# Werkaarders in hoogspanningslijnen

## CIGRE B2 Themadag op 5 maart 2025

2024 Paris Session

Paper ID – 10522
B2 Overhead lines
PS1: Challenges from renewables integration and influences of energy transition on OHL

**Considerations for temporary earthing in compact and heavy loaded OHL**


Ebbo DE MEULEMEESTER *
DNV
The Netherlands
ebbo.demeulemeester@dnv.com

Ranjan BHUYAN
TenneT TSO
The Netherlands
ranjan.bhuyan@tennet.eu

Dhruvi SHUKLA
DNV
The Netherlands
dhruvi.shukla@dnv.com

Pragati KIDAMBI
DNV
The Netherlands
pragati.kidambi@dnv.com

Christiaan ENGELBRECHT
DNV / Technical University Delft
The Netherlands
c.s.engelbrecht@ieee.org


# Werkaarders in hoogspanningslijnen

*Werkaarder = "Portable earthing device" (PED)*


Ebbo de Meulemeester / Principal Consultant T&D Technology


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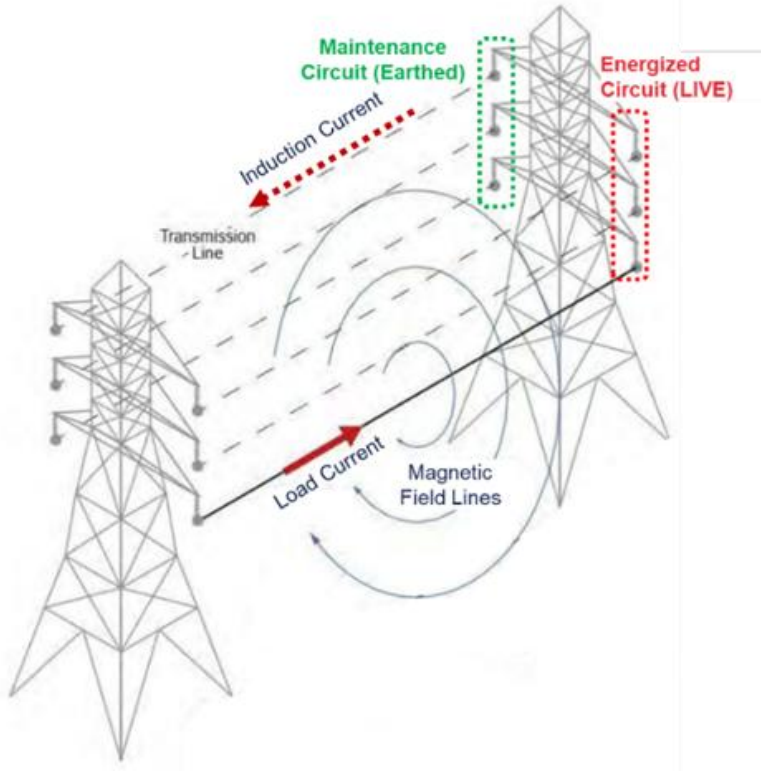
# Introduction

- Trends in OHL due to energy transition:
  - Higher loading : Increased induced currents and voltages
  - Compact design : Increased coupling between phases
  - Multiple circuits and multiple voltage in one tower

- TenneT and DNV investigated potential effects:
  - Voltage unbalance : grid code limits
  - Protection malfunction
  - Substation earthing switches
    - Induced currents and voltages may exceed values according IEC
  - Personal safety for line workers
    - Induced currents and voltages in PED
    - Subject of Cigre paper 2024 and this contribution



# Introduction

- Trends in OHL due to energy transition:
  - Higher loading : Increased induced currents and voltages
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- Temporary earthing in OHL with  Portable Earthing Device (PED)
- Video of PED removal in 765 kV OHL
  - 765kV OHL
  - 2 PEDs in parallel
  - At removing of the last, arcing occurs

# Temporary earthing in OHL

- Safe working in OHL
  - Circuit earthed at both ends in the substation
  - Other circuits in tower may remain in service
  - Application of temporary earthing at work tower (to limit voltage at work location)
  - Application of bracket earthing in neighbouring towers
- Temporary earthing by Portable Earthing Device (PED)
  - Stick type
  - Drop-on type (valaarder)
- PED IEC 61230 requirements
  - Mechanical requirements
  - Short-circuit withstand capability
  - No other electrical requirements

