

TO TenneT-ONL

CLASSIFICATION C1: Public Information
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SUBJECT Harmonic impedance loci at 66 kV connection point, location 'Hollandse Kust Noord' and 'Hollandse Kust West-alpha'

REPORT
DECISION

1. Introduction

This memo specifies the root loci of the calculated harmonic impedances, with reference point at the 66 kV offshore grid busbar. These root loci can be used by the wind farm developers for initial calculations to firstly verify their compliance with the harmonic requirements.

2. Starting points

The calculations are performed based on the following starting conditions:

- The calculations are performed for the offshore wind farm connections to the platforms 'Hollandse Kust Noord' (HKN) and 'Hollandse Kust West'-Alpha (HKW-Alpha). Both platforms are connected to the 380 kV substation Beverwijk.
- The modelled 66 kV inter array collection grid is based on a reference grid. This grid is used for both platforms.
- The modelled 380 kV onshore grid for the year 2025 is used.
- The calculations have been performed for the platform HKW-Alpha, but are also valid for the platform HKN.
- The calculations have been performed for two offshore cases:
 - o Case 1: the platform HKW-Alpha is energised via two 220 kV export cables (normal operating condition), see figure 2;
 - o Case 2: the platform HKW-Alpha is energised via one 220 kV export cable, and the 66 kV busbars are interconnected (abnormal operating condition), see figure 3;
- The harmonic impedance is calculated seen from 66 kV busbar "Alpha-A", with the 66 kV array cables connected to this busbar "Alpha-A" out of service.
- The harmonic impedance is calculated up to the 50th harmonic (2500 Hz). The calculated harmonic impedances for both cases, are divided into four harmonic order sets ($h = 1-5, 5-9, 9-20, 20-30$ and $30-50$). For each set the root locus is defined, including all relevant 'N-0', 'N-1' and 'N-2' onshore grid configurations. The results for case 1 and case 2 are combined in one table.

3. Results

For each onshore grid situation and harmonic order set the outline of the area of the grid impedances is defined. For each area the following general layout of the outline, see figure 1, is valid, specified by the values φ_{min} , φ_{max} , R_{min} , R_{max} , X_{min} , and X_{max} as presented in table 1.

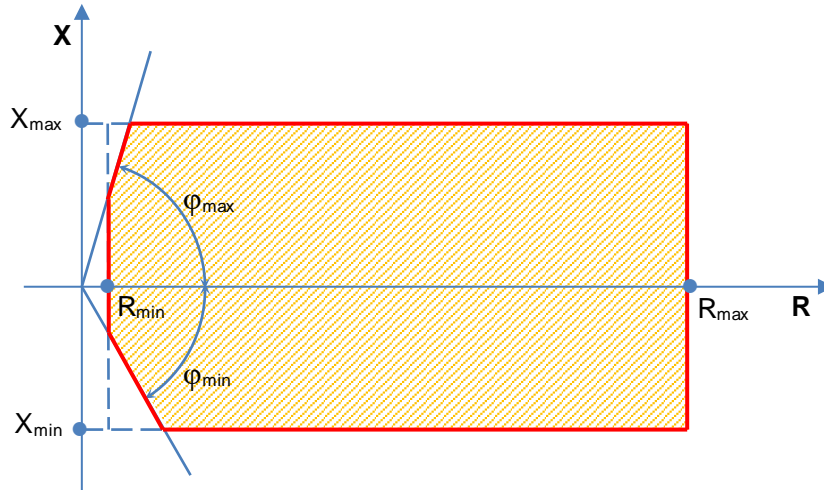


figure 1: General layout outline (in red) of the harmonic impedance profile:

table 1: Defined values for the impedance profiles

harmonic order	defined values					
	φ_{min} (°)	φ_{max} (°)	R_{min} (Ω)	R_{max} (Ω)	X_{min} (Ω)	X_{max} (Ω)
$1 \leq h < 5$	84	90	0,03	0,1	0	2
$5 \leq h < 9$	37	90	0,04	3,9	0	6
$9 \leq h < 20$	-55	90	0,04	32	-12	19
$20 \leq h < 30$	-77	90	0,07	30	-17	13
$30 \leq h < 50$	-82	90	0,11	2,1	-9	22

Remark: the indicated area in figure 1 shall normally be defined by all parameters (φ_{min} , φ_{max} , R_{min} , R_{max} , X_{min} and X_{max}), but in some cases the angle φ_{max} or φ_{min} does not cross the outline of the underlying R-X rectangle and may be ignored.

