Overview, Status and Outline of the New Standards Series - IEC 61400 -21

Measurement and Assessment of Electrical Characteristics Part I - Wind turbines & Part II - Wind Power Plants

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***Abstract*— This paper presents the actual status of the new standard series for the IEC 61400-21 parts, the challenges during the process of the development and the expected outcome of the new standard series: "Measurement and assessment of electrical characteristics" Part I - Wind turbines & Part II - Wind power plants.**

Keywords- Power quality, IEC standard, wind turbine and wind power plant test, validation of electriacl capabilities, electrical simulation models.

I. Introduction

The IEC 61400–21 Standard exists since 13 years and is well established and accepted by the industry, the TSO's, DSO's and developers. In the light of the technology development and experience with the existing 2nd edition of the IEC 61400-21 on wind turbine power quality, a new revision was proposed in the beginning of 2012 and the Maintenance Team of the 61400-21 has worked since 2012 on a new revision. [3]

The IEC and the national committees have further approved in October 2014 to work out a new standard for the measurement and assessment of electrical characteristics for **Wind Power Plants**. This new standard "61400-21-Part II – Wind Power Plants" is the natural development of the existing "61400-21 Part I - Wind Turbine" standard which is close to be released in a 3rd edition.

The new standard series defines uniform methods, to ensure the testing and assessment of the electrical characteristics of grid connected **Wind Turbines & Wind Power Plants**, including: power quality aspects, control characteristics as power control, reactive power control, voltage control, frequency control as well as grid protection and fault ride through tests and measurement procedures.

The Standard series 61400-21 will be prepared from the existing MT 21 team, which consists of 49 members from 13 different countries.

II. 61400-21- Part - I – Wind Turbines

The work on the 3rd edition is ongoing since 2012, and the main changes and status are described below.

A. Actual state

The Committee draft (CD) for the 3rd edition has been published in August 2014. After the publication process through the national committees, the MT 21 team has received over 500 (editorial and technical) comments to the CD. These comments have been discussed and the modifications have resulted in the new version, which will be circulated as a Committee draft for voting (CDV) in October 2015.

Together with the CD the title of the standard has also been changed from:

"Measurement and assessment of power quality characteristics of grid connected wind turbines"

Into the following two parts:

"Measurement and assessment of electrical characteristics - Part 1 - Wind Turbines"

"Measurement and assessment of electrical characteristics - Part 2 - Wind Power Plants"

to reflect more precise the main scope and content of the standard series.

B. Main Changes 61400-21 Part I – Wind Turbines

The main changes for the revision of the IEC 61400-21 – Part I – Wind Turbines - are:

- Alignment of the – 21 with the upcoming IEC 61400-27- 1 standard on electrical simulation models
- Include new test as: Frequency control, voltage control, synthetic inertia etc.
- Update the FRT test with the experience of the 2nd Edition
- Revision of test procedure and assessment procedure for harmonics
- New definition of grid protection test
- Include / update requirements for small wind turbines connected to the LV grid
- Clear statements in the standard that only available functions should be tested and documented

C. Only relavant function to be tested

In the past the purpose of the 61400-21 was often misunderstood and the standard has been misinterpreted as a requirement standard, and many certification bodies, developer and TSO's etc. requested a fulfillment of the 61400-21.

But the aim and purpose of the 61400-21 is purely a measurement and test standard and not a requirement standard. The standard defines only the test and measurement procedure for the different parts of the electrical capabilities, available on the wind turbine level, and, if the manufacturer wants to have a type measurement, of these functions. [3]

This means that each part can be measured and certified separately and it is not required to measure all parts, values and functions mentioned in this standard.

D. Upscale downscale

During the development of the new revision, there has been a discussion if measurements and test results can be adapted to other wind turbine types as there are cases where due to maintenance, different site conditions, up-rating or upgrading of equipment, certain mechanical parts of the wind turbine may be changed. This can for example be the installation of a new gear-box, changing the blades or their length, different tower heights, etc. Such changes to the mechanical parts of the turbine will typically not have a significant impact on the electrical performance of the wind turbine.

Therefore the proposal in the new standard is: *"Type testing one turbine which is part of a product platform shall be considered sufficient to cover the entire turbine product platform, provided that a documented risk assessment is carried out according to Annex F to determine which type tests are valid and which tests need to be repeated on the rest of the turbine product platform".*[1]

A product platform is defined as: Turbines sharing the same mechanical platform, electrical system and main drive train components. These turbines are part of the same turbine family and the differences are typical the IEC classes, there are designed for, with the corresponding rotor diameter and nominal power.

