



TECHNICAL SPECIFICATION

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

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CONTENTS

| | |
|---|----|
| FOREWORD..... | 12 |
| INTRODUCTION | 14 |
| 1 Scope..... | 18 |
| 2 Normative references..... | 19 |
| 3 Terms, definitions, symbols, units and abbreviated terms..... | 20 |
| 3.1 Terms and definitions..... | 20 |
| 3.2 Symbols, units and abbreviated terms..... | 29 |
| 4 Overview of tests..... | 31 |
| 5 Definitions of minimum DUT, components and subsystems | 33 |
| 5.1 General | 33 |
| 5.2 Description of components and subsystems | 33 |
| 6 Test bench systems | 35 |
| 6.1 General | 35 |
| 6.2 Nacelle test benches..... | 37 |
| 6.2.1 General..... | 37 |
| 6.2.2 Nacelle test benches – closed-loop testing (1a)..... | 38 |
| 6.2.3 Nacelle test benches – open-loop testing (1b)..... | 39 |
| 6.3 Electrical generation test benches (2a and 2b) | 40 |
| 6.3.1 General..... | 40 |
| 6.3.2 Electrical generation test benches – closed-loop testing (2a)..... | 40 |
| 6.3.3 Electrical generation test benches – open-loop testing (2b)..... | 41 |
| 6.4 Converter test benches (3a and 3b)..... | 42 |
| 6.4.1 General..... | 42 |
| 6.4.2 Converter test benches – closed-loop testing (3a) | 42 |
| 6.4.3 Converter test benches – open-loop testing (3b) | 43 |
| 6.5 Controller test benches (4a) and (4b)..... | 44 |
| 6.5.1 General..... | 44 |
| 6.5.2 Controller test benches – closed-loop testing (4a) | 45 |
| 6.5.3 Controller test benches – open-loop testing (4b) | 45 |
| 6.6 Auxiliary test benches (5) | 46 |
| 6.6.1 General..... | 46 |
| 6.6.2 Requirements for auxiliary test benches (5) | 47 |
| 6.7 Test bench equipment..... | 47 |
| 6.7.1 General..... | 47 |
| 6.7.2 HiL systems | 47 |
| 6.7.3 Prime mover for test benches..... | 56 |
| 6.7.4 Examples of UVRT/OVRT equipment for test benches | 56 |
| 6.7.5 Full converter based grid emulator..... | 57 |
| 6.7.6 Measurement systems for test benches..... | 60 |
| 6.7.7 Measurement uncertainty..... | 60 |
| 7 Measurement and test of electrical characteristics as defined in IEC 61400-21-1 | 60 |
| 7.1 General | 60 |
| 7.2 Power quality aspects | 60 |
| 7.2.1 Flicker during continuous operation | 60 |
| 7.2.2 Flicker and voltage change during switching operations | 60 |
| 7.2.3 Harmonics..... | 61 |

| | | |
|-----------------------|--|-----|
| 7.3 | Steady state operation | 64 |
| 7.3.1 | General..... | 64 |
| 7.3.2 | Observation of active power against wind speed | 64 |
| 7.3.3 | Maximum power..... | 65 |
| 7.3.4 | Reactive power characteristic ($Q = 0$)..... | 65 |
| 7.3.5 | Reactive power capability | 66 |
| 7.3.6 | Voltage dependency of PQ diagram | 67 |
| 7.3.7 | Unbalance factor..... | 67 |
| 7.4 | Control performance | 68 |
| 7.4.1 | Active power control..... | 68 |
| 7.4.2 | Active power ramp rate limitation | 70 |
| 7.4.3 | Frequency control | 73 |
| 7.4.4 | Synthetic inertia..... | 75 |
| 7.4.5 | Reactive power control | 78 |
| 7.5 | Dynamic performance – Voltage fault ride-through | 79 |
| 7.5.1 | General..... | 79 |
| 7.5.2 | Testing according to Strategy 1 | 79 |
| 7.5.3 | Testing according to Strategy 2 | 86 |
| 7.6 | Disconnection from the grid | 89 |
| 7.6.1 | General..... | 89 |
| 7.6.2 | Grid protection..... | 89 |
| 7.6.3 | RoCoF (df/dt) protection | 90 |
| 7.6.4 | Reconnection time | 91 |
| 8 | Additional measurement and test of electrical characteristics under controllable test conditions | 92 |
| 8.1 | General | 92 |
| 8.2 | Power quality aspects | 93 |
| 8.2.1 | Flicker control..... | 93 |
| 8.2.2 | Flicker and voltage change during switching operations | 95 |
| 8.2.3 | Active filter / sink for harmonics..... | 96 |
| 8.2.4 | Frequency dependent impedance measurement..... | 98 |
| 8.3 | Steady state operation | 103 |
| 8.3.1 | Voltage capability | 103 |
| 8.3.2 | Frequency capability | 104 |
| 8.3.3 | Current unbalance factor capability..... | 106 |
| 8.4 | Control performance | 107 |
| 8.4.1 | Fundamental frequency grid impedance variations | 107 |
| 8.4.2 | Island operation..... | 109 |
| 8.5 | Dynamic performance | 111 |
| 8.5.1 | RoCoF – real df/dt – capability | 111 |
| 8.5.2 | Phase jump | 112 |
| Annex A (informative) | Report template..... | 114 |
| A.1 | Overview | 114 |
| A.2 | General | 114 |
| A.3 | Measurement and test of electrical characteristics | 117 |
| A.3.1 | Power quality aspects..... | 117 |
| A.3.2 | Steady state operation..... | 130 |
| A.3.3 | Control performance..... | 135 |
| A.3.4 | Voltage fault ride-through | 136 |