PED stick-type

PED Drop-on type (valaarder)

# ATP simulations - Induced PED currents & voltages

- PED current : current through PED
- PED voltage : voltage between tower and (HV) conductor at the location where the PED will be installed

| Mast configuratie | PED in circuit | Design current | Transpos. distance | Maximum PED voltage | Maximum PED current |
|---|---|---|---|---|---|
| | | [A] | [km] | [V] | [A] |
| **WITH transpositions** | | | | | |
| **Donau - 2x 400 kV (existing)** | 400 kV | 2500 | 16.7 | 1125 | 235 |
| **Donau - 2x 400 kV** | 400 kV | 4000 | 16.7 | 1800 | 375 |
| **Donau - 2x 150 kV** | 150 kV | 1925 | 16.7 | 1000 | 150 |
| **Moldau - 2x 400 kV / 2x 150 kV** | 400 kV | 4000 / 1925 | 16.7 / 5.6 | 1750 | 400 |
| **Moldau - 2x 400 kV / 2x 150 kV** | 150 kV | 4000 / 1925 | 16.7 / 5.6 | 1550 | 450 |
| **WITHOUT transpositions** | | | | | |
| **Donau - 2x 400 kV** | 400 kV | 4000 | none | 10 | 10 |
| **Moldau -2x 400 kV / 2x 150 kV** | 400 kV | 4000 / 1925 | none | 10 | 5 |
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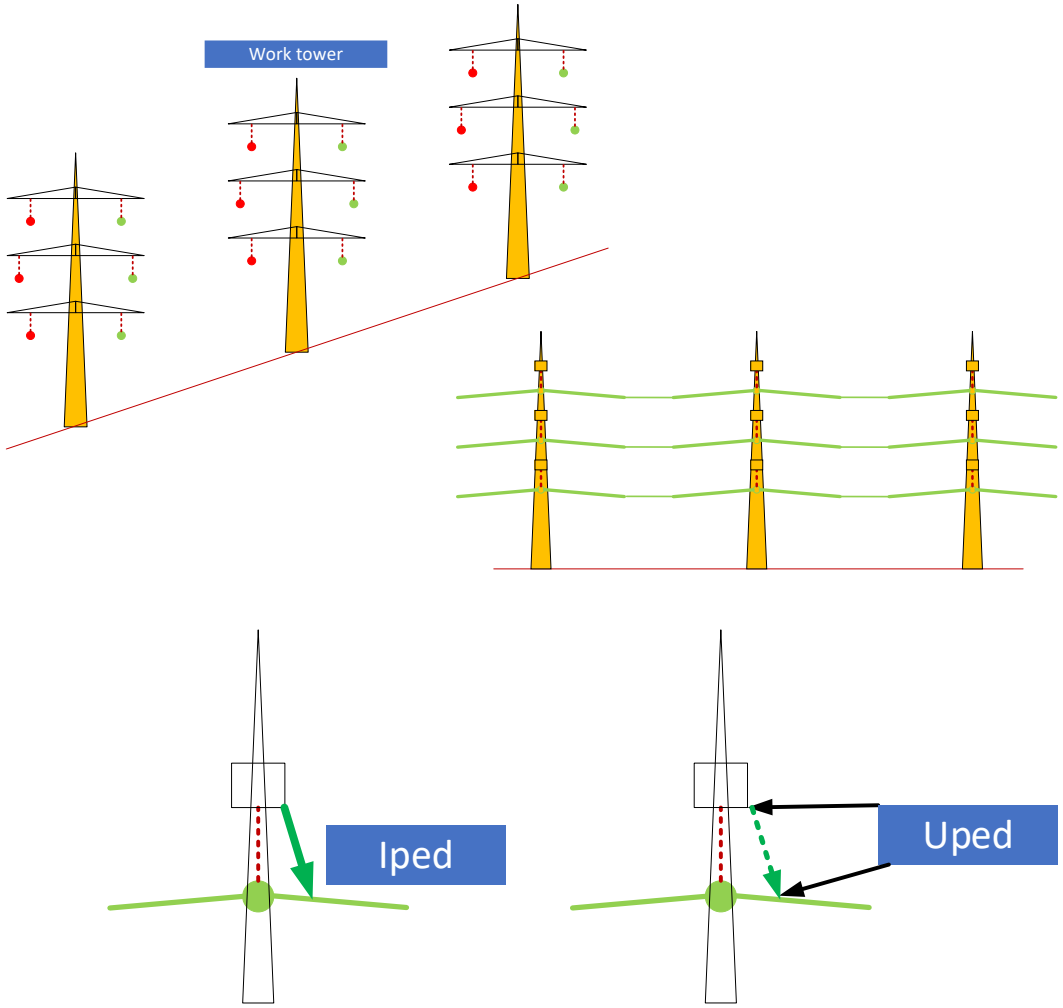