Other examples of turbines from the same platform are e.g. wind turbines with different wind turbine transformer primary side voltage ratings, wind turbines with different rotor diameters, wind turbines with different component manufactures.

E. Power Quality aspects

The main aspects regarding power quality are flicker and harmonic emissions.

1) Flicker

The experience of flicker measurements according to IEC 61400-21 showed that in general the flicker behaviour of wind turbines is not relevant for grid connection. Only for very small wind turbines the flicker can be relevant or in a few cases for larger wind turbines, where sometimes the control causes fast power fluctuations often due to problems in their control or due to interharmonics, which were acting together with harmonics.

The aim of the changes in the flicker procedure was, to simplify the procedure and to reduce the measurement period.

In the new version of the IEc61400-21 the flicker in continuous operation will not be based anymore on wind speed bins, but will be based on power bins. Up to now the flicker measurements are required for an operation of the wind turbine up to a wind speed of 15 m/s. But modern wind turbines often reach their rated power already at 10 to 12 m/s. The new version requires seven flicker measurements of 10 minutes and for all three phases in each active power bin up to the 100 % power bin, which is from 95 % to 105 % of rated active power. From this a 95th percentile will be used to determine the flicker coefficient $c(\psi k)$. From this procedure the flicker coefficient will be given in a table, only dependent on the short-circuit angle of the grid (for angles of 30°, 50°, 70° and 85°), but not more dependent on the annual average wind speed class.

In the annex B of the new version of IEC61400-21 verification tests of the measurement procedure for flicker are given. This will help to specify the flicker procedure, especially the dynamical behaviour of the part from the measured data until the corresponding voltage fluctuations, which are given to the standard flicker meter.

2) Harmonics

The new version of IEC61400-21 specifies a 95 percentile harmonic current for each active power bin, where 7 tests of 10 minutes and three phases must be collected for each active power bin. The 95 percentile gives a more representative value for the harmonic emission than the maximum value, which is used up to now and which could be influenced by single events of the wind turbine.

Due to the fact, that harmonic emission measurements at wind turbines are often influenced by background noise and are often dependent on the grid impedances (resonances in the grid), a new informative annex (Annex D: Harmonic evaluation) was included in the IEC61400-21. This annex gives further methods for analysis of harmonic measurements, like for harmonic voltages and harmonic phase angles. In addition this annex also gives guidance, how to recognize or how to minimize the influence of background noise.

F. Steady state operation and control performance

Reactive power capability as well as control behaviors were subject to change within the new edition of the standard.

Reactive power capability is now measured with a focus on the maximum possible reactive power which can be provided and to clearly determine the voltage dependency. Hence the maximum possible under- and overexcited reactive power is measured and documented together with the voltage.

Experiences showed in the past that the description of control performance tests left room for interpretation. To ensure a similar level of quality, the control performance tests for active and reactive power as well as ramp rate limitation are described in more detail in the new edition of the 61400-21. Additionally, performance tests for frequency control and synthetic inertia have been defined. Highlighted should be that the reactive power control test now explicitly allows using either reactive power, voltage or cos φ control, depending on the wind turbines control system.

G. Dynamic performance

Dynamic performance covers Fault Ride Through, both Under Voltage and Over Voltage Ride Through.

In the new version of the standard Low Voltage Ride Through (LVRT) is renamed to Under Voltage Ride Through (UVRT) to better match the newly added Over Voltage Ride Through (OVRT).

Main objective with the UVRT and OVRT test is to verify the manufactures specified capability and provide data for the simulation models described in IEC 61400-27.

Instead of a given set of tests, the number of tests and test levels must be defined and described by the manufacturer in order to document the turbine's capability.

The background for this is to ensure the standard method always can be used to provide useful test report for any given turbine and specific market. Experience with the 2nd Ed. showed that there in many markets was a need for more or other tests, than the 6 tests specified. It is now up to the manufactures to specify the tests and make sure the requirement from the market is covered.

No specific test set-up is given in the standard, but instead a minimum performance of the dips and swells. This opens up for future test equipment that not has to be based on coils and switches and converters and grid simulators can be used, if the performance full-fills the requirements.

Better definition of what must be reported, step response for reactive current in dip and power recovery after the dip.

It is recommended to test at least four even distributed levels of under voltage and two levels of over voltage inside the manufactures specified capability of the turbine.