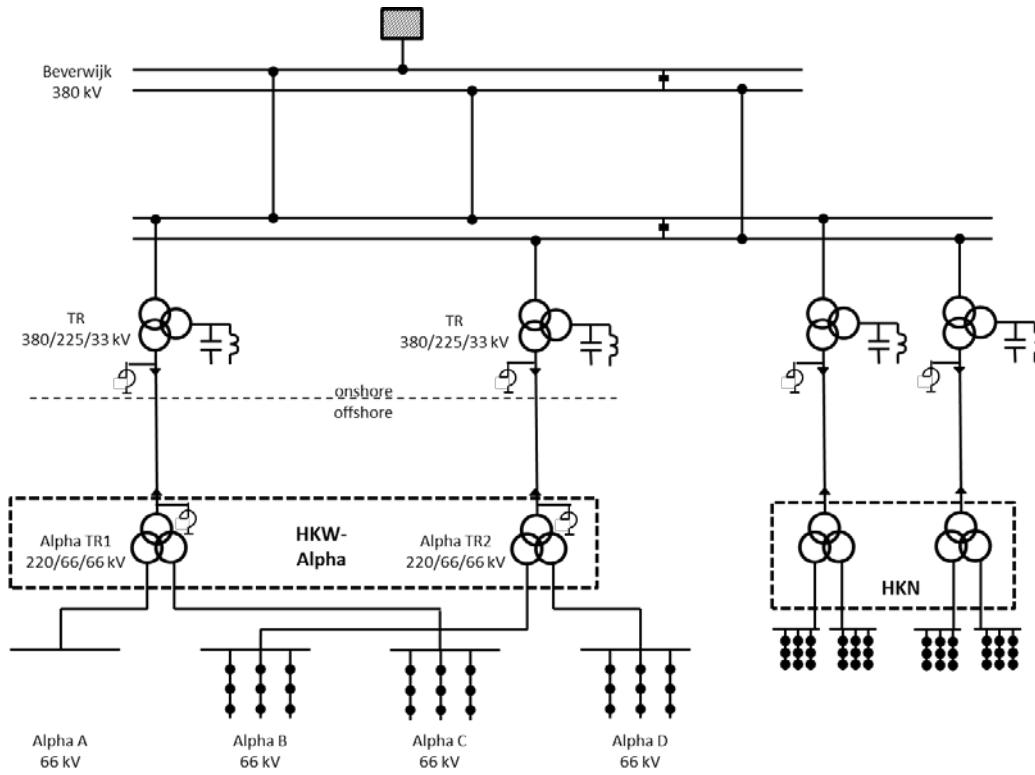


figure 2: grid layout platform HKW-Alpha and HKN (normal operating condition)

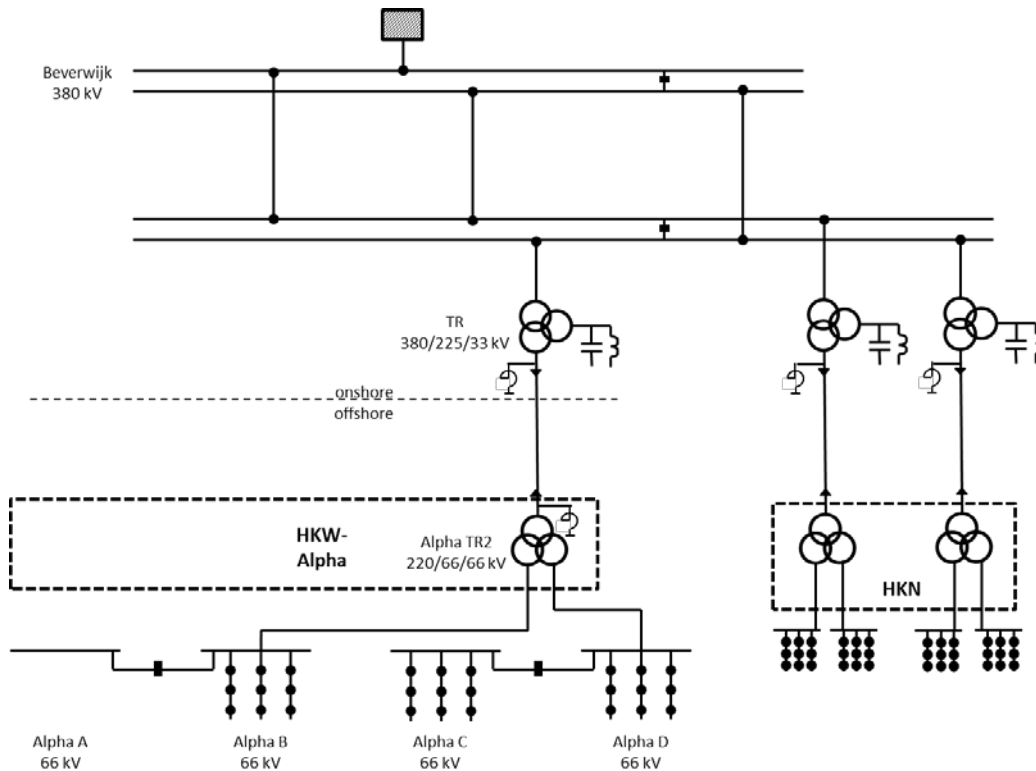


figure 3: grid layout platform HKW-Alpha and HKN (abnormal operating condition)