Compliance activities

Compliance activities in relation to Connection Requirements Wind Farms
System Operations

- Version V3.0 January 2014 -

Inhoudsopgave

1. Scope

This document defines the compliance activities for the connection of Wind Farms to the Dutch Transmission System Operation's perspective. The activities are based on the document Wind Farm Connection Requirements-General Version 5.7, hereafter called 'TenneT requirements (TR)'

2. General remarks

Unless stated otherwise, compliance tests, simulations and audits will be applied at the Connection Point.

The operator of the Power Park Module (PPM) is responsible to justify compliance regarding the requirements.

In addition to these tests and simulations, the operator of the PPM delivers if necessary the relevant technical data of the PPM to prove that the PPM is capable to fulfill the requirements.

Table 1 provides an overview of the compliance procedure starting at the design phase and ending at full operation.

Table 1: overview compliance test procedure

(1)	Design phase	- Technical data (section 3.2) - Load flow study (section 5.2) - Dynamic study (section 5.3) - Power / Voltage Quality simulations (section 5.55) - **Interim statement of compliance,** - **Interim Operational Notification**
(2)	Building phase	- Temporary setting voltage controllers - Temporary no remote control by TenneT - Initial power quality measurement (section 5.56) - Above 60 MW installed: Interim on site tests (section 5.4) - Above 60 MW installed Interim power quality measurements, if required(section 5.6) - **Interim statement of compliance,** - **Interim Operational Notification**
(3)	Full trial operation	- On site test (section 5.4) - Final power quality measurement (section 5.56) - **Statement of compliance (see Appendix)** - **Final Operational Notification**
(4)	Full operation	- Normal settings voltage controller - Remote control by TenneT if necessary: o voltage control o emergency MW shed

Depending on the duration of the building phase TenneT may limit the time without remote control.

The operator of the PPM is responsible for the tests, simulations and technical specifications. The operator shall prepare procedures for the tests and the reports with simulations starting points and results for approval to TenneT, ultimately 6 weeks before the scheduled date for the tests. It is advised however to submit the report with simulation results and the 'TenneT WTG test report' early in the project (e.g. before ordering main components) to avoid delays when report or test is not approved by TenneT.

Test reports and Statement of Compliance shall be submitted to TenneT within 4 weeks after the tests have been performed for approval.

After approval of the test procedures by TenneT and at least 2 weeks before the commencement of the test the operator shall indicate to TenneT the test dates. Final test dates shall be agreed upon.

After receipt of every required report such as mentioned in previous paragraphs TenneT will inform the operator of the PPM within 4 weeks on approval of the reports. In case a revision of the report is required, TenneT will inform the operator of the PPM within 2 weeks after receipt of the revised report.

TenneT may involve a third party as their representative for the compliance activities (review of procedures, test reports, specifications, Statement of Compliance and witnessing of the tests). TenneT is responsible for the Interim and *Final Operational Notification.*

3. Information exchange related to the compliance activities

3.1 Main documents

From operator of the PPM to TenneT:

- Results and details of physical tests;
- Results and details of simulations;
- Results and audit of technical specs;
- Statements of Compliance.

From TenneT to the operator of the PPM:

- Interim Operational Notifications
- Final Operational Notification.

3.2 Technical data

3.2.1 Wind park

- Single line diagram including main parameter
  - *cables including type information and length;*
  - *transformers;*
  - *switchgears;*
  - *all reactive power compensation equipment (including reactive power compensation equipment installed at wind turbine level);*
- Step up transformer:
  - *type data sheet*
  - *tap changer control settings;*
- Reactive power compensation equipment
  - *type data sheet;*
  - *operational concept for reactive power compensation (functional description);*
- Functional description of wind park controller;
- Protection setting (voltage, frequency, current, reactive and active power).

3.2.2 Wind turbine

3.2.2.1 General Information

- Wind turbine: type datasheet including information as in IEC 61400-21 Annex A.1;
- Wind turbine transformer;
    - *type datasheet;*
    - *tap changer setting;*
- Tower cable type and length (if not included in single line);
- Protection setting (voltage, frequency, current, reactive and active power).

