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Wind energy generation systems –
Part 21-4: Measurement and assessment of electrical characteristics – Wind turbine components and subsystems

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FOREWORD

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IEC TS 61400-21-4 has been prepared by IEC technical committee 88: Wind energy generation systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
88/1048/DTS	88/1079/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61400 series, published under the general title *Wind energy generation systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Grid Code Compliance is a crucial element for wind power plant (WPP) connection to the electrical power system. This compliance process is specified by grid codes, standards and guidelines on international as well as national level. From a wind power plant point of view the single wind turbine (WT) is one element (unit) and consists of several subsystems and components, which supports with its given capabilities to the grid compliance. The electrical characteristics of the WPP and WTs are verified and validated as defined in the IEC 61400-21 series.

The IEC 61400-21 series – Measurement and assessment of electrical characteristics consist of the following standards, technical specifications, and technical reports:

- IEC 61400-21-1, *Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines*
- IEC 61400-21-2, *Wind energy generation systems – Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants*
- IEC TR 61400-21-3, *Wind energy generation systems – Part 21-3: Measurement and assessment of electrical characteristics – Wind turbine harmonic model and its application*
- IEC TS 61400-21-4, *Wind energy generation systems – Part 21-4: Measurement and assessment of electrical characteristics – Wind turbine components and subsystems*
- IEC TS 61400-21-5, *Wind energy generation systems – Part 21-5: Configuration, functional specification, and validation of hardware-in-the-loop test bench for wind power plants*[1]

Figure 1 gives an overview of the TC 88 standards, in relation to grid connection requirements, and the interaction to the power system responsible TSOs and the relevant system TCs under IEC as TC8/SC8a.

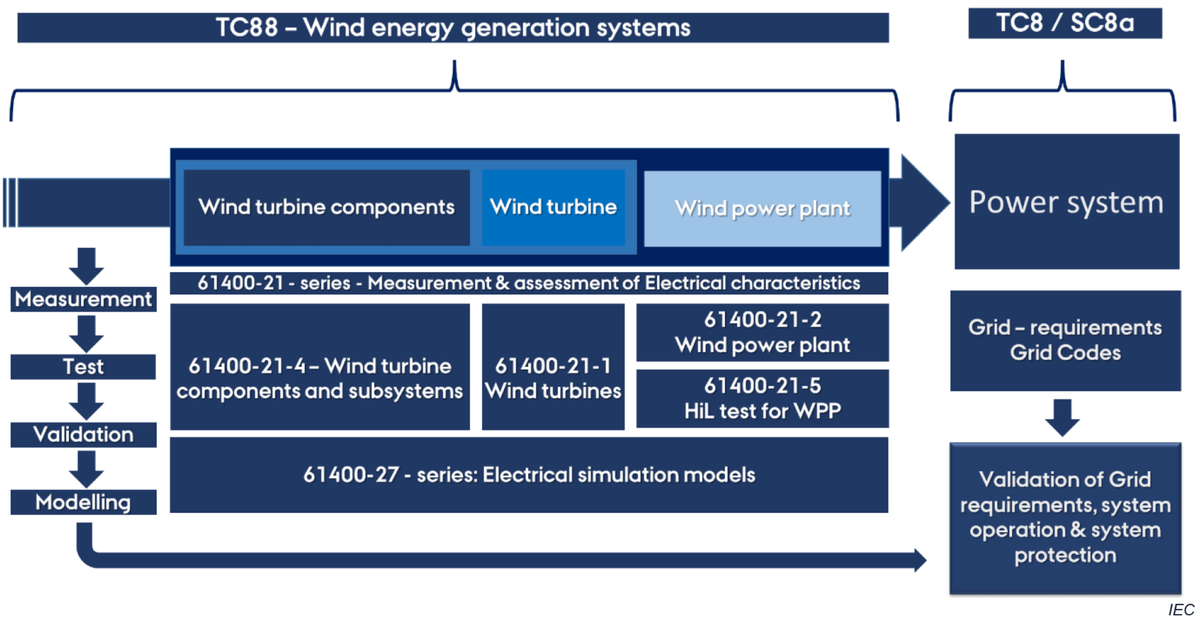

Figure 1 – Overview of TC 88 – Standards related to grid connection

1 Under preparation. Stage at the time of publication: IEC/ACD TS 61400-21-5:2024.

This technical specification is a supplement to IEC 61400-21-1 and IEC 61400-21-2. This part of the IEC 61400-21 series specifies the test procedures and defines a uniform methodology for standardizing the measurement, testing and assessment of the electrical characteristics of wind turbine (WT) components and subsystems. This standardization serves as the basis for verifying the electrical behaviour of WTs and WT families using test bench systems. The results of these component and subsystem tests can be used to replace site specific tests as defined in IEC 61400-21-1. Only a few exceptions may still require test site measurements.

The test and measurement procedures in this document are based on the defined methods and requirements from IEC 61400-21-1. This document defines the same parameters in relation to the validation of the electrical capabilities.