| | | |
|-----------------------|---|-----|
| A.3.5 | Disconnection from the grid..... | 142 |
| A.4 | Additional measurement and test of electrical characteristics | 147 |
| A.4.1 | Power quality aspects..... | 147 |
| A.4.2 | Steady state operation..... | 157 |
| A.4.3 | Control performance..... | 162 |
| A.4.4 | Dynamic performance..... | 164 |
| Annex B (informative) | General information on test strategies and subsystems overview..... | 166 |
| B.1 | General | 166 |
| B.2 | Guideline test strategies – functional, capability and performance test | 166 |
| B.3 | Overview of components, subsystems and control functions..... | 167 |
| Annex C (informative) | Modification and replacement of components | 170 |
| C.1 | General | 170 |
| C.2 | Definition of changes | 170 |
| C.3 | Workflow replacement of component | 170 |
| C.4 | Test & measurement procedure..... | 174 |
| Annex D (informative) | Transferability examples | 178 |
| D.1 | Overview | 178 |
| D.2 | Introduction to the results for test bench type 1a..... | 178 |
| D.2.1 | General..... | 178 |
| D.2.2 | Power quality aspects..... | 178 |
| D.2.3 | Steady state operation..... | 179 |
| D.2.4 | Control performance..... | 180 |
| D.2.5 | Dynamic performance..... | 181 |
| D.3 | Introduction to the results for test bench type 2a..... | 184 |
| D.3.1 | General..... | 184 |
| D.3.2 | Dynamic performance..... | 184 |
| D.4 | Introduction to the results for test bench type 3a..... | 186 |
| D.4.1 | General..... | 186 |
| D.4.2 | Dynamic performance..... | 186 |
| D.4.3 | Reactive power capability | 187 |
| D.4.4 | Impedance scan | 188 |
| Annex E (informative) | Harmonic assessment..... | 190 |
| Annex F (informative) | Examples of FRT functionalities | 198 |
| Annex G (informative) | Variants of HiL..... | 201 |
| Annex H (informative) | Voltage fault types..... | 203 |
| H.1 | Overview | 203 |
| H.2 | Phase-to-neutral voltage for a Type C fault | 204 |
| H.3 | Phase-to-neutral voltage for a Type D fault:..... | 206 |
| Annex I (informative) | Summary of grid emulator requirements..... | 208 |
| Annex J (informative) | Grid adaptability test using grid emulator..... | 211 |
| J.1 | Overview | 211 |
| J.2 | Grid adaptability test setup | 211 |
| J.3 | Grid adaptability requirements | 212 |
| Bibliography | | 215 |