3.2.2.2 Tests of wind turbine type

A report (hereafter called 'TenneT WTG test report') shall cover information from type tests according to IEC 61400-21 as well as information on additional tests and information required by TenneT. In detail the 'TenneT WTG test report' shall include:

- Reactive power capability including PQ and QV diagrams based on measurements;
- Report on fault ride through capability according to requirements of TenneT including measurements as specified in section 5.1.1.
- Power quality measurement;
    - *Voltage fluctuations according to IEC 61400-21 Annex A.2;*
    - *Harmonic and interharmonic currents according to IEC 61400-21 Annex A.3;*
- Test reports for short and long term operation during over and under frequency according to section 2.1 of the <u>TR;</u>
- Test reports for short and long term operation during over and under voltage according to section 2.1 of the <u>TR;</u>

All in this section mentioned measurements and tests shall be performed or witnessed by an independent party.

The 'TenneT WTG test report' also applies to other active components (such as FACTS devices) if these components actively contribute by means of control functions to

- the fault ride through performance at the Connection Point
- short and long term operation during over and under frequency as well as during over and under voltage

3.2.3 Software model

To perform grid stability calculations, information according 'netcode' article 2.5.7.4 and 2.5.7.5 shall be delivered, as a result of that:

- Software model of wind turbine and wind park (PPM) controller and any other active component[1] in PSSE and Power Factory format for dynamic simulations including manual and model controller settings to be applied shall be supplied;
- Report on validation of software models shall be supplied.
- Dynamic simulation models of a wind turbine at the connection terminals and wind power plant/ power plant module shall be described by means of generic terms and parameters given by IEEE or IEC 61400-27 series.
- To evaluate protection settings, Digsilent and PSSE model as defined TR section 'Requirements regarding Voltage stability of Power Park Modules '.

[1] A software model of an active component will only be required if the component actively contributes to the fault ride through performance of the wind park.

4. Compliance activities related to the requirements

4.1 Frequency and Voltage Envelope

'TenneT WTG test report' in combination with a load flow study shall be submitted in order to prove this requirement.

4.2 Steady-State Reactive Power capability P/Pmax – Q/Pmax

The PPM demonstrates its technical capability to inject and absorb reactive power as defined in section 2.2 of the TR.

For this purpose load flow study results shall be submitted using information from 'TenneT WTG test report'.

The functional ability of the PPM to avoid reactive power injection for active power production of less than 10% Pmax according to section 2.2 of the TR shall be demonstrated in a physical test.

4.3 Steady-State Reactive Power capability V- Q/Qmax

The PPM demonstrates its technical capability to inject and absorb reactive power as defined in section 2.3 of the TR. For this purpose load flow studies shall be carried out and results submitted using information from 'TenneT WTG test report'.

4.4 Reactive Power Control Modes

The PPM shall demonstrate sequentially its capability to operate in regarding TR section 2.4

- Voltage control mode
- Reactive control mode
- Power factor control mode.

The different modes are tested by step-changing of the set point in the full-range.
Test will be executed regarding the EHV-grid constraints.

- Voltage control mode, verification of
    - Droop , dead band and range
    - Accuracy of regulation
    - Reaction time of activation
- Power Factor Control Mode, verification of
    - Range
    - Accuracy of regulation
    - Reaction time of activation
- Reactive control mode, verification of
    - Range
    - Accuracy of regulation
    - Reaction time of activation

4.5 Requirements regarding Voltage stability

'TenneT WTG test report' and dynamic simulations results shall demonstrate the PPM’s capability of fast acting reactive power contribution, referring to the requirements for fast acting voltage control (FAVC) as defined in section 2.5 of the TR.

4.6 Requirements regarding Fault ride through capability

'TenneT WTG test report' and dynamic simulations and results shall demonstrate the PPM’s capability to withstand a fault referring to the FRTC requirements as defined in section 2.6 of the TR.

4.7 Active power control

The PPM shall demonstrate its capability to follow the active power set point (in 5 steps). See section 3.1 of the TR.

- Activation of 100 % change in active power

4.8 Active Power Control for Overfrequency

Simulated frequency deviation signals at the Connection Point shall be injected to perform the test (5 steps) See section 3.2 of the TR.

- Activation of 100 % of change in (actual generated) active power

4.9 Power / voltage quality

Netcode, section 2.1.5.8: "*De aangeslotene toont aan dat bij machines, toestellen, materialen en onderdelen in elektrische installaties of aangesloten op elektrische installaties waarvan de elektromagnetische comptabiliteit niet is vastgelegd in een wettelijke regeling, op het netaansluitpunt wordt voldaan aan de voorschriften ter zake van elektromagnetische compatibiliteit die door de netbeheerder zijn vastgesteld*"

This means, the connectee shall demonstrate that machines, devices, materials and parts in electrical installations or connected to electrical installations where the electromagnetic compatibility is not determined in a rule enforced by law, at the connection point, specifications of the grid operator are satisfied regarding electromagnetic compatibility.

