NOTE

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SUBJECT

FOR YOUR INFORMATION ☐

FOR DECISION-MAKING ☐

Text

1. Definition lengths cable section in study

Because it is insufficiently clear which cable lengths in the circuits towards Terneuzen are covered in the technical study regarding the steady state analysis, it was agreed to make an overview of all routing options as listed in the EIA (Environmental Impact Assessment) and relate these lengths with the scope of the technical study.

From the public available information in the EIA (environmental Impact Assessment), the following routing options, see Figure 1, are part of the spatial planning process:

1. Routing on land at Zuid-Beveland: L1, L2, L3 L4. These have been further detailed to the underground options L1O, L2O and L3O. Route option L4 has ultimately been dropped as an alternative for an underground connection.

2. Crossing of the river Westerschelde: K1, K2, K3, K4. These have been further detailed in the tunnel options K1T, K2T, K3T and K4T

3. Location of the new 380 kV substation Terneuzen and the routing from the tunnel outlet to the substation. The latter will be realised by means of overhead line.

Locatie	Tracé	Soort tracé	Lengte (km)
Landtracés Zuid-Beveland	L1O	Ondergronds tracé	1,5
	L2B	Bovengronds tracé	3
	L2O	Ondergronds tracé	3
	L3B	Bovengronds tracé	6
	L3O	Ondergronds tracé	6
	L4B	Bovengronds tracé	5,5
Tracés Westerschelde	K1T	Tunneltracé	6,5
	K2T	Tunneltracé	8
	K2Ba	Baggertracé	9
	K3B	Bovengronds tracé	8
	K3T	Tunneltracé	8
	K3Ba	Baggertracé	8
	K4B	Bovengronds tracé	6,5
	K4T	Tunneltracé	7

Table 1: Excerpt from EIA with defined routing lengths (see Appendix 1 with full table)

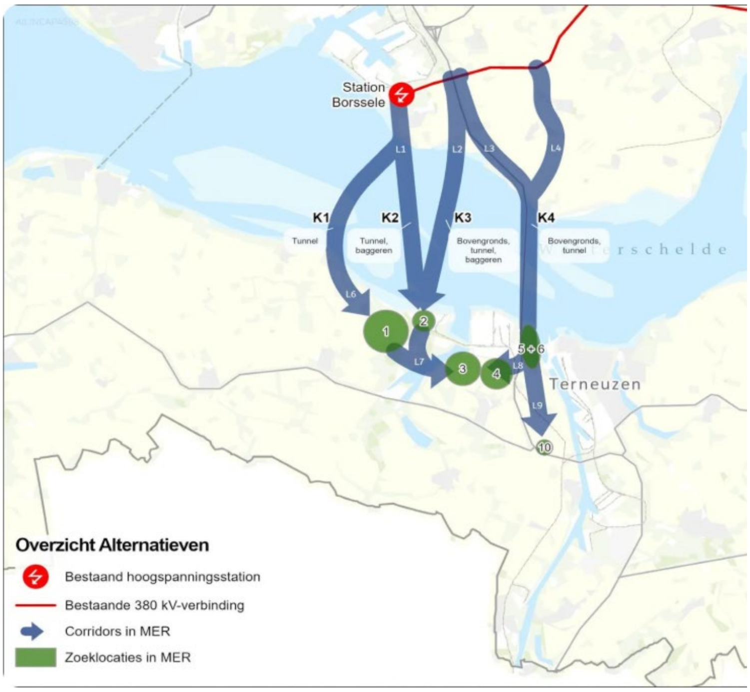

Figure 1: Map with routing options

The information from Table 1 and Figure 1 is further processed in Table 2:

Project 380 kV Zeeuws-Vlaanderen					
Input from IEA (Environmental Impact Assessment)	Route options at Zuid-Beveland, as presented in the NRD		Tunnel options crossing the Westerschelde, as presented in the NRD		
		[km]		[km]	
	L1O	1,5	K1T	6,5	
	L2O	3	K2T	8	
	L3O	6	K3T	8	
			K4T	7	
Variant	**Length of cable section applied at route option at Zuid-Beveland [L] [km]**	**Length of cable applied in tunnel crossing the Westerschelde [K] [km]**	**Total length of cable section in each circuit towards new substation Terneuzen 380 kV [L] + [K] [km]**	**Covered under study case number**	**Length of cable section in each circuit towards Terneuzen applied in the model for the steady state analysis [km]**
K1T		6,5	**6,5**	1	**7**
K2T		8	**8**		
K3T		8	**8**		
K4T		7	**7**		
L1O + K1T	1,5	6,5	**8**		
L1O + K2T	1,5	8	**9,5**	2	**10**
L2O + K3T	3	8	**11**		
L3O + K4T	6	7	**13**	3	**14 *)**

***)** At the start of the study route option L4 with a maximum length of 6,5 km was also considered to be part of the scope of the technical study (L4 + K4T = 13,5 km). This explains the choice of 14 km for case 3. This underground route option has however been dropped during the spatial planning proces.