| | |
|---|----|
| Figure 2 – Overview of performance-, capability- and functionality test, and their relation to the field tests..... | 16 |
| Figure 3 – Example of step response..... | 25 |
| Figure 4 – Simulated equivalent circuit of the grid emulator and the DUT | 28 |
| Figure 5 – Generic structure of WT types | 33 |
| Figure 6 – General overview of test bench systems included in this TS, including the logical distinction between closed-loop and open-loop testing of wind turbines | 36 |
| Figure 7 – Hierarchy of the different test bench types..... | 37 |
| Figure 8 – Example of a nacelle test bench and a Type IV WT setup for closed-loop testing..... | 38 |
| Figure 9 – Example of a nacelle test bench and a type IV WT setup for open-loop testing..... | 39 |
| Figure 10 – Example of an electrical generation test bench and a Type IV WT setup for closed-loop testing | 40 |
| Figure 11 – Example of an electrical generation test bench and a Type IV WT setup for open-loop testing..... | 41 |
| Figure 12 – Example of a converter test bench and a Type IV WT setup for closed-loop testing..... | 42 |
| Figure 13 – Example of a converter test bench and a Type IV WT setup for open-loop testing..... | 44 |
| Figure 14 – Example of a controller test bench for closed-loop testing | 45 |
| Figure 15 – Illustration of a controller test bench for open-loop testing..... | 46 |
| Figure 16 – Example of auxiliary test bench | 47 |
| Figure 17 – Block diagrams of the HiL systems for different test bench types..... | 48 |
| Figure 18 – Overview of the process from offline simulation models to real time suitable models used within the HiL system and the data used for verification | 53 |
| Figure 19 – Suggested reporting form for comparison between HiL-operated test bench results and offline simulation results..... | 54 |
| Figure 20 – Example Power Spectral Density (PSD) of power from simulation and experiment..... | 55 |
| Figure 21 – Example structure of a typical grid emulator..... | 57 |
| Figure 22 – Example of active power response step..... | 69 |
| Figure 23 – Active power dynamic step response..... | 70 |
| Figure 24 – Example of available active power and active power in ramp rate limitation mode..... | 72 |
| Figure 25 – Example of an active power control function $P = f(f)$, with the different measurement points and related steps of frequency..... | 74 |
| Figure 26 – Synthetic inertia – example response and definition..... | 76 |
| Figure 27 – Tolerance of the positive sequence voltage for the undervoltage event with disconnected DUT under test [16] | 80 |
| Figure 28 – Example of an undervoltage test chart..... | 81 |
| Figure 29 – Tolerance of the positive sequence voltage for the overvoltage event with disconnected DUT | 82 |
| Figure 30 – Example of an over voltage capability chart | 83 |
| Figure 31 – Example FRT impedance profile | 85 |
| Figure 32 – Variable voltage and impedance grid emulator (case a)..... | 93 |
| Figure 33 – Constant voltage and impedance grid emulator with controllable load (case b)..... | 94 |

| | |
|---|-----|
| Figure 34 – Generic topology of (a) current and (b) voltage perturbation tests[12] | 99 |
| Figure 35 – Example of a grid emulator structure for voltage perturbation application (1)..... | 99 |
| Figure 36 – Impedance measurement test methodology for wind turbines using perturbation tests | 100 |
| Figure 37 – Impedance variation – example of steady state procedure & stepwise impedance increase..... | 108 |
| Figure 38 – Single line diagram of Impedance load (Z-load) connected with DUT | 109 |
| Figure A.1 – Maximum integer harmonic voltages versus harmonic order (background noise measurement) | 121 |
| Figure A.2 –Maximum interharmonic voltages versus frequency (background noise measurement)..... | 121 |
| Figure A.3 –Maximum higher frequency voltage components versus frequency (background noise measurement) | 121 |
| Figure A.4 – Maximum (Option 1) or maximum of the 95 th percentiles (Option 2) of integer harmonic currents versus harmonic order..... | 129 |
| Figure A.5 – Maximum (Option 1) or maximum of the 95 th percentiles (Option 2) of interharmonic currents versus frequency..... | 129 |
| Figure A.6 – Maximum (Option 1) or maximum of the 95 th percentiles (Option 2) of higher frequency current components versus frequency | 129 |
| Figure A.7 – Maximum (Option 1) or maximum of the 95 th percentiles (Option 2) of integer harmonic voltages versus harmonic order | 129 |
| Figure A.8 – Maximum (Option 1) or maximum of the 95 th percentiles (Option 2) of interharmonic voltages versus frequency | 130 |
| Figure A.9 – Maximum (Option 1) or maximum of the 95 th percentiles (Option 2) of higher frequency voltage components versus frequency | 130 |
| Figure A.10 – Reactive power versus active power | 131 |
| Figure A.11 – PQ diagram at nominal voltage..... | 132 |
| Figure A.12 – PQ diagram at maximum voltage | 133 |
| Figure A.13 – PQ diagram at minimum voltage | 134 |
| Figure A.14 – IUF-P diagram | 135 |
| Figure A.15 – Wave shape of 3-phase voltages during entrance of voltage dip/swell when the DUT is not connected | 137 |
| Figure A.16 – Wave shape of 3-phase voltages during clearance of voltage dip/swell when the DUT is not connected | 137 |
| Figure A.17 – 3-phase voltages as RMS (1 line period) during the test when the DUT is not connected | 138 |
| Figure A.18 – Positive sequence voltage during the test when the DUT is not connected..... | 138 |
| Figure A.19 – Negative sequence voltage during the test when the DUT is not connected..... | 138 |
| Figure A.20 – Wave shape of 3-phase voltages during entrance of the voltage dip/swell when the DUT is connected | 140 |
| Figure A.21 – Wave shape of 3-phase voltages during clearance of the voltage dip/swell when the DUT is connected..... | 140 |
| Figure A.22 – 3-phase voltages as RMS (1 line period) during the test when the DUT is connected..... | 140 |
| Figure A.23 – Positive and negative sequence fundamental voltage during the test when the DUT is connected | 141 |