4.9.1 Fluctuating voltages

The PPM shall demonstrate its capability to limit their fluctuating emissions towards the HV and EHV power system.

4.9.2 Harmonics

The PPM shall demonstrate its capability to limit their distorting harmonic emissions towards the HV and EHV power system.

4.9.3 Transient overvoltage

The PPM shall demonstrate its capability to limit their transient overvoltage emissions towards the HV and EHV power system.

5. Detailed compliance descriptions

section	title	TenneT WTG test	Load flow	Dynamic simulation	on-site test	power quality simulations	power quality measure-ments
4.1	Frequency and Voltage Envelope	■	■				
4.2	Steady-State Reactive Power capability P/Pmax - Q/Qmax	■	■		1)		
4.3	Steady-State Reactive Power capability V - Q/Qmax	■	■		2)		
4.4	Reactive Power Control Modes				■		
4.5	Requirements regarding voltage stability	■		■			
4.6	Requirements regarding Fault Ride Through Capability	■		■			
4.7	Active Power Control				■		
4.8	Active Power Control for Overfrequency				■		
4.9	Power / voltage quality,	■				■	■

1) Onsite tests included in on-site tests for *reactive power control modes* and *active power control.*

2) Onsite tests included in on-site tests for *reactive power control modes.*

5.1 Tests of wind turbine type

Tests on the wind turbine shall be performed in order to provide the 'TenneT WTG test report' as specified in section 3.2.2.2.

The required fault ride through test according to TenneT requirements is specified in 5.1.1.

5.1.1 Fault ride through capability of wind turbine

Objective:
- To prove fault ride through capability of the wind turbine according to sections 2.5 and 2.6 of the TR

Procedure:
- Tests shall be executed according to IEC 61400-21 Chapter 7.5 and active voltage support by fast reactive current injection according the section 2.5 of the TR. Deviating from IEC 61400-21 the test shall be executed for the following fault scenarios
  - Fault voltage: lower than 5% of rated voltage, fault duration more than 300 ms
  - Fault voltage: between 40% and 50% of rated voltage, fault duration more than 1750 ms
  - Fault voltage: between 70% and 80% of rated voltage, fault duration more than 2700 ms
- Tests shall be executed for an active power output of the wind turbine of 20 %-35% and higher than 80% of rated wind turbine power.
- Tests shall be executed for symmetrical and unsymmetrical faults.
- Applied k-factor [2]shall be equal to or higher than 2

Documentation / measured parameters:
- At the wind turbine terminals (primary and secondary side of wind turbine transformer): P, Q, V, I
- Applied parameter settings of wind turbine controller
- K-factor at wind turbine and values including time step applied in order to calculate the k-factor
- Check calculated parameters with protection settings (Voltage, Current, Power) at wind turbine generator

Evaluation Criteria:
- K-factor according to controller setting
- Fault ride through capability
- No protection trip.

[2] K-factor is defined in section 2.5 of connection requirements document.

5.2 Load Flow Study

Objective:
- Proof of compliance with operational voltage envelope according to section 4.1
- Proof of compliance regarding reactive power capability according to sections 4.2 and 4.3

Procedure:
- Load flow calculations shall reproduce the in Table 2 mentioned scenarios at the Connection Point considering the reactive power capability of the wind turbines. Figure 1 visualizes the calculations cases referring to P/Pmax - Q/Pmax profile and V - Q/Qmax according to sections 2.2 and 2.3 of the TR.
- Reactive power compensation equipment shall be considered according to the implemented operational settings of the wind park controller (if applicable) or alternatively according to applied operational concepts.
- Q max for reactive power absorption respective injection shall be complied with in the first two calculation cases as described in Table 2.