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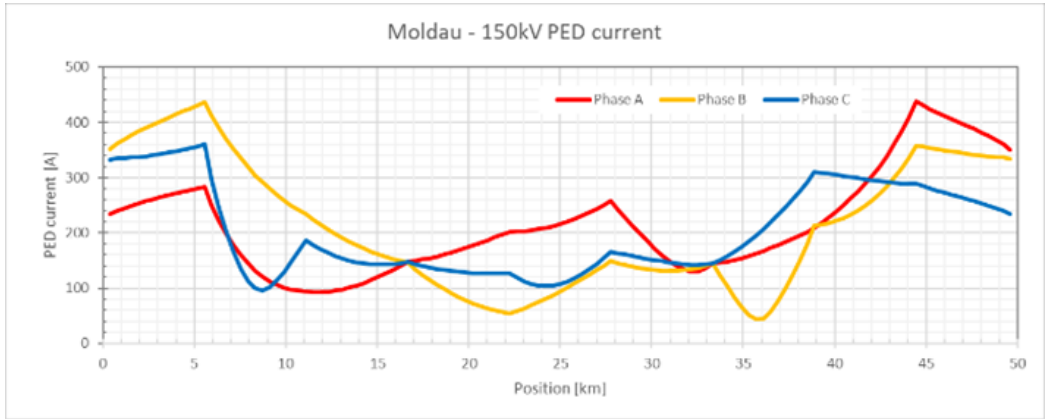