| | |
|---|-----|
| Figure A.24 – 3-phase currents as RMS (1 line period) during the test when the DUT is connected..... | 141 |
| Figure A.25 – Pos. and neg. sequence fundamental current during the test when the DUT is connected..... | 141 |
| Figure A.26 – Pos. sequence fundamental active power during the test when the DUT is connected..... | 141 |
| Figure A.27 – Pos. sequence fundamental reactive power during the test when the DUT is connected..... | 141 |
| Figure A.28 – Pos. sequence fundamental active current during the test when the DUT is connected..... | 142 |
| Figure A.29 – Pos. sequence fundamental reactive current during the test when the DUT is connected..... | 142 |
| Figure A.30 – Wind speed or available power during the test when the DUT is connected..... | 142 |
| Figure A.31 – Voltage during the reconnection test of 10 s..... | 146 |
| Figure A.32 – Active power during the reconnection test of 10 s, including the recovery | 146 |
| Figure A.33 – Time-series of measured wind speed during the reconnection test of 10 s..... | 146 |
| Figure A.34 – Voltage during the reconnection test of 60 s..... | 146 |
| Figure A.35 – Active power during the reconnection test of 60 s, including the recovery | 146 |
| Figure A.36 – Time-series of measured wind speed during the reconnection test of 60 s..... | 146 |
| Figure A.37 – Voltage during the reconnection test of 600 s..... | 147 |
| Figure A.38 – Active power during the reconnection test of 600 s, including the recovery..... | 147 |
| Figure A.39 – Time-series of measured wind speed during the reconnection test of 600 s..... | 147 |
| Figure A.40 – Maximum (Grid emulator) or Maximum of the 95 th percentiles (Public grid) of integer harmonic currents versus harmonic order without AF..... | 155 |
| Figure A.41 – Maximum (Grid emulator) or Maximum of the 95 th percentiles (Public grid) of integer harmonic currents versus harmonic order with AF..... | 155 |
| Figure A.42 – Maximum (Grid emulator) or Maximum of the 95 th percentiles (Public grid) of integer harmonic voltages versus harmonic order without AF..... | 155 |
| Figure A.43 – Maximum (Grid emulator) or Maximum of the 95 th percentiles (Public grid) of integer harmonic voltages versus harmonic order with AF..... | 155 |
| Figure A.44 – Voltage during the minimum voltage test..... | 157 |
| Figure A.45 – Active power during the minimum voltage test..... | 157 |
| Figure A.46 – Reactive power during the minimum voltage test..... | 158 |
| Figure A.47 – Voltage during the nominal voltage test..... | 158 |
| Figure A.48 – Active power during the nominal voltage test..... | 158 |
| Figure A.49 – Reactive power during the nominal voltage test..... | 158 |
| Figure A.50 – Voltage during the maximum voltage test..... | 158 |
| Figure A.51 – Active power during the maximum voltage test..... | 159 |
| Figure A.52 – Reactive power during the maximum voltage test..... | 159 |
| Figure A.53 – Frequency during the minimum frequency test..... | 159 |
| Figure A.54 – Voltage during the minimum frequency test..... | 159 |
| Figure A.55 – Active power during the minimum frequency test..... | 160 |
| Figure A.56 – Reactive power during the minimum frequency test..... | 160 |
| Figure A.57 – Frequency during the nominal frequency test..... | 160 |