Table 2: calculation cases for load flow study

Calculation case	U	P	Q	Reference to TR
1	100%	100% Pmax	Q/Pmax=-0.4	*Section 2.2 (P/Pmax - Q/Pmax profile)*
2	100%	100% Pmax	Q/Pmax=0.35	*Section 2.2 (P/Pmax - Q/Pmax profile)*
3	100%	20% Pmax	Q/Pmax=0.35	*Section 2.2 (P/Pmax - Q/Pmax profile)*
4	100%	10% Pmax	0	*Section 2.2 (P/Pmax - Q/Pmax profile)*
5	100%	10% Pmax	Q/Pmax=-0.4	*Section 2.2 (P/Pmax - Q/Pmax profile)*
6	110%	100% Pmax	-100% Qmax	*Section 2.3 (V - Q/Qmax profile)*
7	110%	100% Pmax	0	*Section 2.3 (V - Q/Qmax profile)*
8	90%	100% Pmax	100% Qmax	*Section 2.3 (V - Q/Qmax profile)*
9	90%	100% Pmax	-25% Qmax	*Section 2.3 (V - Q/Qmax profile)*
10	80 %	100% Pmax	open	*Section 2.1 (V, f - envelope)*
11	115 %	100% Pmax	open	*Section 2.1 (V, f - envelope)*

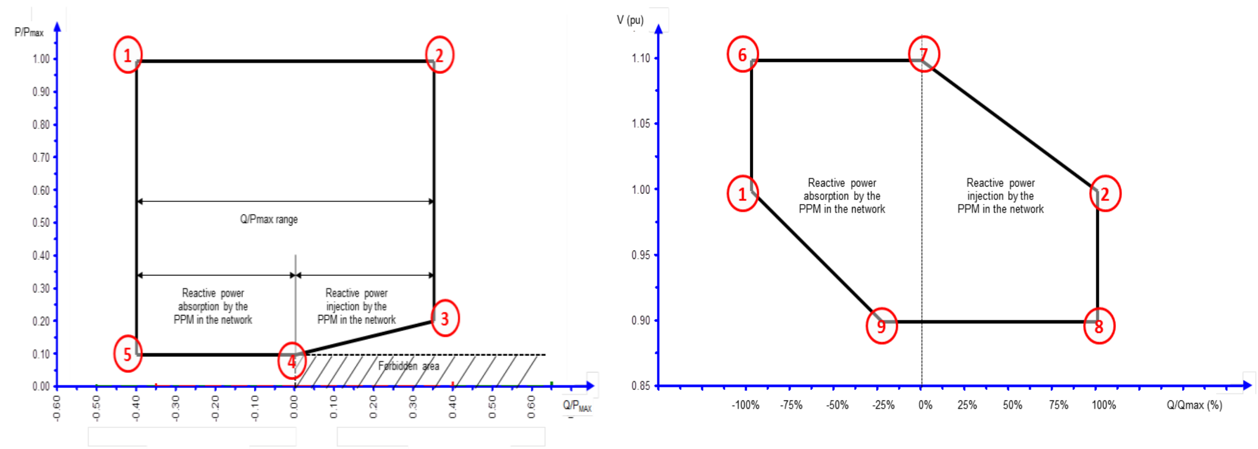


Figure 1: assigned calculation cases of P/Pmax - Q/Pmax profile (left) and V - Q/Qmax profile (right). Qmax production = 0.35 Pmax – Qmax consumption = - 0.4 Pmax

Documentation / Calculated parameters:

- The following calculated parameters for each case shall be documented
- At the point of common coupling: P, Q, V, I.
- At the wind turbine terminals (primary and secondary side of wind turbine transformer): P, Q, V, I
- Loading (I) of main components (wind turbine generator, cable, transformer, circuit breaker)
- Tap changer positions of transformers
- Switching on/off position of reactive power compensation equipment if applicable
- Check calculated parameters against protection settings (Voltage, Current, Power) at wind turbine generator, MV grid and HV connection

Evaluation Criteria:

- Requirements as specified in sections 2.1 – 2.3 of the TR including the following issues:
  - voltage shall be in an acceptable range (normal practice 0.9-1.1 p.u. or better) at all bus bars.
  - wind turbine generators operate within in their operational limits
  - no overloading of components
  - no protection trip

5.3 Dynamic Simulations

Objective:

- Proof of compliance with voltage stability requirements according to section 4.5
- Proof of compliance with fault ride through capability according to section 4.6

Procedure:

- Simulation of fault ride through profile at the Connection Point according to section 2.6 of the TR.
- Simulation of Voltage stability at voltage drops of 9%, 11%, 50% 100% of nominal voltage at PCC
- Simulation shall be performed for a power factor at the Connection Point during normal operation. This power factor is to be provided by TenneT.
- Simulation shall be performed at active power output of 35%, 80% and 100% Pmax
- Simulation shall be performed for both, symmetrical and asymmetrical (1- and 2-phase) faults
- Based on the simulation results (additional reactive current, voltage dip) the k-factor at the Connection Point shall be calculated for a three phase fault according to the definition and equation given in section 2.5 of the TR

