

TO TenneT-ONL

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SUBJECT Harmonic impedance loci at EHV-grid connection point for the offshore areas HKN and HKW-alpha

REPORT



DECISION



## 1. Introduction

This memo specifies the root loci of the calculated harmonic impedances at the 380 kV substation Beverwijk, the connection point to the onshore grid. 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). This platform will be connected to the 380 kV substation Beverwijk.
- The modelled 380 kV onshore grid for the year 2025 is used.
- The harmonic impedance is calculated at the 380 kV busbar at the substation Beverwijk, but with the platform disconnected.
- The harmonic impedance is calculated up to the 50<sup>th</sup> harmonic (2500 Hz). The calculated harmonic impedances are divided into five harmonic order sets ( $h = 1-13, 13-18, 18-33, 33-38$  and  $38-50$ ). For each set the root locus is defined, including all relevant 'N-0', 'N-1' and 'N-2' onshore grid configurations.

### 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  $\varphi_{\min}$ ,  $\varphi_{\max}$ ,  $R_{\min}$ ,  $R_{\max}$ ,  $X_{\min}$ , and  $X_{\max}$  as presented in table 1.

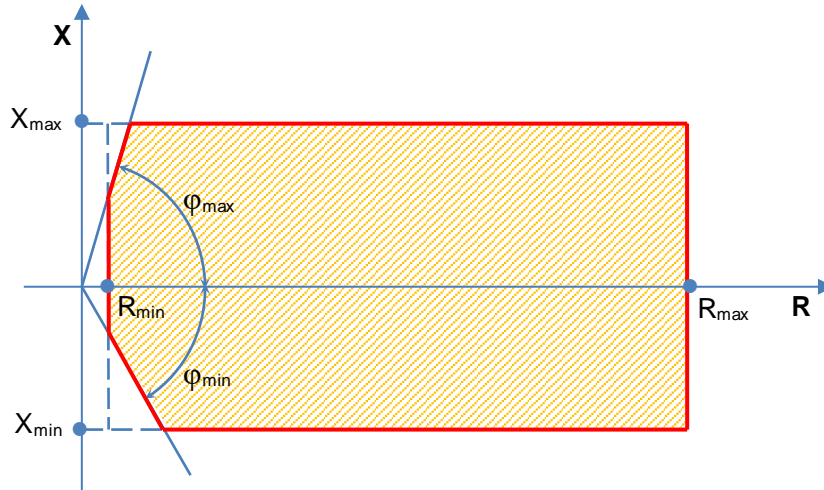


figure 1: General layout outline (in red) of the harmonic impedance profile:

table 1: Defined values for the impedance profiles

| harmonic order   | defined values          |                         |                   |                   |                   |                   |
|------------------|-------------------------|-------------------------|-------------------|-------------------|-------------------|-------------------|
|                  | $\varphi_{\min}$<br>(°) | $\varphi_{\max}$<br>(°) | $R_{\min}$<br>(Ω) | $R_{\max}$<br>(Ω) | $X_{\min}$<br>(Ω) | $X_{\max}$<br>(Ω) |
| $1 \leq h < 13$  | -61                     | 82                      | 1                 | 142               | -64               | 74                |
| $13 \leq h < 18$ | -84                     | 83                      | 2                 | 422               | -224              | 226               |
| $18 \leq h < 33$ | -86                     | 89                      | 1                 | 337               | -164              | 274               |
| $33 \leq h < 38$ | -71                     | 86                      | 4                 | 596               | -362              | 282               |
| $38 \leq h < 51$ | -87                     | 89                      | 2                 | 419               | -350              | 448               |

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