| | |
|--|-----|
| Figure A.58 – Voltage during the nominal frequency test | 160 |
| Figure A.59 – Active power during the nominal frequency test..... | 160 |
| Figure A.60 – Reactive power during the nominal frequency test | 161 |
| Figure A.61 – Frequency during the maximum frequency test..... | 161 |
| Figure A.62 – Voltage during the maximum frequency test..... | 161 |
| Figure A.63 – Active power during the maximum frequency test | 161 |
| Figure A.64 – Reactive power during the maximum frequency test..... | 161 |
| Figure A.65 – Time series of the positive sequence voltage measured at the DUT terminals | 162 |
| Figure A.66 – Time series of the measured positive and negative sequence current | 162 |
| Figure A.67 – Time series of the measured active and reactive power..... | 163 |
| Figure A.68 – Time series of measured frequency at the DUT | 163 |
| Figure A.69 – Time series of positive and negative sequence voltage at the DUT..... | 163 |
| Figure A.70 – Time series of positive and negative sequence current | 163 |
| Figure A.71 – Time series of active and reactive power from the DUT | 163 |
| Figure A.72 – Time series of measured frequency or frequency reference value | 164 |
| Figure A.73 – Time series of positive sequence active power output..... | 164 |
| Figure A.74 – Time series of measured positive and negative sequence voltage at the DUT | 165 |
| Figure A.75 – Time series of measured positive and negative sequence current | 165 |
| Figure A.76 – Time series of measured active and reactive power from the DUT..... | 165 |
| Figure A.77 – Instantaneous voltage and current measurements from 20 ms before the phase jump event until min 200 ms after the event..... | 165 |
| Figure B.1 – Overview of three different test strategies..... | 167 |
| Figure C.1 – Flowchart of the procedure to handle a hardware or software update | 171 |
| Figure C.2 – Illustration of a set-up on a test field, when testing a complete wind turbine with the in- and outputs, the parameter, references, measurements, the grid and disturbances including a certain component type A..... | 175 |
| Figure C.3 – Illustration of a set-up on a test bench according to the second step in this procedure..... | 176 |
| Figure C.4 – Illustration of the above described comparison of one component A tested in the field and on the test rig, whereas the component B is only tested on a test rig | 177 |
| Figure D.1 – Flicker comparison under different operating conditions..... | 178 |
| Figure D.2 – Comparison of maximum active power in normal operation, observed in the field and at the test benches [14]..... | 179 |
| Figure D.3 – Comparison of Reactive Power Capability Test Results [14]..... | 180 |
| Figure D.4 – Static error of the active power control..... | 180 |
| Figure D.5 – Reactive power controls results derived at the test bench and in the field | 181 |
| Figure D.6 – Positive sequence voltage for a three-phase dip to 25 % U_N during WT full load operation [14] | 182 |
| Figure D.7 – Observed phase angle during different 2-phase voltage dips..... | 182 |
| Figure D.8 – Comparison of reactive current injection during three-phase dip to 25 % U_N with the WT being in full load operation [14]..... | 183 |
| Figure D.9 – Transient voltage transition for a two-phase fault with the WT being in No- Load operation | 183 |