Documentation / Calculated parameters:

- At the Connection Point: P, Q, V, I
- At the wind turbine terminals (primary and secondary side of wind turbine transformer): P, Q, V, I
- Tap changer positions of transformers
- Applied parameter settings of wind turbine and wind park controller models
- K-factor and values including time step applied in order to calculate the k-factor
- Switching on/off position of reactive power compensation equipment if applicable
- Check calculated parameters with protection settings (Voltage, Current, Power) at wind turbine generator, MV grid and HV connection

Evaluation Criteria:

- Voltage stability according to 2.5 of the TR. The k-factor value is to be evaluated against the required k-factor set point which is to be provided by TenneT
- Fault ride through capability will be evaluated according to section 2.6 of the TR.
- No protection trip.

5.4 On site Tests

5.4.1 Reactive Power Control Modes

The different modes are tested by step-changing of the set-point in the full-range which may be limited by operational limits of the TenneT network.

Objective:

- Functional test of reactive power control modes according to section 4.4

Procedure:

- Starting point for the following three tests is normal operation. This means the unit is in steady state operation with a power factor at the Connection Point as determined with TenneT.
- The set-point of reactive power control mode may be adjusted in the park-controller in case no TenneT EMS (Energy Management System) is available.
- While executing the tests the active power output of the wind park shall be more than 20 % Pmax.
- Tests shall be executed by step-changing the set-point in both directions in full range until one of the following restrictions applies.
  - min. or max. set-point position is reached
  - max. absorbed or injected reactive power is reached according to P/Pmax - Q/Pmax and V - Q/Qmax profiles in section 2.2 and 2.3 of the TR
  - operational limits of the TenneT network is reached. This restriction needs to be determined by TenneT. Usually an operated voltage range of 95-105% of rated voltage applies.
- Max. and min. reached set-point shall be maintained for at least ten minutes.
- Voltage control mode
  - Voltage set point shall be step-wise changed by 1% steps in both directions until one of above mentioned restrictions applies
- Power factor control mode
  - Power factor set point shall be step-wise changed by 0.01 steps in both directions until one of above mentioned restrictions applies.
- Reactive power control mode
  - Reactive power set point shall be step-wise changed by 10% steps in both directions until one of above mentioned restrictions applies.

Documentation / Measurements:

- P, Q, V shall be measured for each step. The measurement location depends on the availability of the set-point signal. Transient measurement equipment will be required to evaluate speed of response and damping of set point change and voltage/reactive power/power factor response. Preferable this should be the HV side of the wind park step-up transformer or at the Connection Point. If both is not possible, also LV side of the step-up transformer might be chosen. In case the set point signal is not available at the Connection Point or the HV side, the Droop, dead band and range, reactive power and power factor shall be determined by correcting the measurement at LV side of the step-up transformer with the voltage drop and reactive power consumption of the step-up transformer.
- Reaction time of activation shall be determined for all three tests.
- A measuring error of max. 3 % will be accepted

Evaluation Criteria:

Measurements will be evaluated based on Based on section 2.4 of the TR considering also the following aspects:

- Droop, dead band and deviation of reactive power and power factor from set point
- Reaction time of activation shall be determined for all three tests
- Range of controller

5.4.2 Active Power Control (with and without over frequency)

Objective:

- Functionality of active power control according to section 4.7
- Functionality of active power control at over frequency according to section 4.8
- Functionality of reactive power control to prevent reactive power injection when active power output is dropping below 10 % Pmax. according to section 4.2

Procedure:

- Starting points for these tests shall be
    - an active power output of more than 60 %Pmax
    - reactive power injection
- For functionality of active power control
    - Activation of 100 % of maximum capacity change of active power in 5 steps
- For functionality of active power control at over frequency
    - injected of simulated frequency deviation signals at the Connection Point in order to activate 100 % of maximum capacity change in active power in 5 steps
    - calculation of frequency droop

Documentation / Measurements:

- P, Q, V shall be measured as function of the time at the Connection Point and/or at LV side of step-up.
- Transient registration of P at LV side of step-up transformer and injected frequency signal
- Applied settings of wind park and wind turbine controller including frequency droop setting
- A measuring error of max. 3 % will be accepted

Evaluation Criteria:

Measurements will be evaluated based on based on:

- section 3.1 of TR for active power control
- section 3.2 of TR for active power control in case of over frequency
- Reaction time of activation
- Accuracy of measured frequency droop
- No reactive power injection when active power output is dropping below 10 % Pmax according to section 2.2 of the TR