It also defines additional tests, which are only possible in a controlled test bench environment, such as:

- Power quality aspects: flicker control, active filtering, impedance measurement
- Steady state operation: voltage, frequency and current unbalance capability
- Control performance: grid impedance variations and island operation
- Dynamic performance: real RoCoF and phase jump

The procedures defined in this technical specification provide the measurement data that, for example, form the basis for the validation of simulation models, as defined in the IEC 61400-27 series, as shown in Figure 1.

This document defines:

- The minimum test setup in relation to the test & measurements of the electrical characteristics in relation to grid compliance requirements.
- The system requirements for the test bench to perform these measurements.
- The procedures for the transferability of test results to wind turbine and wind turbine families
- The documentation requirements for the wind turbine component and subsystem test results

The defined test and measurement procedures can be performed as a combination of performance, capability, and functionality tests (Figure 2), which are carried out on different test benches. As shown in Figure 2, two strategies can be followed to derive measurement results:

Strategy I: Performance tests can be carried out on a suitable subsystem test bench. The measurement results are directly transferable to WT measurements.

Strategy II: Capability and functionality tests on subsystems and/or components on appropriate test benches in combination with performance tests. The combination of the measurement results are transferable to WT measurements.

NOTE 1 Performance tests include all aspects of capability and functionality tests.

NOTE 2 The strategy description above and Figure 2 describe the case when a test report with all tests is required, hence performance, capability and functionality tests are included. Naturally, if a report for single tests, e.g. grid protection, is needed, this might only require a functionality, or a capability test.

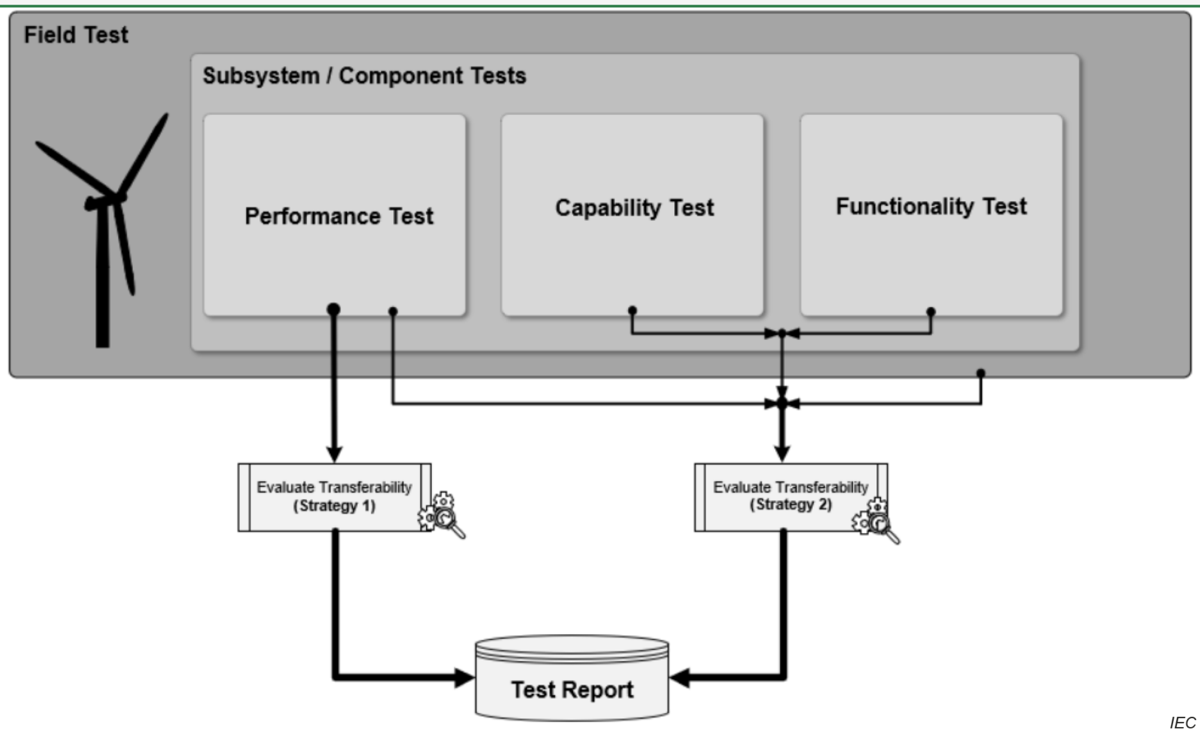

Figure 2 – Overview of performance-, capability- and functionality test, and their relation to the field tests

A detailed test overview including the minimal required setup for the verification and assessment of the electrical characteristics are defined in Annex B. An overview of the required test level is given in Clause 4.

If it has been validated and verified that the test results are not affected by the different hierarchy of test bench level, a lower hierarchy level than stated (see Figure 7) would be acceptable.

If a procedure other than those described here is agreed with the responsible stakeholders, like certification bodies, testing labs, manufacturers of the DUT, it can be used, provided that the procedure used is validated and verified.

NOTE 3 This document will be further developed with the increased experience of the defined test procedures as well as the development of test systems and simulation model validation as defined e.g. in the IEC 61400-27 series.