Table 2: overview of routing options and translation to scope of study

TenneT has grouped all routing options and divided them into three main study cases:

Case 1: In this case a total length of **7 km** cable is assumed in each circuit towards Terneuzen. The conclusions with respect to the analysis of Case 1 are applicable to the tunnel route options "K1T / K2T / K3T / K4T" and to route combination "L1O + K1T".

Case 2: In this case a total length of **10 km** cable is assumed in each circuit towards Terneuzen. The conclusions with respect to the analysis of Case 2 are applicable to the route combinations "L1O / L2O" and "K2T / K3T".

Case 3: In this case a total length of **14 km** cable is assumed in each circuit towards Terneuzen. The conclusions with respect to the analysis of Case 3 are applicable to route combination "L3O + K4T"

As indicated in the Table 2, initially route option L4 was also assumed to have an underground routing option but has been dropped during the process. But, this explains the initial choice of 14 km for case 3.

The motivation for the division into three study cases, instead of performing a calculation for each individual cable length, has several aspects, as further explained below:

- The amount of reactive power in the grid cannot be attributed to only 380 kV cable sections, also overhead lines do generate (and consume) reactive power. Next to that reactive power is also injected or consumed by customer connections and it is exchanged with the 150 kV network.
- Reactive power is in general a necessary system need, required to be able to operate an AC grid. The amount of reactive power in the grid fluctuates continuously, depending on the actual grid topology, voltage and system loading.
- The need for reactive power compensation is based on the analysis of the operational voltage calculated for different locations (substations) in the overall grid in the province Zeeland and Western-Brabant for different scenarios. In the study covering the steady state analysis, the 380 kV cable sections in the connections Terneuzen-Rilland (location: Krabbendijke) and Rilland-Tilburg (location: Markiezaatsmeer) were added to the study model and were part of the overall analysis. The same applies for the Borssele offshore connections.
- Because cable sections do highly contribute to the generation of reactive power, their contribution is at first calculated separately to indicate the required amount of installed compensation capacity. This calculation however must take a manufacturer dependent margin into account. The cable capacitance is determined by the cable design and production margins and will normally vary between 0,21 and 0,26 uF/km. This study has taken C = 0,232 uF/km as a reference.
- The installation length of cable has also some margins: the cable will normally be installed meandering within the indicated route corridors. Furthermore, some overlength will be installed to cover for possible future cable failures at a cable end termination.
- Reactive power compensation equipment installed in the TenneT operated grid has standard ratings varying between 75, 100 to 150 Mvar. Therefore, there is always a threshold difference between reactive power generation and compensation.

2. Policies related to reactive power compensation

TenneT sets the following requirements for the installation of reactive power compensation means in the grid. The requirements are laid down in policy documents.

- At a 380 kV substation a maximum amount of 750 Mvar of reactive power compensation capacity can be connected. To comply with the Power Quality requirements, the amount per substation has a maximum value to limit the impact on the fast voltage variations in case of loss of reactive power due to a busbar outage. This is further detailed by the connection possibilities to a single 380 kV busbar:
    - one 380 kV reactor (total 150 Mvar);
    - one 380 kV reactor and one transformer with a reactor at the tertiary winding (total 250 Mvar);
    - two transformers with a reactor at the tertiary winding (total 200 Mvar).
- At a 380 kV substation maximum four (4) power transformers 380/150 kV will be installed. A power transformer has a standard rating of 500 MVA. The maximum number of 4 is based on the defined maximum size of a 150 kV pocket of maximum 1000 MW load, even under N-2 grid condition. This is a grid code requirement and is defined to manage the Security of Supply.
- At a 380/150 kV transformer (standard rating 500 MVA) only one reactor with a maximum rating of 100 Mvar can be connected. This value is the result of an economical and technical optimisation of the power transformer design.
- The standard rating of a 380 kV reactor is 150 Mvar. This value has been concluded based on an technical analysis on the calculated fast voltage variations and switching transients during energisation. With this value the Power Quality requirements are met.
- An overshoot of reactive power, for instance due to a 380 kV cable section in a connection, has a local effect on the operational voltages in the grid. To be effective, compensation must be installed close to the source of reactive power, preferably in the substations at both sides of that connection.
- A reactor connected to the tertiary winding of a power transformer is in general approx. 50% effective for the 380 kV grid and 50% effective for the 150 kV grid.
- The installation of additional power transformers at a substation (while respecting the maximum number of four) will always take priority above the installation of reactive power compensation.

