capacity	**6 MW**	
Number turbines per string	Capacity per string	# J-tubes
2	12	38
3	18	26
4	24	19
5	30	16
6	36	13
7	42	11
8	48	10
9	54	9

Wind turbine capacity	**6 MW**	
Number turbines per string	Capacity per string	# J-tubes
5	30	16
6	36	13
7	42	11
8	48	10
9	54	9
10	60	8
11	66	7
12	72	7

Wind turbine capacity	**5 MW**	
Number turbines per string	Capacity per string	# J-tubes
3	15	31
4	20	23
5	25	19
6	30	16
7	35	14
8	40	12
9	45	11
10	50	10

Wind turbine capacity	**5 MW**	
Number turbines per string	Capacity per string	# J-tubes
7	35	14
8	40	12
9	45	11
10	50	10
11	55	9
12	60	8
13	65	8
14	70	7

Infield redudancy layout schemes

TenneT has been made aware of layout philosophies that use infield cable redundancy schemes at the expense of increased total infield cable length. However, when requested, DNV-GL indicated that while they are aware many projects without end-of-circuit redundant links, they are aware of only one that redundant links. TenneT therefore chooses to base its design on the majority of the current industry practice, with only a limited number of spare J-tubes and strings to facilitate flexibility in overall wind farm layout.

Impact of specific site constraints

The initial draft layouts for all five wind areas as prepared for the TenneT position paper on T.1. Voltage Level indicate that taking into account site specific constraints (such as pipelines and telecom cables) yields an effective minimum for the worst case of 21 and 12 strings for a 33 kV or 66 kV layout per (700 MW) offshore platform respectively. From these draft layouts, it can be concluded that the site specific constraints for the different wind areas do not lead to an increase of the minimum number of strings required to connect the wind farm to the offshore platform.

Cost, uncertainties and risk

To determine the impact on cost, the 66 kV infield cable scenario is compared to an equivalent 33 kV cable scenario (see 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 switchgear bays, extension of the busbar 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 PPM.

A large density of cables is a risk with respect to operations with jack-up vessels near the offshore substation and possible cable repair work in the operational phase. Clearly this risk will be higher with an increasing number of infield cables connecting to the same offshore sub-station.

Next to the amount of J-tubes to connect the wind farms, 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 as extra spare.

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.

Cost impact: high level breakdown

Quantitative	LCoE Impact	Uncertainty	Comment
Cost element TenneT			
Substation: Connection	0.1%	Low	Increase in costs by increase in number of bays (from 26 to 34 for 33 kV), switchgear constitutes ~5% of Offshore Substation CAPEX (1).
Substation: J-tubes	0.0%	Low	Increase in costs by increase in number of J-tubes (from 26 to 34 for 33 kV), but LCoE impact is insignificant (2).
Society			
Borssele Alpha LCoE impact	0.2%	Medium	Summation of the LCoE impact from separate items above (2).
Impact future years	0.2%	Medium	Price for 66 kV equipment expected to decrease by 10% - 20% in the coming years (1). LCoE impact estimate (2).

References: DNV GL Report (1) Ecofys internal (2)

In case of standardisation at 33 kV, adding eight additional J-tubes to provide flexibility and spare capacity results in a small increase of cost.

Cost impact: high level breakdown

Quantitative	LCoE Impact	Uncertainty	Comment
Cost element TenneT			
Substation: Connection	0.1%	Low	Increase in costs by increase in number of bays (from 14 to 16 for 66 kV), switchgear constitutes ~5% of Offshore Substation CAPEX (1).
Substation: J-tubes	0.0%	Low	Increase in costs by increase in number of J-tubes (16 for 66 kV), but LCoE impact is insignificant (2).
Society			
Borssele Alpha LCoE impact	0.1%	Medium	Summation of the LCoE impact from separate items above (2).
Impact future years	0.1%	Medium	Price for 66 kV equipment expected to decrease by 10% - 20% in the coming years (1). LCoE impact estimate (2).

References: DNV GL Report (1) Ecofys internal (2)

In case of standardisation at 66 kV, adding four additional J-tubes to provide flexibility and spare capacity results in a small increase of cost.

For both cases, 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 ensuring availability and/or facilitating innovation. Note also, that in both case the cost impact figures given above can be reduced further by matching the windpark design with the number of switchgear bays at the time.

3. Position TenneT

TenneT states that in case of **66 kV inter-array cables** (based on conservative 64 MW per cable) a standard platform shall be equipped with 18 J-tubes for the inter array system:

- 2x 8 J-tubes for offshore PPM
- 1 J-tube installed for possible test purposes
- 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 34 J-tubes for the inter array system:

- 2x 16 J-tubes for offshore PPM
- 1 J-tube installed for possible test purposes
- 1 J-tube installed for the connection to the neighbouring platform

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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.

Next to this of course also J-tubes for the 220kV export system are required for the platform.

4. Topic consultation

The expert meeting of 15-16 April, 2015 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.