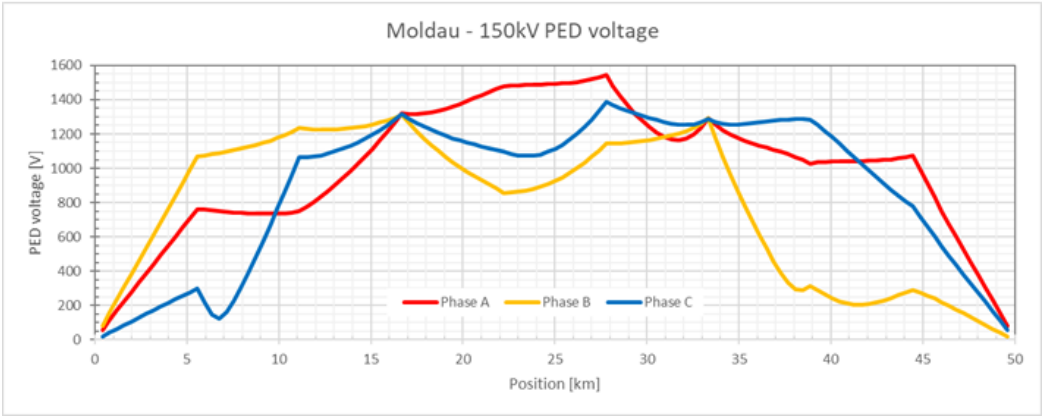
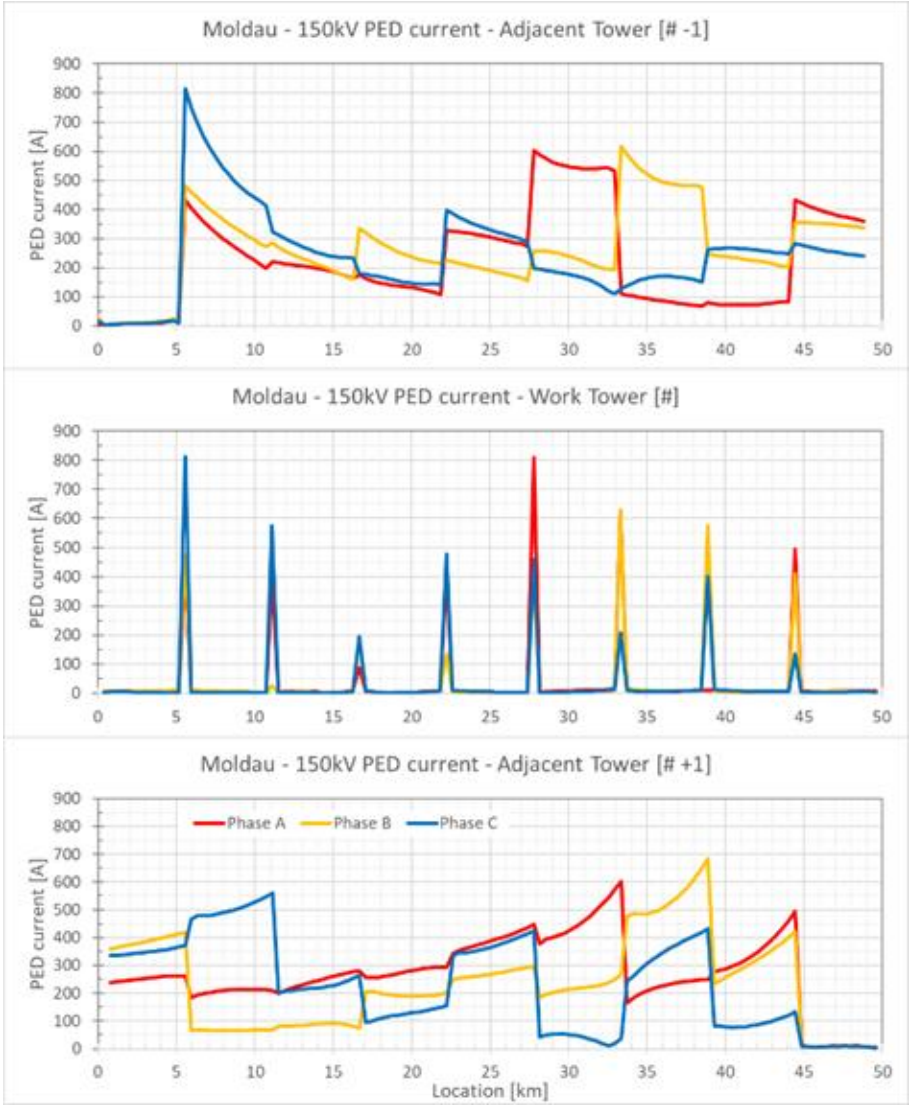



