POSITION PAPER

STAKEHOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
Type:	Position paper
Work Stream:	Technical
Topic:	T11 - J-tubes & Number of bays
Filename:	ONL TTB05419
Version:	V3.0
Pages:	6 pages

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

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1. Background Material

LITERATURE USED:
• None

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.

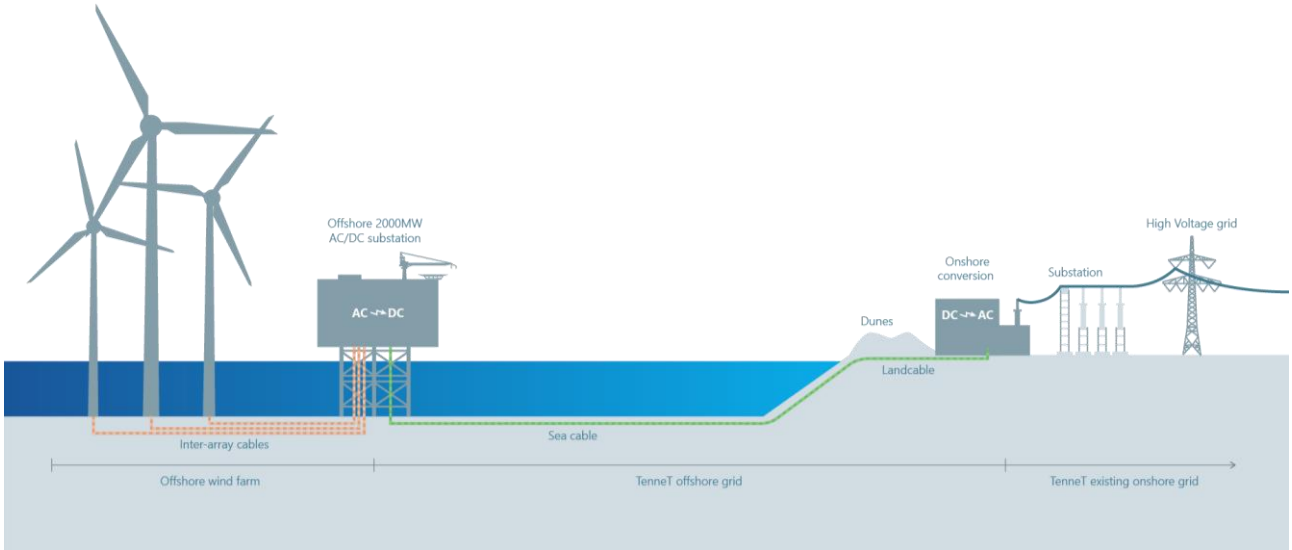

Figure 1 - HVDC grid connection concept

This paper describes how TenneT, as the offshore grid connection owner, proposes to deal with the number of J-tubes on the offshore converter station allocated for the inter-array cables, the design of the J-tubes, the minimum and maximum capacity per 66 kV GIS bay and the number of 66 kV GIS bays.

1. Evaluation of topologies

Various topologies (i.e. various numbers of WTGs per infield string) with different types of WTG (10, 12, 15, 17 and 20 MW) are investigated in terms of power/current per string, number of strings, number of J-tubes and number of 66 kV bays (reference is made to the table in the Appendix).

The table in the Appendix consists of 4 “main columns” (separated by the bold borders). The 1st main column (with 3 sub-columns) show the number of WTG per string resulting in the power (MW) per string and the current (A) per string. The higher currents (>1250 A) and the lower powers (<45 MW) are marked orange: these topologies are not realistic. In order to make adequately use of TenneT’s assets, the preferred minimum current per 66 kV bay is 625 A. The yellow marked currents do not fulfil this preference.

The 2nd ,3rd and 4th main columns (each with 3 sub-columns) have the same format and show the resulting number of strings per 500 MW (as mathematical number!) and the resulting total number of J-tubes (per platform of 2000 MW) and the resulting number of 66 kV bays (per platform of 2000 MW). These 3 main columns are for:

1. generator block of 500 MW (the base case),
2. generator block of 500 MW incl. 15% overplanting (i.e. 575 MW),
3. generator block of 500 MW incl. 20% overplanting (i.e. 600 MW).

Another preselection is done by limiting the number of J-tubes per platform to less than 30. The orange marked numbers of J-tubes are 30 or more.

These preselection on high currents, low powers and high numbers of J-tubes leaves us with the remaining, more realistic combinations (WTG power, WTGs per string). They are marked green and dark green.

1.1 2 GW without overplanting (base case)

The base case is a 2 GW platform with 2 offshore windfarms of 1 GW. Given the converter transformer sizes (rating), this 2 GW is split into 4 so called generator blocks of 500 MW.