The structure of this document is as follows:

Clause 4: Provides an overview of the required tests and measurement procedures.

Clause 5: Defines the minimum setup and the interfaces of the DUT, used for the validation of the electrical characteristics.

Clause 6: Defines the minimum system requirements and characteristics for the test bench systems to perform tests of the requested minimal DUT configuration, as well the overall requirements for the measurement systems. The detailed requirements are defined in the specific chapters.

Clause 7: Defines the test setup and test conditions for the IEC 61400-21-1 specific tests in relation to power quality, steady state operation, dynamic response and control performance, as well as the documentation requirements and an evaluation for the transferability of the test results towards the WT.

Clause 8: Defines the additional tests, which are only possible in a controlled test bench setup as described in this document in relation to power quality, steady state operation, control performance and dynamic response, as well as the documentation requirements and an evaluation for the transferability of the test results towards the WT.

This document contains further the following informative annexes:

Annex A: Defines a report template, which can be used as basis for the reporting.

Annex B: Provides a detailed overview of the WT components and subsystems and their influence on the different tests according to the modular structure defined in the IEC 61400-27.

Annex C: Defines the test and validation procedure for the replacement of hardware and software components.

Annex D: Shows measurement, validation examples and comparisons for the validity of the transferability of test results from WT measurements.

Annex E: Shows examples and procedures for the harmonic assessment methods.

Annex F: Examples of Fault ride-through validation procedures for the functionality & capability test.

Annex G: Overview of Hardware in the loop (HiL) systems and there interfaces.

Annex H: Overview and definition of voltage fault types.

Annex I: Summary of grid emulator requirements

Annex J: Grid adaptability test using grid emulator

WIND ENERGY GENERATION SYSTEMS –

Part 21-4: Measurement and assessment of electrical characteristics – Wind turbine components and subsystems

1 Scope

This part of IEC 61400, which is a Technical Specification, specifies a uniform methodology, defining measurement, testing and assessment procedures of electrical characteristics of wind turbine components and subsystems, as basis for the verification of the electrical capabilities of wind turbines and wind turbine families.

This document includes the following aspects:

- definitions of test bench, subsystems and interface;
- definitions of system requirements for the test bench to perform relevant measurements (grid strengths, short circuit power, THD, …);
- measurement procedures for quantifying the electrical characteristics;
- test and measurement procedures for verifying and validating the electrical characteristics of components and subsystems in relation to grid compliance requirements;
- procedures for the transferability of the component and subsystem test results, measured at the test bench, to WT product families;
- documentation requirements and validation procedures of components, subsystems and wind turbines.

The results of the measurements and assessments of the wind turbine components and subsystems will be used as input for the verification of electrical capabilities as described in IEC 61400-21-1 and for the validation and verification of the electrical simulation models for wind power plants (WPP) as described in IEC 61400-27.

Out of scope of this technical specification are:

- design requirements of test bench systems;
- model development of WT subsystems and WT as e.g. described in the IEC 61400-27 series;
- Power Plant control function test (e.g. FSM, Voltage Control) as described in IEC 61400-21-2;
- specific component design test and validation of the wind turbine equipment (switchgears, cables, transformer, generator etc.), which are covered by other IEC standards;
- mechanical, structural loads and lifetime test;
- noise and acoustical measurements;
- certification procedures and grid compliance at wind power plant level;
- communication system functional and performance tests as defined in e.g. the IEC 61400-25 series.

NOTE For the purposes of this document, the following terms for system voltage apply, based on IEC 60038:

- Low voltage (LV) refers to 100 V < $U_n \leq 1$ kV;
- Medium voltage (MV) refers to 1 kV < $U_n \leq 35$ kV;
- High voltage (HV) refers to 35 kV < $U_n \leq 230$ kV;
- Extra high voltage (EHV) refers to U_n > 230 kV.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60255-127, *Measuring relays and protection equipment – Part 127: Functional requirements for over/under voltage protection*

IEC 60255-181, *Measuring relays and protection equipment – Part 181: Functional requirements for frequency protection*

IEC TR 61000-3-6:2008, *Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*

IEC 61000-4-7:2002, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*
IEC 61000-4-7:2002/AMD1:2008

IEC 61400-1, *Wind energy generation systems – Part 1: Design requirements*

IEC 61400-3-1, *Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines*

IEC 61400-3-2, *Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines*

IEC 61400-21-1:2019, *Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines*

IEC 61400-21-2, *Wind energy generation systems – Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants*

IEC TR 61400-21-3:2019, *Wind energy generation systems – Part 21-3: Measurement and assessment of electrical characteristics – Wind turbine harmonic model and its application*

IEC 61400-27-1, *Wind energy generation systems – Part 27-1: Electrical simulation models – Generic models*

IEC 61557-12, *Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 12: Power metering and monitoring devices (PMD)*

IEC 62586-2, *Power quality measurement in power supply systems – Part 2: Functional tests and uncertainty requirements*

ISO/IEC GUIDE 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*