- ➢ PED currents and voltages can be high in circuits with transpositions
- ➢ PED currents and voltages are very low in circuits without transpositions

# Impact Bracket PEDs (in neighboring towers)

- Bracket PEDs (in neighboring towers) have large influence on the PED current in the work tower
  - Bracket PED currents are higher than in the (work tower) PED (up to 825 A)
  - Work tower PED current reduces to (almost) negligible value), if bracket PEDs are applied
  - Unless the work tower is transposition tower
- Maximum PED current in case of application of bracket PEDs is 825 A (in 150kV Moldau circuit)



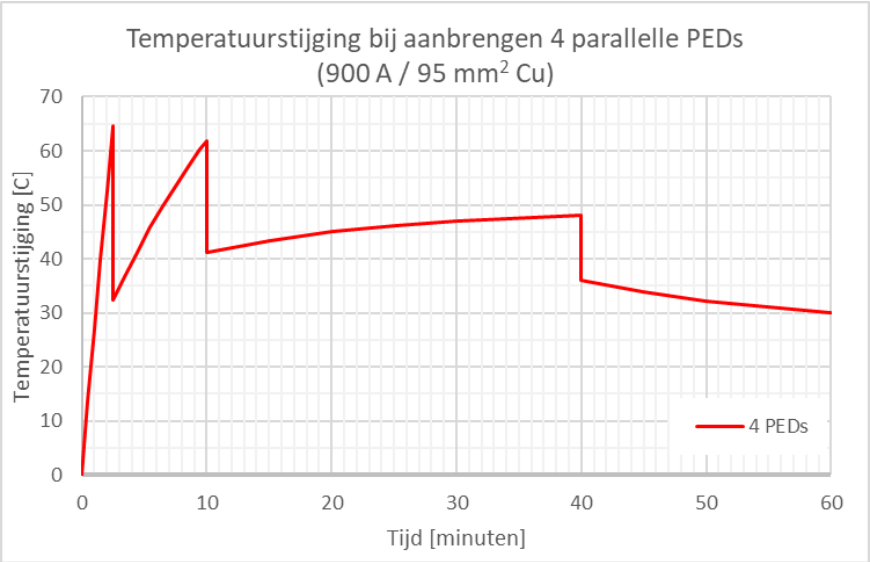

- ➢ Highest PED currents occur in bracket towers
- ➢ PED currents and voltages DO NOT decrease due to PEDs in bracket towers

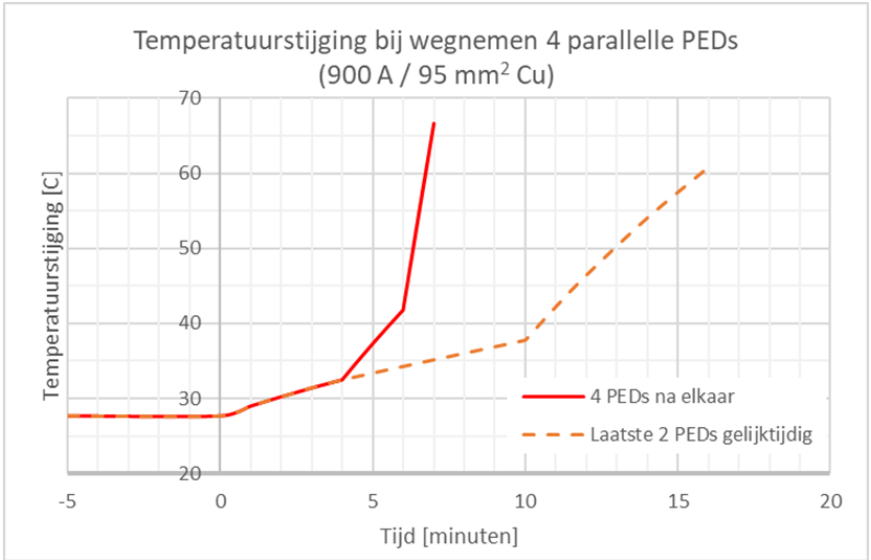
# Temperature rise PED

- Typically, earthing cables of 35 or 50 sqmm are used and upto 2 in parallel. Estimated (continuous) current carrying capability for earthing cables (in parallel) is:

| Number parallel PED | Maximum current[A] | | | |
|---|---|---|---|---|
| | 35 $mm^2$ | 50 $mm^2$ | 70 $mm^2$ | 95 $mm^2$ |
| 1 | ≤ 125 | ≤ 150 | ≤ 200 | ≤ 250 |
| 2 | | ≤ 300 | ≤ 400 | ≤ 500 |
| 3 | | ≤ 450 | ≤ 600 | ≤ 750 |
| 4 | | | ≤ 800 | ≤ 1000 |

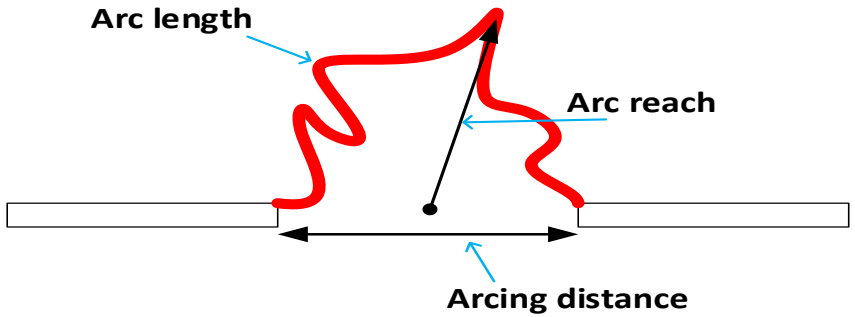
- Induced PED currents are continuous currents upto 825 A
- More PEDs with higher cross-section have to installed in parallel for highly loaded circuits
- Special attention needed for removal (and installation) of parallel PEDs:
  - Need to be removed within a short (defined) time
  - Otherwise temperature of remaining PEDs will rise rapidly