5.5 Power / Voltage Quality simulations

5.5.1 Fluctuating voltages

5.5.1.1 Rapid voltage change

Objective:

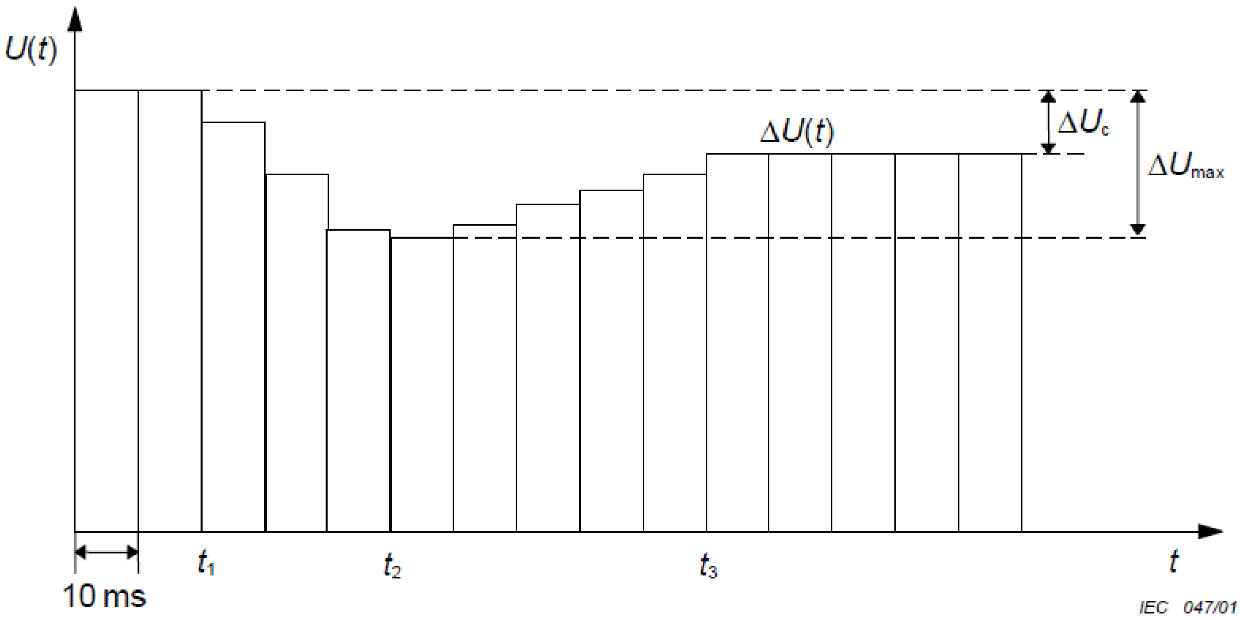
- The PPM shall demonstrate its capability to limit their rapid voltage change towards the HV and EHV power system.

Procedure:

- An engineering assessment is required to demonstrate the capability of the PPM.
- This assessment has to include the switching operation of wind turbines, based on IEC 61400-21 and transient rms simulations of switching cables, transformer and reactive power compensation equipment.
- Starting points of these simulation shall be
    - Minimum short circuit power and X/R ratio of the grid at the Connection Point

Documentation / calculated parameters:

- At the Connection Point these parameters should be listed:
    - *U* are phase-to-phase voltages;
    - r.m.s. voltage shape, $U(t)$
        - the time function of r.m.s. voltage refreshed each half-cycle, evaluated as a single value for each successive half period between zero-crossings of the source voltage (see Figuur 2);
    - voltage change characteristic, $\Delta U(t)$
        - The time function of the r.m.s. voltage change evaluated as a single value for each successive half period between zero-crossings of the source voltage between time intervals in which the voltage is in a steady-state condition for at least 1 s (see Figuur 2). Since this characteristic is only used for assessments using calculations, the voltage in the steady-state condition is assumed to be constant within the measurement accuracy.
    - maximum voltage change characteristic, ΔU_{max}
        - the difference between maximum and minimum r.m.s. values of a voltage change characteristic (see Figuur 2);
    - steady-state voltage change, ΔU_c
        - the difference between two adjacent steady-state voltages separated by at least one voltage change characteristic (see Figuur 2).
    - determine ΔU (kV) according the evaluation criteria;
    - determine ΔU/Un (%) according the evaluation criteria;
    - determine Number of changes (per day) or (per hour) according the evaluation criteria;
- List the sequence of events that causes the rapid voltage change;
- Apart from the voltages also the currents at the Connection Point shall be simulated, in time correlation with the voltage quality aspects;