For most topologies 6 bays per generator block of 500 MW (i.e. 6 bays per 66 kV GIS section) and up to 26 J-tubes turns out to be sufficient (marked green). For some topologies (with lower wind power per string) 7 bays per generator block and 28 J-tubes are needed (marked dark green).

1.2 2 GW with overplanting

The Ministry of Economic Affairs has not taken their position on overplanting yet. Also TenneT’s cable design is developed far enough to determine its design limit in terms of overplanting. For this position paper the effect of overplanting by 15% and by 20% is investigated. This should be seen as 2 rather extreme examples

of overplanting, just to determine the impact it has on the number of J-tubes and bays.
Furthermore, it is important to realize that this overplanting can only be used to increase the load factor of the offshore windfarm. The maximum power output of 1 generator block therefore remains 500 MW.

For most topologies 6 bays per generator block of 500 MW (i.e. 6 bays per 66 kV GIS section) and up to 26 J-tubes turns out to be sufficient (marked green).
For some topologies (with lower wind power per string) 7 bays per generator block and 28 J-tubes are needed (marked dark green).
It is more or less the same as the base case, but with higher wind power (currents) per string due to overplanting of course.

2. J-tubes

2.1 Number of J-tubes

For the base case as well as for the overplanting cases 26 J-tubes per platform covers most of the topologies. Only a couple topologies (with lower powers per string) are not covered and need 28 J-tubes. The number of J-tubes allocated for the OWFs is set to a maximum of 28 per platform. This covers all topologies and leaves some flexibility for the infield lay-out for most of the topologies.

It is at TenneT's discretion to remove or re-assign J-tubes if the OWF operator requires less than 28 J-tubes.

2.2 Design of J-tubes

For the design of the J-tubes the conductor sizes of 630 and 800 mm^2 are considered. If larger cable diameters are foreseen, this would be possible, but it is then also assumed that the transmission capacity of the cables increases and therefore reducing the number of required J-tubes. The recommended practice DNVGL-RP-0360 is taken as the basis for the design of the J-tubes.

The diameter of the 66 kV inter-array cables is estimated to be 180 mm. Following the recommended practice DNVGL-RP-0360; the inner diameter of the J-tube should be 2,5 times the diameter of the cable, resulting in an inner diameter of 450 mm for the J-tubes.

3. 66 kV GIS bays

3.1 Capacity of 66 kV GIS bay

The rated current of the 66 kV GIS bay is 1250 A, therefore the same maximum capacity applies to the connected string(s) per 66 kV GIS bay. To establish an efficient way of utilising the capacity of the 66 kV GIS bays, which is the obligation of TenneT, the minimum capacity of the connected string(s) is set at 625 A per bay. The main driver for this 625 A is that strings with less than 625 A can be combined and remain below the maximum of 1250 A per bay. A lower capacity per string than 625 A is allowed, however it is at TenneTs' discretion to combine two strings into one 66 kV GIS bay.

3.2 Number of 66 kV GIS bays

For the base case as well as for the overplanting cases 6 bays per generator block covers most of the topologies. Only a couple topologies (with lower powers per string) are not covered and need 6 and/or 7 bays per generator block.
The number of 66 kV GIS bays allocated for the OWFs is set to a maximum of 6 per generator block. This will lead to an optimal use of assets by TenneT.

TenneT's design of the 66 kV busbar sections also includes a universal bay. TenneT may need this bay in the future (e.g. in case of a HVDC "wind connector" the 66 kV transformer bay per section must be split into 2 transformer bays per section).
If TenneT chooses to make this universal bay upon request available for the OWP as a 7th bay per generator block, then TenneT has also to reserve space for yet another bay per busbar section. Such an extra 7th bay will be made available to the OWP, if the OWP bears the extra costs.

4. Position TenneT

TenneT states that with the 66 kV inter-array cables the 2000 MW offshore HVDC converter station shall be equipped with maximum 28 J-tubes for the inter array system.

The number of bays per generator block of 500 MW is set to 6 bays.
A 7th bay can be made available, granted that the costs are allocated to the OWP.

The minimum current for per 66 kV bay is 625 A.

An inner diameter of 450 mm is considered for the J-tubes.