The ride through capability of the turbine must be demonstrated in a field test, but it can be supplemented by test bench tests to report different operations mode, different grid codes setting or different components.

Both full production and partial load must be verified, where partial load can be verified with the turbine down regulated, but at least two partial load dips must be performed in natural wind. The new test procedure allows a faster test campaign and gives more accurate results.

H. Grid Protection

Grid protection test is a verification of the functionality of the turbines grid protection, not a verification of a specific voltage level or time. It is the ability to react correctly according to the given parameter that is tested, not the level or time of the parameters and by demonstrating this it is proven that the protection can be set-up to follow a specific setting.

Changed from the previous version is that the step size and length of each step is not fixed, but adapted to the grid protection that is tested. Either a step ramp or a pulse ramp can be used. This makes it possible to test more levels of protection with different timing without having to disable any protections during the test.

To find the level for each protection voltage or frequency the test starts by stepping from nominal voltage or frequency to 2% /2Hz below the trip level and then step 0,5% / 0,5 Hz for 1,5 times the release time for the tested protection until the turbine trips and the level is found.

To find the release time the voltage or frequency or step to 1% or 1Hz below the trip level and then stepped to 1% or 1 Hz above the trip level and the time is measured from the step until the turbine disconnect.

The test can be done in the turbine, as a component test or a sub system test.

III. 61400 – 21 – Part II – Wind Power Plants

The need to define a standard on the Power plant level was identified during the development of the new revision for Part I – Wind Turbine - standard.

Therefore a New Work Item Proposal (NWIP) for the 61400-21 Part II – Wind Power Plants was prepared and circulated to the members of the TC 88 and other relevant standard groups.

The proposal was accepted and supported by all members in October 2014. Since then there has been held 3 Working meetings to start with the preparation of the new standard.

A. Motivation for the Part II

Based on the characteristics of a wind power plant, a detailed analysis of the power system interface is required, in order to analyze the grid support requirements, in the point of common coupling (PCC), to fulfil the grid connection code / the grid connection agreements.

The existing IEC 61400 – 21 Ed. 2 [1], includes some assessment procedures and guidelines for the evaluation of the flicker performance, switching effects, harmonic assessment etc. of a Wind power plants, but these rules are only guidelines and subject to discussions about the validity of the calculation methods, furthermore the existing -21 does not define how to measure the performance of the wind power plant controller and other components in the wind power plant, in respect to the electrical capabilities and control aspects.

This is the reason why there is a need for standardization of the methods for the power quality measurements and the calculation of grid performance characteristics on the Point of Common Coupling (PCC) of the wind power plant, as all connection requirements of the wind power plant are based on the performance on the PCC.

B. Aim and Purpose

The aim of the new Part II includes:

- Definition and specification of the quantities to be determined for characterizing the electrical characteristics of grid connected wind power plants
- Measurement and test procedures for quantifying the electrical characteristics
- Procedures and methods for the estimation of the wind power plant's electrical capabilities, using the results from single wind turbine measurements
- Procedures for measurement and fault recording for the verification of wind power plant models as described in the existing 61400-27 standard – Electrical simulation models

The described measurement and test procedures can therefore be used as a reference during the planning phase of a new wind power plant as well as reference for e.g. commissioning tests of wind power plants.

C. Power Plant controller

The implementation of different controls is not only highly dependent on the wind turbine type, but even more on the control strategy of the manufacturer. Being aware of this fact makes it not only crucial to explicitly point out that not all control performance tests need to be executed on wind turbine level, as they may not be implemented in the wind turbine control, but also to define corresponding tests on power plant level.

When it comes to accuracy of active and reactive power control not only the power plant control has a significant influence but also smoothing effects on power plant level should be taken into account and evaluated. Especially when evaluating dynamic behaviors like synthetic inertia.

D. Power Quality aspects

The previous version of IEC61400-21 already includes summation rules for calculation of the flicker and harmonic emission of wind farms from the measured values at single wind turbines. This will be also included in part II of the new IEC61400-21. Within actual research projects for harmonic emission one item is also the investigation of the summation law for harmonic evaluation. But up to now, there is still no new status.

In principle the measurement procedures for flicker and harmonics of part I can also be used in part II for wind farms. For verification of the wind farm behaviour regarding the limiting values from grid codes it will also be possible to include simplified measurement methods, based on voltage measurements (flicker and harmonics)

E. Steady state operation

Steady state operation tests in part II will concentrate on measurement procedures for evaluation of reactive power capability on power plant level, including not only the wind turbines capability but external compensation equipment as well. To ensure a coherent measurement procedure the necessary parameters e.g. nominal active power, available power, Point of Interconnection (POI) etc. of a wind power plant will be clearly defined.