3. Overview of reactive power compensation at 380 kV substations

In this section an overview of the actual amount of installed reactive power compensation at the relevant 380 kV substations in province Zeeland and Western-Brabant is presented. Besides that, also the planned extension of compensation means is presented and the additional extension possibilities will be explained.

3.1 Existing 380 kV substations

Substation Borssele 380 kV

Double busbar layout with longitudinal coupling breaker.
Installed reactive power compensation capacity:

- 3 x 100 Mvar, at the tertiary winding of the 380/150 kV transformers. This capacity is allocated to the compensation of the TOV-filters at the offshore connection (2 filters, each approx. 70 Mvar) and to compensate the reactive power generated in the 150 kV grid.

Planned reactive power compensation capacity:

- 1 x 150 Mvar (380 kV reactor). Provisionally allocated to compensate the reactive power generated by the new connection Borssele – Terneuzen (including crossing river Westerschelde).

Extension options to increase installed reactive power compensation capacity:

- 1 x 100 Mvar by the installation of a 4th power transformer with a reactor. (50% effective)

Remark: The substation BSL380 has no physical space left for further expansion and cannot be extended anymore.
Remark 2: The installation of new power transformers will not be done just for reactive power compensation.

Borssele 380 kV							
		[Mvar]				Total installed capacity [Mvar]	Effective at 380 kV grid [Mvar]
actual per 2026	Reactor capacity at 380 kV	-		-		300	150
	Reactor capacity at 3rd winding power transformer	100	100	100	-		
planned per 2035	Reactor capacity at 380 kV	150		-		450	300
	Reactor capacity at 3rd winding power transformer	100	100	100	-		
remaining extension options per 2035	Reactor capacity at 380 kV	x		n.a. (no space)		550	350
	Reactor capacity at 3rd winding power transformer	x	x	x	100		

Substation Rilland 380 kV

Triple busbar layout.

Installed reactive power compensation capacity:

- 0 Mvar

Planned reactive power compensation capacity:

- 2 x 150 Mvar (two 380 kV reactors). Provisionally allocated to compensate the reactive power generated by the new 380 kV connection Rilland – Tilburg (cable sections near Markiezaatsmeer).

Extension options to increase installed reactive power compensation capacity:

- 2 x 100 Mvar by adding a reactor to the tertiary winding of existing power transformers. Half of this capacity will be used by the 150 kV grid.
- 2 x 100 Mvar by the installation of a 3rd and 4th power transformer with a reactor. (50% effective)

Remark: The installation of new power transformers will not be done just for reactive power compensation.

Rilland 380 kV							
		[Mvar]				Total installed capacity [Mvar]	Effective at 380 kV grid [Mvar]
actual per 2026	Reactor capacity at 380 kV	-		-		0	0
	Reactor capacity at 3rd winding power transformers	-	-	-	-		
planned per 2035	Reactor capacity at 380 kV	150		150		300	300
	Reactor capacity at 3rd winding power transformers	-	-	-	-		
remaining extension options per 2035	Reactor capacity at 380 kV	x		x		700	500
	Reactor capacity at 3rd winding power transformers	100	100	100	100		

3.2 Future 380 kV substations

Substation Terneuzen 380 kV

Triple busbar layout.

Planned reactive power compensation capacity:

- 2 x 150 Mvar (two 380 kV reactors). Provisionally allocated to compensate the reactive power generated by the new 380 kV connection Borssele-Terneuzen, Terneuzen-Rilland and expected future possible harmonic filters (approx. 2 x 70 Mvar).
- 4 x 100 Mvar at the tertiary winding of the power transformers. 200 Mvar is allocated to compensate the reactive power in the 150 kV grid

Extension options to increase installed reactive power compensation capacity:

- 0 Mvar, maximum substation capacity with respect to reactive power compensation has been reached.

Terneuzen 380 kV								
		[Mvar]					Total installed capacity [Mvar]	Effective at 380 kV grid [Mvar]
planned per 2035	Reactor capacity at 380 kV	150		150			700	500
	Reactor capacity at 3rd winding power transformers	100	100	100	100			
remaining extension options per 2035	Reactor capacity at 380 kV	x		x			700	500
	Reactor capacity at 3rd winding power transformers	x	x	x	x			

Substation Nieuwdorp-Liechtensteinweg 380 kV

Triple busbar layout.

Planned reactive power compensation capacity:

- 2 x 150 Mvar (two 380 kV reactors).

Extension options to increase installed reactive power compensation capacity:

- 4 x 100 Mvar. Substation is prepared to connect future 150 kV substation by means of four power transformers, including reactor connected to tertiary winding. 200 Mvar is then allocated to compensate the reactive power in the 150 kV grid

Remark: This substation is not directly connected to connections with cable sections. The compensation will therefore not be maximum effective.