| | |
|---|-----|
| Figure D.10 – UVRT-event: Comparison of dynamic behaviour MoWiT simulation vs. test bench [23] | 184 |
| Figure D.11 – complete positive (solid), negative (dash-dotted), and zero (dotted) sequence components of the MV quantities for a symmetrical 20 % UVRT in field (orange) and on the test bench (green): PCC voltage (a), active current (b), reactive current (c)..... | 185 |
| Figure D.12 – detailed sections of positive – (solid), negative- (dash-dotted), and zero- (dotted) sequence components of the medium voltage quantities in case of a asymmetrical 0 % UVRT in field (orange) and on the test bench (green): PCC voltage (a), active current (b), reactive current (c) [24]..... | 185 |
| Figure D.13 – UVRT test results..... | 187 |
| Figure D.14 – Reactive power capability – comparison of test bench and field measurements | 188 |
| Figure D.15 – Comparison of the G-CTR and frequency domain model impedance scan.... | 189 |
| Figure E.1 – Test setup..... | 190 |
| Figure E.2 – Equivalent circuit of experiment setup..... | 191 |
| Figure E.3 – Thevenin model of the test set-up..... | 191 |
| Figure E.4 – Sample results from averaging the results of 10 combinations of 5 experiments with varying filter capacitance; $v_d(f)$ and $z_d(f)$ are absolute values..... | 193 |
| Figure E.5 – Sample results from averaging the results of 10 combinations of 5 experiments with varying filter capacitance after outlier detection; $v_d(f)$ and $z_d(f)$ are absolute values | 194 |
| Figure E.6 – Sample results from averaging the results of 10 combinations of 5 experiments after filtering of the Thevenin impedance; $v_d(f)$ and $z_d(f)$ are absolute values | 195 |
| Figure E.7 – Harmonic measurement and PAR calculation of a wind turbine field measurement with asynchronous pulse pattern..... | 196 |
| Figure F.1 – Example for FRT detection and voltage base determination..... | 198 |
| Figure F.2 – Example for detection of threshold and dead band of current support | 198 |
| Figure F.3 – Example for variation of fault current contribution functionality..... | 199 |
| Figure F.4 – Example for current priority based on positive and negative voltage sequence..... | 199 |
| Figure F.5 – Example for current limitations functionality | 200 |
| Figure F.6 – Example for active power ramp rates after FRT event..... | 200 |
| Figure G.1 – Different HiL systems..... | 202 |
| Figure H.1 – Power system fault classification according to [13]..... | 203 |
| Figure H.2 – Mains phasor diagram phase-to-neutral voltage fault type C..... | 204 |
| Figure H.3 – Phasor diagram phase-to-neutral voltage fault type D..... | 206 |
| Figure J.1 – Recommended grid adaptability test setup | 211 |
| Table 1 – Overview of tests according to Clause 7 | 31 |
| Table 2 – Overview of tests according to Clause 8..... | 32 |
| Table 3 – Overview of subsystems and main functions | 34 |
| Table 4 – Functions of the rotor and structural dynamic model and related requirements..... | 50 |
| Table 5 – Recommended rotor model used for different tests on closed-loop test benches | 50 |
| Table 6 – Functions of the electrical generator model and related requirements..... | 51 |

| | |
|---|-----|
| Table 7 – List of system of required sensor, actuator and interfaces models | 52 |
| Table 8 – Static requirements for converter-based grid emulators..... | 58 |
| Table 9 – Dynamic requirements for a converter-based grid emulators..... | 58 |
| Table 10 – Harmonic voltage emission limits of the grid emulator at no-load (disconnected DUT)..... | 61 |
| Table 11 – Active power ramp rate calculation..... | 72 |
| Table 12 – Example of settings for the frequency dependent active power function | 75 |
| Table 13 – Synthetic inertia settings..... | 77 |
| Table 14 – Synthetic Inertia results | 78 |
| Table 15 – Indicative range of input relative voltage fluctuation $\Delta U/U_n$ for P_{st} output range about 0,2 and 0,5 | 95 |
| Table 16 – Example of specification of voltage or current perturbation tests | 101 |
| Table 17 – Current unbalance factor in an unbalanced system | 107 |
| Table A.1 – General report information | 114 |
| Table A.2 – General information DUT and WT, which the DUT is part of..... | 115 |
| Table A.3 – General information test bench system..... | 115 |
| Table A.4 – General test information | 117 |
| Table A.5 – Background noise: 10 min integer harmonic voltage subgroups and total distortions of voltage harmonics as percentages of U_n | 117 |
| Table A.6 – Background noise: 10-min voltage interharmonic subgroups as percentages of U_n | 119 |
| Table A.7 – Background noise: 10-min higher frequency components voltage subgroups as percentages of U_n | 120 |
| Table A.8 – Overview of harmonic measurements..... | 121 |
| Table A.9 – Integer harmonic currents (max or 95 th percentiles) | 122 |
| Table A.10 – Integer harmonic voltages (max or 95 th percentiles) | 123 |
| Table A.11 – Interharmonic currents (max or 95 th percentiles)..... | 124 |
| Table A.12 – Interharmonic voltages (max or 95 th percentiles)..... | 125 |
| Table A.13 – Higher frequency current components (max or 95 th percentiles) | 127 |
| Table A.14 – Higher frequency voltage components (max or 95 th percentiles) | 128 |
| Table A.15 – Maximum active power | 130 |
| Table A.16 – Reactive power characteristic..... | 131 |
| Table A.17 – PQ diagram at nominal voltage..... | 132 |
| Table A.18 – PQ diagram at maximum voltage | 133 |
| Table A.19 – PQ diagram at minimum voltage | 134 |
| Table A.20 – Voltage and current unbalance measurement results | 135 |
| Table A.21 – Results for tests where the DUT is not connected..... | 136 |
| Table A.22 – Results for tests where the DUT is connected | 138 |
| Table A.23 – Documentation requirements for grid protection test | 143 |
| Table A.24 – Voltage protection | 143 |
| Table A.25 – Frequency protection | 143 |
| Table A.26 – Complete trip circuit test | 143 |
| Table A.27 – Documentation requirements for RoCoF (df/dt) protection test | 144 |

