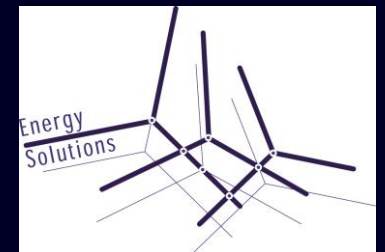


## Overview of harmonic compliance studies of large windfarms in The Netherlands

C4 PS1 Q1

On the subject of management of PQ in evolving power systems,  
what are the difficulties/drawbacks with the existing approaches?

Daniël Vree – The Netherlands  
**Energy Solutions**



# Overview of harmonic compliance studies of large (type D) windfarms in The Netherlands

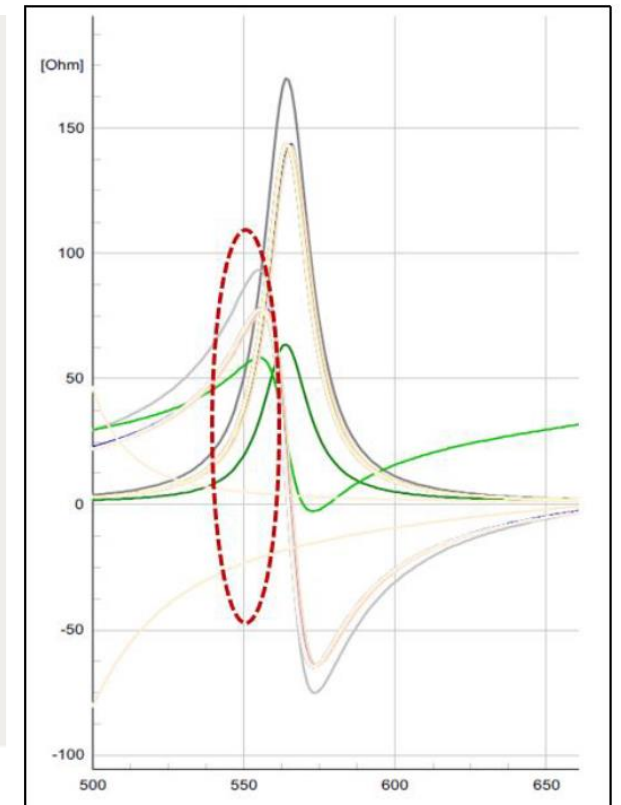
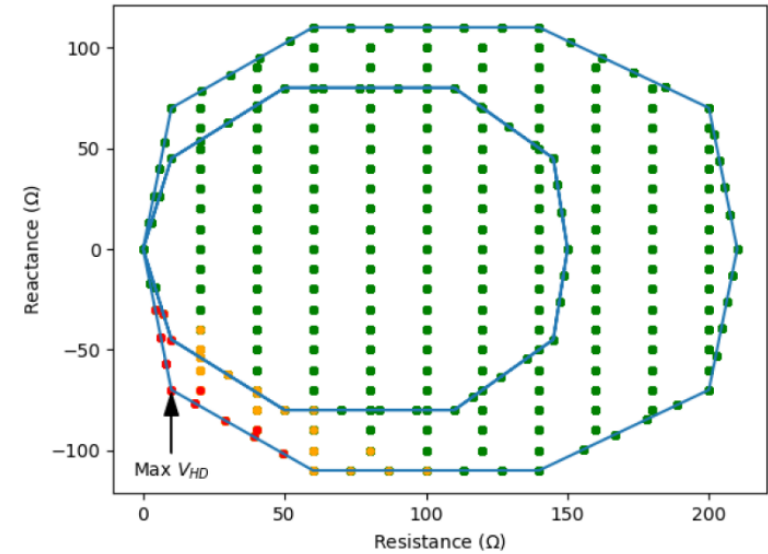
In support of various wind farm (WF) developers, Energy Solutions performed as well as reviewed many pre-connection harmonic compliance studies of type D WF in the past years.

Main characteristics of the studies:

- WF power level between 80 MW and 400 MW, 15 – 90 Wind Turbine Generators
- Connection point voltage level: 50 kV – 150 kV
- Scope: Wind Turbine Generators (WTG) + array cables, step up transformer. export cable (up to 55 km)
- Assessment methodology:
  - TSO /DSO provides impedance envelopes and limits for each harmonic order
  - WF to determine maximum voltage distortion  $U_{hi}$  (%) per harmonic order

# Assessment practice

- Some low order harmonic orders usually exceed limits
- Compliance still can be achieved by:
  - TSO/DSO checking exceedance plot on actual loci
  - $U_{hi}$  reduced by phase angle randomization (even h only)
- Exceedance plot example (h = 11):
  - grid impedance area (R / X) where WF is not compliant
  - Assessment of impedance scans (by WF or TSO/DSO)
  - Chance of resonance is usually very low (e.g. related to an N-2 grid outage situation)
  - Operational agreement between wind farm and TSO/DSO accepting the risk:
  - If voltage distortion at PCC would exceed the planning level, the wind farm shall reduce power or switch-off.



## Conclusions and possible improvements

- Filter installations at WF could be avoided on all assessed WF, but:
  - Administration and workload for both TSO/DSO and WF is high
  - Operational agreement has to be implemented
- Only limited converter/WTG OEM provide supporting measurements to substantiate phase angle randomization for even and triple harmonic orders.
- Possible improvements:
  - TSO/DSO to provide envelopes for each individual harmonic order separately for N, N-1 and N-2 grid states. Alternatively, impedance scan data could be provided.
  - As a standard, measurements on prevailing angle ratio (IEC61400-21) including substantiation how a low PAR of a certain harmonic order can be used to randomize phase angles in harmonic load flow simulations