Figuur 2: Histogram evaluation of U(t)

Evaluation Criteria:

- Evaluation will be performed based on national legislation, standards, rules and best practices:
  - Netcode
  - Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-7 (en) Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems;

The rapid voltage change should be less or in accordance with Tabel 3 for grids given a system voltage Un of: 110kV ≤ Un ≤ 380 kV; during normal operating conditions defined by the netcode. Tabel 3 is constructed based on the netcode and NPR-IEC/TR 61000-3-7.

Number of changes: n (pu)	ΔU/Un (%)
n ≤ 4 per day	3
n ≤ 2 per hour and > 4 per day	3
2 < n ≤ 10 per hour	2,5

Tabel 3: levels for rapid voltage changes as a function of the number of such changes in a given period for grids given a system voltage Un of: 110kV ≤ Un ≤ 380 kV

The permissible voltage change ΔU/Un (%) and number of changes in a given period should be applied so that the number of changes of magnitude ΔU/Un does not exceed the number specified within the total time period corresponding to the rate: e.g. no more than 4 changes of 3 % are permitted during any one 24 hour period.

5.5.1.2 Flicker emission P_{ST}, P_{LT}

Objective:

- The PPM shall demonstrate its capability to limit their Flicker emission[3] P_{ST} and P_{LT} towards the HV and EHV power system.

Procedure:

- Flicker P_{ST} and P_{LT} shall be determined at the connection point. This should be done at least according to procedure described in NEN-EN-IEC 61400-21

Documentation / calculated parameters:

- Emitted P_{ST}, P_{LT} at point of connection PPM
- Applied Short circuit power and X/R ratio.
- Applied wind turbine characteristics such as flicker coefficient

Evaluation Criteria:

- Evaluation will be performed based on national legislation, standards, rules and best practices:
  - Netcode
  - Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-7 (en) Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems;

5.5.2 Harmonic simulation

Objective:

The PPM shall demonstrate its capability to limit their emission of harmonic, interharmonic, subharmonics and THD voltages towards the HV and EHV power system.

Procedure:

- Simulations of the harmonics produced by the wind farm.
- Starting point shall be:
  - An active power output of 50, 75 and 100 %Pmax
  - A reactive power output of Qmax consumption, Qmax production and zero Mvar at Connection Point
  - Harmonic impedance (loci) of the network at Connection Point

Documentation / calculated parameters:

- Emitted harmonic, interharmonic, subharmonics and THD voltages at Connection Point.

Evaluation Criteria:

- Evaluation will be performed based on national legislation, standards, rules and best practices:
  - Netcode

[3] Flicker emission P_{ST} (short term) and P_{LT} (long term) according to IEC 61400-21

- Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-6 (en) Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems.

5.5.3 Transient overvoltage simulation

Objective:

- The PPM shall demonstrate its capability to limit their transient overvoltage emissions towards the HV and EHV power system.

Procedure:

- Calculations of transient overvoltage due to events, given:
  - NEN-EN-IEC 60071-1 Insulation co-ordination - Part 1: Definitions, principles and rules;
  - IEC 60071-2 Insulation co-ordination - Part 2: Application guide;
  - Praktijkrichtlijn NPR-IEC/TR 60071-4 Insulation co-ordination - Part 4: Computational guide to insulation coordination and modelling of electrical networks;

Documentation / calculated parameters:

- List and motivation of:
  - calculated events;
  - non calculated events;
  - types of transient overvoltage generated;
  - non calculated types of transient overvoltage generated;
- Time functions of emitted transient overvoltage at point of connection PPM;
- Values of rate-of-rise: du/dt and di/dt;
- Correlate time function to relevant rate of rise: du/dt, di/dt values and calculated values;
- Tables correlating emitted transient overvoltages and rate-of-rise at point of connection PPM to withstand values of various electrical installation components.