| | |
|--|-----|
| Table A.28 – RoCoF test results | 144 |
| Table A.29 – Other settings relevant for the RoCoF function (example relay type SEG MCA4)..... | 145 |
| Table A.30 – Reconnection test results..... | 145 |
| Table A.31 – Flicker P_{st} per power range and fluctuation frequency..... | 148 |
| Table A.32 – Flicker mitigation factor (F) per power range and fluctuation frequency | 148 |
| Table A.33 – Active filtering (AF) evaluation table for current harmonics (Step 1: without AF) | 149 |
| Table A.34 – Active filtering (AF) evaluation table for voltage harmonics (Step 1: without AF) | 150 |
| Table A.35 – Active filtering (AF) evaluation table for current harmonics (Step 2: with AF) | 152 |
| Table A.36 – Active filtering (AF) evaluation table for voltage harmonics (Step 2: with AF) | 153 |
| Table A.37 – Example of representation of the harmonic impedance..... | 156 |
| Table A.38 – Specification of DUT's voltage capability range | 157 |
| Table A.39 – Specification of DUT's frequency capability range..... | 159 |
| Table A.40 – Impedance steps and values as complex value as well as the accuracy of the impedance | 162 |
| Table A.41 – Reference values of the protection level and release time | 164 |
| Table A.42 – Phase angle difference of the voltage before and after the phase jump | 164 |
| Table B.1 – Overview of components, subsystems and control functions according to Clause 7..... | 168 |
| Table B.2 – Overview of components, subsystems and control functions according to Clause 8..... | 169 |
| Table D.1 – Settling times of the active power control during a reference power step | 180 |
| Table E.1 – Example representation/template of the harmonic voltage source | 197 |
| Table E.2 – Example representation/template of the harmonic current source..... | 197 |
| Table E.3 – Example representation/template of the harmonic equivalent impedance | 197 |
| Table H.1 – Exemplary calculation results for type "C" faults including over voltage tests..... | 205 |
| Table H.2 – Exemplarily calculation results for type "D" faults including over voltage tests..... | 207 |
| Table I.1 – Summary of grid emulator requirements | 208 |
| Table I.2 – Background voltage harmonic recommendations in the range 100 Hz to 9 kHz..... | 210 |
| Table J.1 – Example of maximum allowable errors between the outputs of the test device under no-load and load conditions | 212 |
| Table J.2 – Voltage deviation adaptability test items | 212 |
| Table J.3 – Frequency deviation adaptability test items | 212 |
| Table J.4 – WT RoCoF response test items..... | 213 |
| Table J.5 – WT frequency regulation response test items | 213 |
| Table J.6 – Three-phase voltage unbalance adaptability test items..... | 213 |
| Table J.7 – Voltage fluctuation and flicker adaptability test items..... | 213 |

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WIND ENERGY GENERATION SYSTEMS –**Part 21-4: Measurement and assessment of electrical characteristics –
Wind turbine components and subsystems****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 plants¹*

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.