F. Dynamic performance aditional requirments

For getting data to verify performance during faults on park level the standard relies on on-site recording of actual events in the grid, rather than setting up any park level Fault Ride Through testing.

In case of a fault the data can be used to verify the simulation model and verify the correct performance of the park.

There has to be requirements to the fault recording equipment and the information that need to be recorded, like operation mode of the park, number of turbines running and compensation equipment.

IV. TR_ HARMONIC MODEL

Until now there has been no systematic approach of representing wind turbine (WT) from harmonic performance perspective. This brings inconsistency in WT harmonic performance assessment, background distortion evaluation in grid-connected WTs, harmonic analysis of onshore and offshore wind power plants (WPPs). Therefore a working group under the umbrella of the maintenance team (MT) 21 within technical committee TC 88 has been initiated to prepare a technical report (TR) providing guidance to the wind power industry.

A. Purpose

There is an understandable requirement from the wind power industry, i.e. transmission system operators (TSOs), distribution network operators (DNOs), WPP developers, WT manufacturers, WT component suppliers, academic units, research institutions, certifying bodies and standardization groups (e.g. TC88 MT21), of having a standardized WT harmonic model. The utilization of WT harmonic model could recognized in the following areas:

- Provide universal measure of WT harmonic performance
- Supplement the harmonic measurements report from IEC 61400-21
- Introduce standardised way of performing harmonic analysis in WPPs
- Introduce common interfaces to various engineering tools
- Define common basis for dialog with manufacturers, developers, TSOs and DNOs
- Provide benchmark for the academia and industry
- Allow to assess the external network influence

B. Requirements

The WT harmonic model in order to be broadly used by the industry needs to have a standardized and universal structure. This would allow WT manufacturers, WPP developers, TSOs, DNOs, universities and other potential stakeholders to have a common understanding and easier establish a dialog between each other. However the minimal requirements need to be defined for such a harmonic model which would constitute as solid basis in overall harmonic model understanding of its purpose. It would be:

- Application
- Input parameters
- Point of connection
- Output variables
- Structure
- Tolerances/uncertainties
- Validation

C. Interfaces

1) IEC 61400-21-1 Annex D – Harmonic evaluation

The harmonic current emission of a WT can be influenced by e.g.:

- Harmonic grid background distortion
- Resonances in the grid impedances
- Short circuit power at the grid connection point

The aim of Annex D is to evaluate the harmonic emission of a WT independently on the above influences as accurate as possible. Thus it may be necessary to identify other influences on the harmonic emission of the WT and possibly exclude these influences.

The above mentioned influences are dependent on the WT type, on the grid configuration and situation at the site of the measured WT as well as on the actual grid background harmonic voltage distortions during the measurements. Thus it is still not possible to give a specific procedure, how to identify the influences and how to exclude them.

The WT harmonic assessment can be also done based on WT harmonic model evaluation. The model can be developed based on measurement data as well as sophisticated simulation tools. The model describes the harmonic behavior of the WT in theory excluding influence of a distorted grid to which the WT is connected.

The model can be used in order to evaluate the background distortion impact on the measurement process as specified in the Annex D.

2) IEC 61400-21-2 – Harmonic summation

The number of WTs in modern large offshore and onshore WPPs is increasing. This creates new challenges in harmonic analysis of such complex systems leading to harmonic emission evaluation at the point of connection or point of common coupling and as a consequence to introduction of harmonic mitigation measures by means of active or passive filtering.

Therefore there is a need of having appropriately developed and validated harmonic model in order to estimate the influence of WT on harmonic level at the point of interest. This would cover possible harmonic summation and cancellation between WT. The standardized harmonic model also includes information about harmonic phase angle which can allow estimation of harmonic cancellation/summation on a system level.

Nowadays there is no standard approach of doing harmonic analysis in WPPs. Within the scope of IEC 61400-21 Part II, would be to provide recommendations and guidance of performing harmonic emission assessment on a WPP level including estimation of harmonic current flows within a WPP system as an extension of already existing recommendation in IEC 61000-3-6. Such recommendation will also directly be reflected in the WT harmonic model structure and its application.