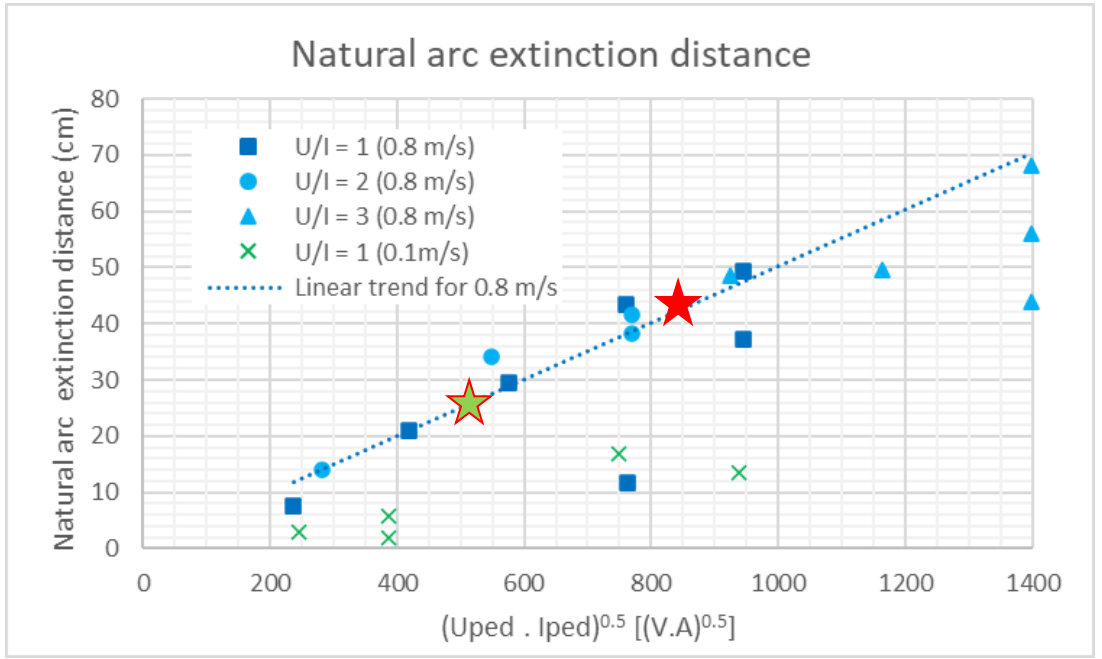



# Arcing during removal (or installation) of PED

- During removal of a PED, an arc will occur due to the interruption of the PED current and the PED (recovery) voltage
- The arc will extinguish at the so-called “natural arc extinction distance”: distance at which free burning arc (in air) will extinguish without external or additional support.




- Tests have been perfomed with (dummy) PED (Damstra lab, Eaton, Hengelo)
- HS video – PED arc (ca. 2000 V/ 500 A)