Remark 2: The installation of new power transformers will not be done just for reactive power compensation.

Nieuwdorp-Liechtensteinweg 380 kV								
		[Mvar]					Total installed capacity [Mvar]	Effective at 380 kV grid [Mvar]
planned per 2035	Reactor capacity at 380 kV	150		150			300	300
	Reactor capacity at 3rd winding power transformers	-	-	-	-			
remaining extension options per 2035	Reactor capacity at 380 kV	x		x			700	500
	Reactor capacity at 3rd winding power transformers	100	100	100	100			

Substation Tilburg 380 kV

Triple busbar layout.

Planned reactive power compensation capacity:

- 3 x 100 Mvar. At tertiary winding of power transformers. 150 Mvar is allocated to compensate the reactive power in the 150 kV grid.

Extension options to increase installed reactive power compensation capacity:

- 1 x 100 Mvar by the future installation of a 4th power transformer with a reactor. (50% effective)

Remark: Compensation located at substation Tilburg is not effective anymore for the circuits crossing the river Westerschelde.
Remark 2: The substation Tilburg 380 kV has no spare bays left for further expansion. If substation expansion would be possible, the new bays will be prioritized to facilitate the connection of new line bays.
Remark 3: The installation of new power transformers will not be done just for reactive power compensation.

Tilburg 380 kV

		[Mvar]				Total installed capacity [Mvar]	Effective at 380 kV grid [Mvar]
planned per 2035	Reactor capacity at 380 kV	-		-		300	150
	Reactor capacity at 3rd winding power transformers	100	100	100	-		
remaining extension options per 2035	Reactor capacity at 380 kV	n.a. (no space)		n.a. (no space)		400	200
	Reactor capacity at 3rd winding power transformers	x	x	x	100		

Substation Halsteren 380 kV

Triple busbar layout.

Planned reactive power compensation capacity:

- 3 x 100 Mvar. At tertiary winding of power transformers. 150 Mvar is allocated to compensate the reactive power in the 150 kV grid.

Extension options to increase installed reactive power compensation capacity:

- 2 x 150 Mvar. Two 380 kV reactors.
- 1 x 100 Mvar by the future installation of a 4th power transformer with a reactor.

Remark: The installation of new power transformers will not be done just for reactive power compensation.

Halsteren 380 kV							
		[Mvar]				Total installed capacity [Mvar]	Effective at 380 kV grid [Mvar]
planned per 2035	Reactor capacity at 380 kV	-		-		300	150
	Reactor capacity at 3rd winding power transformers	100	100	100	-		
remaining extension options per 2035	Reactor capacity at 380 kV	150		150		700	500
	Reactor capacity at 3rd winding power transformers	x	x	x	100		

Appendix 1: Full copy of table 4-1 from the EIA

Tabel 4-1: Eigenschappen en aantallen objecten per tracé geanalyseerd in fase 1 (Bouwstenen)

Locatie	Tracé	Soort tracé	Lengte (km)	Steun-masten	Hoek-masten	Aantal geleiders	Dikte geleiders (mm²)	Spoelen
Landtracés Zuid-Beveland	L1O	Ondergronds tracé	1,5	0	0	24	2500	4
	L2B	Bovengronds tracé	3	14	2	36	882	0
	L2O	Ondergronds tracé	3	0	0	24	2500	4
	L3B	Bovengronds tracé	6	30	4	36	882	0
	L3O	Ondergronds tracé	6	0	0	24	2500	4
	L4B	Bovengronds tracé	5,5	28	6	36	882	0
Tracés Westerschelde	K1T	Tunneltracé	6,5	0	0	24	2500	4
	K2T	Tunneltracé	8	0	0	24	2500	4
	K2Ba	Baggertracé	9	0	0	24	2500	4
	K3B	Bovengronds tracé	8	9	0	24	983	0
	K3T	Tunneltracé	8	0	0	24	2500	4
	K3Ba	Baggertracé	8	0	0	24	2500	4
	K4B	Bovengronds tracé	6,5	7	0	24	983	0
	K4T	Tunneltracé	7	0	0	24	2500	4
Tracés Zeeuws-Vlaanderen	L5B	Bovengronds tracé	3,5	20	0	36	882	0
	L6B	Bovengronds tracé	2	12	0	36	882	0
	L7B	Bovengronds tracé	3,5	20	0	36	882	0
	L8B	Bovengronds tracé	3	14	2	36	882	0
	L9B	Bovengronds tracé	1	8	0	36	882	0
	L10B	Bovengronds tracé	2,5	14	2	36	882	0
	L11B	Bovengronds tracé	4,5	24	0	36	882	0