D. Validation

Every modern WT has built-in unique technical solutions in many cases protected by patent law. Therefore it is up to the WT manufacturer how the harmonic model structure and model development is done. However the harmonic model validation process is something which will give a common understanding of WT harmonic performance to the industry and academia.

Harmonic current emission from the WT is strongly dependent on the WT internal impedance as well as the external network frequency-dependent short circuit impedance. To be able to get more accurate assessment procedure, the new revision of IEC 61400-21 specifies besides the harmonic currents also the harmonic voltage measurement procedures including phase angle information and aggregation techniques. Such extensive measurement dataset can be used either for WT harmonic model validation or even development.

Furthermore it also addresses the evaluation of uncertainties of the measurements and the data analysis. The new edition also provides guidelines how to detect which harmonics currents are affected by the background harmonic distortion.

V. Interface to other standards and activities

As there are many other parallel and complementary activities ongoing in this area, it is important to follow and align the different activities in the other national and international standard organizations, working committees etc. by e.g. active participation, combined working groups, exchange of information's and through the Technical Committees in the IEC. Some major ongoing activates are mentioned below.

A. 61400-27 - Electrical simulation models - Series

The increasing penetration of wind energy in power systems implies that TSO's and DSO's need to use dynamic models of wind power generation for power system stability studies.

One of the reasons for revising IEC 61400-21 is to have an alignment with the work on the new international standard IEC 61400-27.

These standard series specifies standard dynamic electrical simulation models for wind power generation. IEC 61400-27-1 specifies wind turbine models and model validation procedure. IEC 61400-27-2 will specify wind power plant models and model validation procedure. [2]

To avoid additional test for the validation of these models, the validation of these simulation models for the wind turbines and plant models, including the power plant controller, is based on the measurements and test specified in the 61400-21 series.

B. TC8 and SC8a

The newly established SC8a – Grid Integration of Renewable Energy Generation under the TC8, is responsible in co-operation with the other TC to develop standards for the grid integration of renewable power generation, with emphasis the overall system aspects of electrical power supply as defined in the TC8.

C. TC 8 - IEC 62786 Ed.1: Distributed Energy Resources Interconnection with the Grid

The latest activities in the TC8 have resulted in a new Committee draft CD - IEC 62786 Ed.1: Distributed Energy Resources Interconnection with the Grid, which is dealing with the technical requirements for the grid connection of distributed energy systems, as e.g. WT & WPP's.

D. TC 73 - IEC 60909

The increased penetration of Wind power in the energy system has furthermore resulted in a new IEC 60909 – 0 - Short circuit currents in three phase a.c. systems - Calculation of currents. This new proposal includes now short circuit calculations of Wind power plants, based on the different technologies of Wind turbines.

E. Cigré - Network Modelling for Harmonic Studies

On European level there have been established Joint working groups under Cigré e.g. JWG C4/B4.38 - Network Modelling for Harmonic Studies, as the harmonic voltage distortion calculation methods needs to be redefined due to the increased connection of converter based energy systems.

Therefore a close co-operation is necessary between the TC88 including there working groups and the activities in the other TC's, to avoid overlapping and to have a common consensus on the different definitions, requirements and responsibilities.

VI. TIME LINE AND FUTURE WORK

An indicative time line for 61400-21 Part 1 – Wind turbines and Part II - Wind Power Plants is shown in Table 1; it is assumed that a Committee Draft for Voting (CDV) of Part 1 will be submitted by MT21 in October 2015. The FDIS is expected to be released in the middle of 2016 and the final standard will be available some months later.

Table 1: Timeline for the IEC-61400-21- Part I and Part II

Stage	**Part I Target dates**	**Part II Target dates**
RR	2-2012	10-2014
CD	6-2014	3-2016
CDV	10-2015	10-2016
FDIS	5-2016	10-2017

The CD Committee Draft for the Part II will be released in the middle of 2016 and the final standard is expected to be published in the end of 2017.

VII. CONCLUSION

This paper presents the actual state of the development of the 3rd edition, the main ideas and changes for the new revision of the IEC 61400-21- Part I, which has now reached a well-developed stage for the CDV. The changes in the new revision are not finalized and approved yet and can therefore be subject to change according to the comments from the national committees on the CDV.

The work on the Part II has been started as a natural further development of the IEC 61400-21 series and will be circulated as a first committee draft in the first half of 2016.

For the future work of the Part II it would be beneficial if more TSO's and DSO's could participate in the development of this standard as they are the main customer of the measurement reports.

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