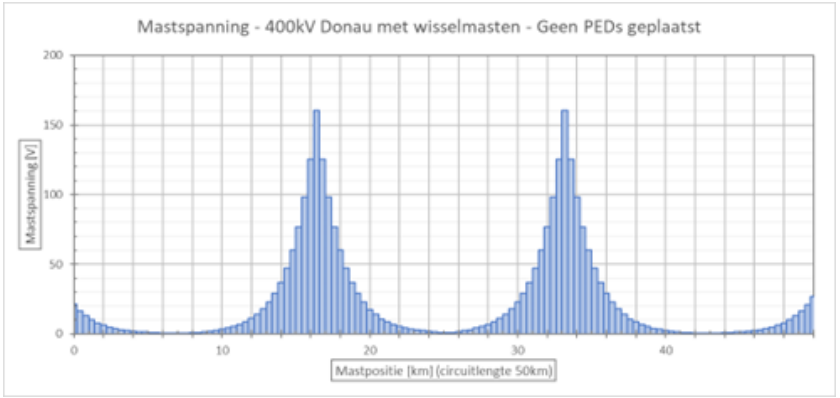


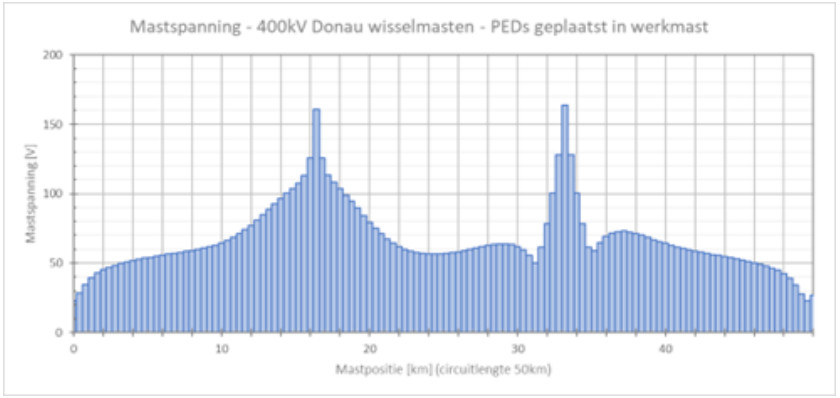

- User experience: 2x 400kV / 2500 A :
  - PED current / voltage = 1125 A / 235 V
  - Natural arc extinction distance = ca. 25 cm
- Maximum (from calculations) :
  - PED current / voltage= 1750 A / 400 V
  - Natural arc extinction distance = ca. 45 cm

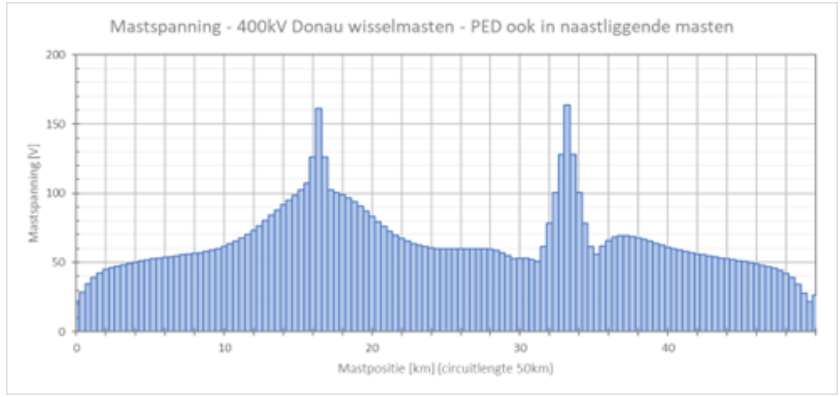
# Tower step & touch voltage

- Step & touch voltage are determined by tower voltage and voltage profile
  - Step & touch voltage < tower voltage
- The voltage profile varies with the tower conditions (construction, soil resistivity, …)
- Comparison is made for tower voltages without and with application of PEDs

- The tower voltages change due to the application of PEDs
- But, the maximum values for without and with PED are the same



# Conclusions

- Heavy loaded OHL and/or multi-circuit multi-voltage OHL high induced currents in the PED or across the PED (location) may occur in circuits with transpositions
  - PED voltage up to 2000V
  - PED current up to 800 A
- PED currents and voltages in circuits without transpositions are low
- IEC standards for PED DO NOT take into account effects of high PED currents and voltages:
  - Temperature rise
  - Length of arcing and related safety issues / perception
  - Effect of arcing (ageing)
- High PED currents require
  - Several PEDs to be installed in parallel
  - Removal and application of parallel PEDs have to be realized in a defined (short) time.
- Step & touch voltage do not to change due to application of PED

# Thanks

ebbo.demeulemeester@dnv.com
+31.6.1506.3320

**www.dnv.com**