Appendix: Overview of topologies

			base case = 500 MW			overplanting 15% = 575 MW			overplanting 20% = 600 MW		
20 MW turbines		20									
			total of 25 WTG = 500 MW		25	total of 28 WTG = 560 MW		28	total of 30 WTG = 600 MW		30
max # WTGs per string	MWs per string	Amps per string	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)
2	40	369	12,5			14,0			15,0		
3	60	553	8,3	34		9,3	38		10,0	40	
4	80	738	6,3	26	2 x 7 + 2 x 6	7,0	28	4 x 7	7,5	30	
5	100	922	5,0	20	4 x 5	5,6	24	4 x 6	6,0	24	4 x 6
6	120	1.106	4,2	18	2 x 4 + 2 x 5	4,7	20	4 x 5	5,0	20	4 x 5
7	140	1.291	3,6			4,0			4,3		
8	160	1.475	3,1			3,5			3,8		
9	180	1.659	2,8			3,1			3,3		
17 MW turbines		17									
			total of 29 WTG = 493 MW		29	total of 33 WTG = 561 MW		33	total of 35 WTG = 595 MW		35
max # WTGs per string	MWs per string	Amps per string	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)
2	34	313	14,5			16,5			17,5		
3	51	470	9,7	50		11,0	44		11,7	48	
4	68	627	7,3	30		8,3	34		8,8	36	
5	85	784	5,8	24	4 x 6	6,6	28	2 x 7 + 2 x 6	7,0	28	4 x 7
6	102	940	4,8	20	4 x 5	5,5	22	2 x 6 + 2 x 5	5,8	24	4 x 6
7	119	1.097	4,1	18	2 x 5 + 2 x 4	4,7	20	4 x 5	5,0	20	4 x 5
8	136	1.254	3,6	16	4 x 4	4,1	18	2 x 5 + 2 x 4	4,4	18	2 x 5 + 2 x 4
9	153	1.411	3,2			3,7			3,9		
15 MW turbines		15									
			total of 33 WTG = 495 MW		33	total of 38 WTG = 570 MW		38	total of 40 WTG = 600 MW		40
max # WTGs per string	MWs per string	Amps per string	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)
3	45	415	11,0			12,7			13,3		
4	60	553	8,3	34		9,5	38		10,0	38	
5	75	691	6,6	28	4 x 7	7,6	32		8,0	32	
6	90	830	5,5	22	2 x 6 + 2 x 5	6,3	26	2 x 7 + 2 x 6	6,7	28	4 x 7
7	105	968	4,7	20	4 x 5	5,4	22	2 x 6 + 2 x 5	5,7	24	4 x 6
8	120	1.106	4,1	18	2 x 5 + 2 x 4	4,8	20	4 x 5	5,0	20	4 x 5
9	135	1.245	3,7	16	4 x 4	4,2	18	2 x 5 + 2 x 4	4,4	18	2 x 5 + 2 x 4
10	150	1.383	3,3			3,8			4,0		
12 MW turbines		12									
			total of 41 WTG = 492 MW		41	total of 48 WTG = 576 MW		48	total of 50 WTG = 600 MW		50
max # WTGs per string	MWs per string	Amps per string	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)
4	48	443	10,3	42		12,0	48		12,5	50	
5	60	553	8,2	34		9,6	40		10,0	40	
6	72	664	6,8	28	4 x 7	8,0	32		8,3	34	
7	84	774	5,9	24	4 x 6	6,9	28	4 x 7	7,1	28	4 x 7
8	96	885	5,1	22	2 x 6 + 2 x 5	6,0	24	4 x 6	6,3	26	2 x 7 + 2 x 6
9	108	996	4,6	20	4 x 5	5,3	22	2 x 6 + 2 x 5	5,6	24	4 x 6
10	120	1.106	4,1	18	2 x 5 + 2 x 4	4,8	20	4 x 5	5,0	20	4 x 5
11	132	1.217	3,7	16	4 x 4	4,4	18	2 x 5 + 2 x 4	4,5	18	2 x 5 + 2 x 4
10 MW turbines		10									
			total of 50 WTG = 500 MW		50	total of 57 WTG = 570 MW		57	total of 60 WTG = 600 MW		60
max # WTGs per string	MWs per string	Amps per string	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)	# strings	total # J-tubes (per 2000 MW)	# bays (per 2000 MW)
5	50	461	10,0	40		11,4	46		12,0	48	
6	60	553	8,3	34		9,5	38		10,0	40	
7	70	645	7,1	28	4 x 7	8,1	34		8,6	36	
8	80	738	6,3	26	2 x 7 + 2 x 6	7,1	28	4 x 7	7,5	30	
9	90	830	5,6	24	4 x 6	6,3	26	2 x 7 + 2 x 6	6,7	28	4 x 7
10	100	922	5,0	20	4 x 5	5,7	24	4 x 6	6,0	24	4 x 6
11	110	1.014	4,5	18	2 x 5 + 2 x 4	5,2	22	2 x 6 + 2 x 5	5,5	22	2 x 6 + 2 x 5
12	120	1.106	4,2	18	2 x 5 + 2 x 4	4,8	20	4 x 5	5,0	20	4 x 5
13	130	1.198	3,8	16	4 x 4	4,4	18	2 x 5 + 2 x 4	4,6	20	4 x 5
14	140	1.291	3,6			4,1			4,3		