IEC TR 61400-21-3

Edition 1.0 2019-09

TECHNICAL REPORT

colour inside

Wind energy generation systems –
Part 21-3: Measurement and assessment of electrical characteristics – Wind turbine harmonic model and its application

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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WIND ENERGY GENERATION SYSTEMS –

Part 21-3: Measurement and assessment of electrical characteristics – Wind turbine harmonic model and its application

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IEC TR 61400-21-3, which is a Technical Report, has been prepared by IEC Technical Committee 88: Wind energy generation systems.

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

DTR	Report on voting
88/698/DTR	88/717/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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

- reconfirmed,
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- replaced by a revised edition, or
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INTRODUCTION

The purpose of this IEC Technical Report (TR) is to provide a methodology that will ensure understanding, consistency and accuracy in application, structure and validation of the harmonic model of grid connected wind turbines (WTs).

There is an understandable requirement from wind power industry shareholders, e.g. transmission system operators (TSOs) and distribution system operators (DSOs), wind power plant (WPP) developers, WT manufacturers, WT component suppliers, academic units, research institutions, certifying bodies and standardization groups (e.g. TC88 MT21), for having a standardized WT harmonic model.

The standardized harmonic model would find a broad application in many areas of electrical engineering related to design, analysis, and optimisation of electrical infrastructure of onshore as well as offshore WPPs. Among others, this could be the evaluation of the WT harmonic performance, system-level harmonic studies, electrical infrastructure design and proposal of harmonic mitigation measures.

Standardized WT harmonic models as a performance measure starts to be important in such multi stakeholder systems as large offshore WPPs where TSOs, WPP developers and operators as well as WT manufacturers need to have a common understanding about harmonic modelling of WTs and harmonic studies in WPPs.

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WIND ENERGY GENERATION SYSTEMS –

Part 21-3: Measurement and assessment of electrical characteristics – Wind turbine harmonic model and its application

1 Scope

This part of IEC 61400 provides guidance on principles which can be used as the basis for determining the application, structure and recommendations for the WT harmonic model. For the purpose of this Technical Report, a harmonic model means a model that represents harmonic emissions of different WT types interacting with the connected network.

This document is focused on providing technical guidance concerning the WT harmonic model. It describes the harmonic model in detail, covering such aspects as application, structure, as well as validation. By introducing a common understanding of the WT representation from a harmonic performance perspective, this document aims to bring the overall concept of the harmonic model closer to the industry (e.g. suppliers, developers, system operators, academia, etc.).

A standardized approach of WT harmonic model representation is presented in this document. The harmonic model will find a broad application in many areas of electrical engineering related to design, analysis, and optimisation of electrical infrastructure of onshore as well as offshore WPPs.

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The structure of the harmonic model presented in this document will find an application in the following potential areas:

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- evaluation of the WT harmonic performance during the design of electrical infrastructure and grid-connection studies;
- harmonic studies/analysis of modern power systems incorporating a number of WTs with line side converters;
- active or passive harmonic filter design to optimize electrical infrastructure (e.g. resonance characteristic shaping) as well as meet requirements in various grid codes;
- sizing of electrical components (e.g. harmonic losses, static reactive power compensation, noise emission, harmonic compatibility levels, etc.) within WPP electrical infrastructure;
- evaluation of external network background distortion impact on WT harmonic assessment;
- standardised communication interfaces in relation to WT harmonic data exchange between different stakeholders (e.g. system operators, generators, developers, etc.);
- universal interface for harmonic studies for engineering software developers;
- possible benchmark of WT introduced to the academia and the industry.

The advantage of having standardized WT harmonic performance assessment by means of the harmonic model is getting more and more crucial in case of large systems with different types of WTs connected to them, e.g. multi-cluster wind power plants incorporating different types of WTs connected to the same offshore or onshore substation.

The WT harmonic model can cover the integer harmonic range up to the 40th, 50th, or 100th. And can be expanded, depending on requirements and application, to higher harmonic range as well as can also cover interharmonic components.

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 60050-415:1999, *International Electrotechnical Vocabulary – Part 415: Wind turbine generator systems* (available at <http://www.electropedia.org/)

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

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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For the purposes of this document, the terms and definitions given in IEC 60050-415 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
compatibility levels
reference levels of a particular disturbance in a particular environment defined for co-ordinating the emission and immunity of equipment which is part of, or supplied by, a supply system in order to ensure the EMC in the whole system (including system and connected equipment)

Note 1 to entry: Compatibility levels are generally based on the 95 % probability levels of entire systems, using statistical distributions which represent both time and space variations of disturbances.

Note 2 to entry: There is allowance for the fact that the system operator or owner cannot control all points of a system at all times. Therefore, evaluation with respect to compatibility levels should be made on a system-wide basis and no assessment method is provided for evaluation at a specific location.

3.1.2
factor K
indicator of the ability of a transformer to be loaded with non-sinusoidal currents

Note 1 to entry: The equivalent power rating is equal to the power based on the RMS value of the non-sinusoidal current multiplied by the factor K.