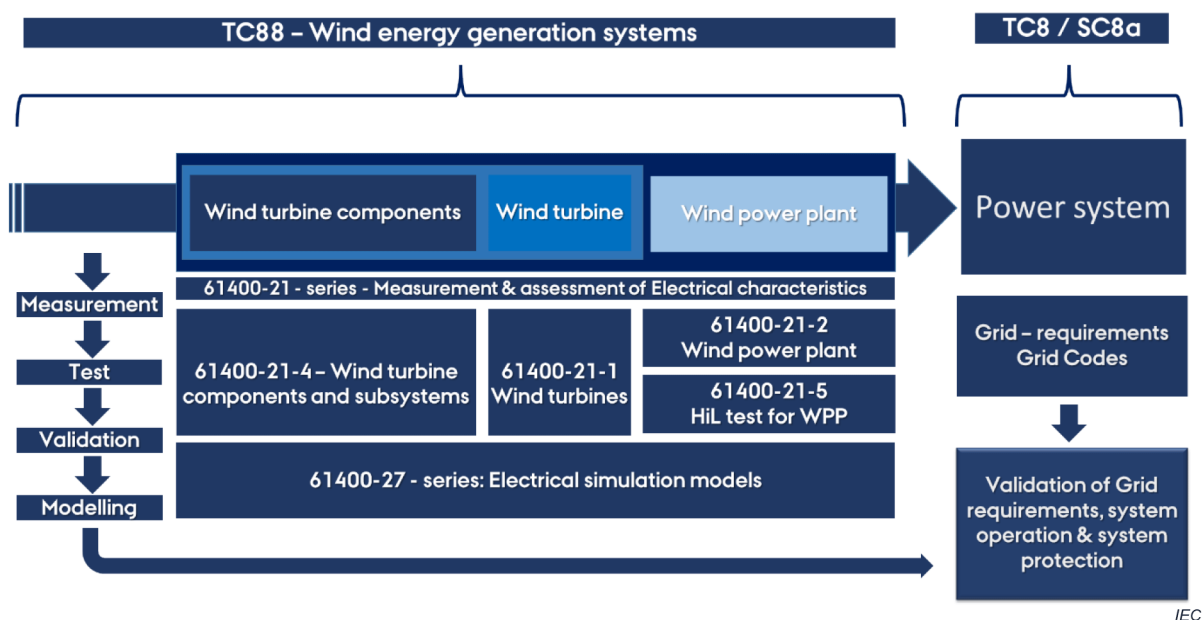


Figure 1 – Overview of TC 88 – Standards related to grid connection

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

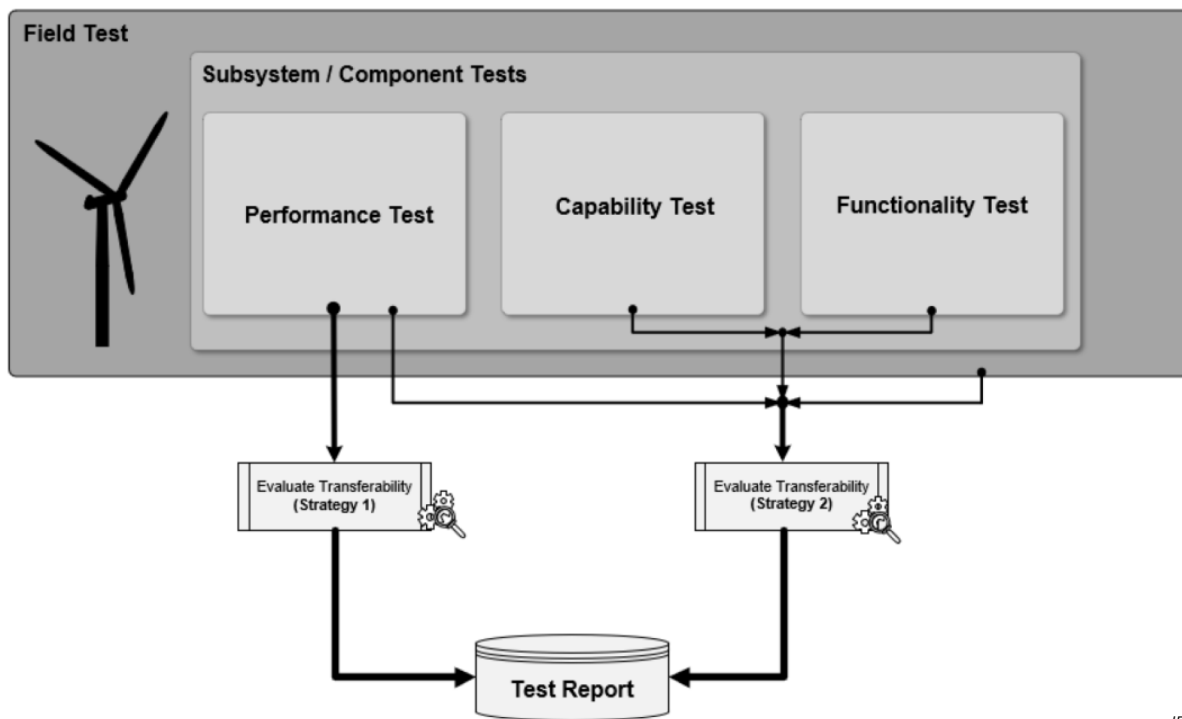
The defined test and measurement procedures can be performed as a combination of performance, capability, and functionality tests (Figure 2), which are carried out on different test benches. As shown in Figure 2, two strategies can be followed to derive measurement results:

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.



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

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)*