Evaluation Criteria:

- Evaluation will be performed based on national legislation, standards, rules and best practices
- Netcode 2.1.4.3 'de isolatiecoördinatie';
- NEN-EN-IEC 60071-1 Insulation co-ordination - Part 1: Definitions, principles and rules;
- IEC 60071-2 Insulation co-ordination - Part 2: Application guide;
- Praktijkrichtlijn NPR-IEC/TR 60071-4 Insulation co-ordination - Part 4: Computational guide to insulation coordination and modelling of electrical networks;
- A brief summary of considered evaluated events of:'isolatie coordinatie', NEN-EN-IEC 60071-1, IEC 60071-2 and NPR-IEC/TR 60071-4 are:
  - Load rejection see 2.3.2.2 in IEC 60071-2;
  - Transformer energization;
  - Parallel line resonance;
  - Uneven breaker poles;
  - Backfeeding;
  - Line fault application see 2.3.3.2 in IEC 60071-2;
  - Fault clearing see 2.3.3.2 in IEC 60071-2;
  - Line energization see 2.3.3.1 in IEC 60071-2;
  - Line re-energization;

- Line dropping;
- AIS busbar switching ;
- Switching of inductive and capacitive current see 2.3.3.4 in IEC 60071-2,
- Back flashover;
- Direct lightning stroke see 2.3.3.5 in IEC 60071-2;
- Switching inside GIS substation;
- SF6 circuit-breaker inductive and capacitive current switching;
- Flashover in GIS substation.

5.6 Power / voltage quality measurements

Objective:

- Power / voltage quality compliance according to section 4.9

Procedure:

At least the initial and final power quality measurements of one week each shall be performed:

- Initial power quality measurement:
  - Voltage quality measurement shall be performed during at least one week starting with first energization. This shall cover first energization of the step-up transformer and cables of the collection grid of the PPM.
- Interim power quality measurement:
  - In case an interim power quality measurement is required during the building phase this measurement shall be performed according to the procedure for the final power quality measurement if not agreed otherwise.
- final power quality measurement:
  - Voltage quality measurement shall be performed during one week during full operation of the wind park with forecasted high average output (more than 50% Pn)
  - This measurement has to include the switching operation of wind turbines, cables, transformer and reactive power compensation equipment. These switching operations should preferably be performed manually initiated.

Documentation / Measurements:

- The measurements shall be taken at the the Connection Point, given the measurement quality of the netcode. The following voltage quality aspects will be measured with a class 'A' measurement device:
  - slow voltage variations ('langzame spanningsvariaties')
  - fast voltage variations ('snelle spanningsvariaties') including
    - flicker: PLT, PST;
    - voltage dips;
    - rapid voltage change due to inrush phenomena, definitions according to section 5.5.1.1;
  - asymmetry ('asymmetrie');
  - THD, harmonic and interharmonic voltages ('harmonische');
- Time functions of the current are measured during the measurement of the rapid voltage change during inrush phenomena; the current time function is in correlation with the rapid voltage change;
- During the measurement of the harmonic voltages, the harmonic interharmonic and power frequency currents at the Connection Point shall be measured, in time correlation with the voltage quality aspects;
- A report shall analyze the measurements and point out the switching events;
- The voltage quality aspects measurements will be delivered in comma separated file or excel-file.

Evaluation Criteria:

- Evaluation will be performed based on national legislation, standards, rules and best practices:
  - Netcode;
  - 'Richtlijnen voor toelaatbare - harmonische stromen geproduceerd door apparatuur met een vermogen groter dan 11 kVA' d.d. Januari 1996 published by EnergieNed;(to check harmonics generated according IEC 61400-21 type test measurements

- Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-6 (en) Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems;
- Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-7 (en) Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems;
- NEN-EN-IEC 61400-21, (en) Wind turbines - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines;
- NEN-EN-IEC 61000-4-30, (en) Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques – Power quality measurement methods;

Appendix

- Used terms

Power Park Module (PPM) - Generating Unit or ensemble of Generating Units which is not synchronously connected to the network. This includes any connection through power electronics and any ensemble of units having a single Connection Point to the network.

Statement of Compliance - a document provided by the Power Generating Facility Operator to the Network Operator stating the current status with respect to compliance. Compliance shall be stated with reference to the executed compliance activities and the TR.

Final Operational Notification - a notification issued by the Relevant Network Operator to a Power Generating Facility operator confirming that the Power Generating Facility operator is entitled to operate the Power Park Module by using the network connection because compliance with the technical design and operational criteria mentioned in this document has been demonstrated.

Connection Point - is the interface at which the Power Park Module is connected to a transmission, distribution or closed distribution Network according to Article 28 of Directive 2009/72/CE as identified in the Connection Agreement

'TenneT connection requirements document' (TR) – The TenneT connection requirements document refers to the document 'Wind Farm Connection Requirements-General 5.7 '.