[SOURCE: EN 50464-3:2007, modified – additional elaboration, creation of a note to entry and deletion of the formula]

3.1.3
harmonic phase or angle
phase (angle) α_h of the spectral component y_h, that is, the phase between the harmonic current component or harmonic voltage component and the fundamental component voltage defined in Figure 1 and equation below

$$y_h = c_h \sin(h\omega_1 t + \alpha_h)$$

where c_h is the spectral component magnitude

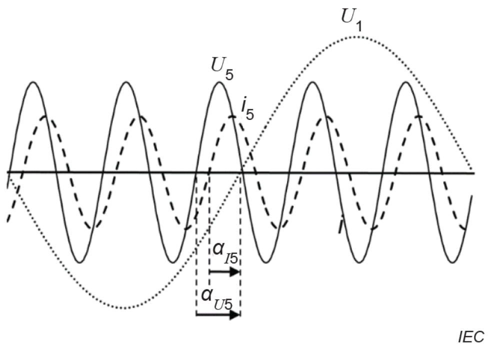

Figure 1 – Example of a phase angle between the harmonic current and the harmonic voltage component as well as the fundamental voltage

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Note 1 to entry: The sign convention used for the voltages and currents is the generator convention as defined in IEC 61400-21-1:2019, Annex C.

Note 2 to entry: Please check IEC 61400-21-1:2019, Annex D for more details.

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3.1.4
harmonic distortion
cyclic departure of a waveform from the sinusoidal shape

Note 1 to entry: This can be described by the addition of one or more harmonics to the fundamental.

3.1.5
harmonic model
model that represents harmonic emissions of a WT interacting with the connected network

Note 1 to entry: Different WT types may be modelled by changing the model parameters.

3.1.6
harmonic model terminals
reference point on the electric power system where here the harmonic model is connected

3.1.7
negative-sequence component of 3-phase voltages (or currents)
symmetrical vector system derived by application of the Fortescue's transformation matrix, and that rotates in the opposite direction to the power frequency voltage (or current)

[SOURCE: IEC TR 61000-3-13:2008, 3.26.4, modified – the formula has been deleted]

3.1.8
operational mode
<wind turbine> operation according to control setting, for example voltage control mode, frequency control mode, reactive power control mode, active power control mode, etc.

[SOURCE: IEC 61400-21-1:2019, 3.9]

3.1.9
percentile
the value of a variable below which a certain percent of observations fall

3.1.10
planning level
level of a particular disturbance in a particular environment, adopted as a reference value for the limits to be set for the emissions from the installations in a particular system, in order to co-ordinate those limits with all the limits adopted for equipment and installations intended to be connected to the power supply system

Note 1 to entry: Planning levels are considered internal quality objectives to be specified at a local level by those responsible for planning and operating the power supply system in the relevant area.

[SOURCE: IEC TR 61000-3-6:2008, 3.16]

3.1.11
point of connection
reference point on the electric power system where here the WPP is connected

[SOURCE: IEC 60050-617:2009, 617-04-01, modified – "user's electrical facility" has been replaced by WPP]

3.1.12
positive-sequence component of 3-phase voltages (or currents)
symmetrical vector system derived by application of the Fortescue's transformation matrix, and that rotates in the same direction as the power frequency voltage (or current)

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[SOURCE: IEC TR 61000-3-13:2008, 3.26.3, modified – the formula has been deleted]

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3.1.13
power bin
consecutive, non-overlapping intervals of WT active power measured at WT terminals

Note 1 to entry: The bins (intervals) shall be adjacent, and are usually equal size, e.g. 0, 10, 20, … , 100 % of P_n. 0, 10, 20, … , 100 % are the bin midpoints.

[SOURCE: IEC 61400-21-1:2019, 3.62, modified – "active" has been deleted from the term defined; in the note, "shall be adjacent" has been added and the text has been slightly modified]

3.1.14
prevailing angle
phase of the spectral component is described by

$$\alpha_{\mathrm{h,avg}} = \arctan\left(\frac{\sum_{i=1}^{n}\mathrm{Im}\left(\underline{C}_{\mathrm{h,i}}\right)}{\sum_{i=1}^{n}\mathrm{Re}\left(\underline{C}_{\mathrm{h,i}}\right)}\right), \quad \text{if } \sum_{i=1}^{n}\mathrm{Re}\left(\underline{C}_{h,i}\right) \geq 0$$

$$\alpha_{\mathrm{h,avg}} = \pi + \arctan\left(\frac{\sum_{i=1}^{n}\mathrm{Im}\left(\underline{C}_{\mathrm{h,i}}\right)}{\sum_{i=1}^{n}\mathrm{Re}\left(\underline{C}_{\mathrm{h,i}}\right)}\right), \quad \text{if } \sum_{i=1}^{n}\mathrm{Re}\left(\underline{C}_{h,i}\right) < 0$$

where

n is the number of DFT windows;