

Wind energy generation systems - Part 27-2: Electrical  
simulation models - Model validation

## EESTI STANDARDI EESSÕNA

## NATIONAL FOREWORD

See Eesti standard EVS-EN IEC 61400-27-2:2020 sisaldab Euroopa standardi EN IEC 61400-27-2:2020 ingliskeelset teksti.	This Estonian standard EVS-EN IEC 61400-27-2:2020 consists of the English text of the European standard EN IEC 61400-27-2:2020.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 25.09.2020.	Date of Availability of the European standard is 25.09.2020.
Standard on kättesaadav Eesti Standardikeskusest.	The standard is available from the Estonian Centre for Standardisation.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile [standardiosakond@evs.ee](mailto:standardiosakond@evs.ee).

ICS 27.180

Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardikeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega:  
Koduleht [www.evs.ee](http://www.evs.ee); telefon 605 5050; e-post [info@evs.ee](mailto:info@evs.ee)

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation:

Homepage [www.evs.ee](http://www.evs.ee); phone +372 605 5050; e-mail [info@evs.ee](mailto:info@evs.ee)

ICS 27.180

English Version

**Wind energy generation systems - Part 27-2: Electrical  
simulation models - Model validation  
(IEC 61400-27-2:2020)**

Systèmes de génération d'énergie éolienne - Partie 27-2:  
Modèles de simulation électrique - Validation des modèles  
(IEC 61400-27-2:2020)

Windenergieanlagen - Teil 27-2: Elektrische  
Simulationsmodelle - Validierung der Modelle  
(IEC 61400-27-2:2020)

This European Standard was approved by CENELEC on 2020-08-18. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization  
Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

**CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels**

## European foreword

The text of document 88/763/FDIS, future edition 1 of IEC 61400-27-2, prepared by IEC/TC 88 "Wind energy generation systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61400-27-2:2020.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-05-18
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2023-08-18

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

## Endorsement notice

The text of the International Standard IEC 61400-27-2:2020 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61400-21-2      NOTE      Harmonized as EN IEC 61400-21-2<sup>1</sup>

IEC 61400-25 (series)      NOTE      Harmonized as EN 61400-25 (series)

---

<sup>1</sup> To be published. Stage at the time of publication: prEN IEC 61400-21-2:2020.

## Annex ZA (normative)

### Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: [www.cenelec.eu](http://www.cenelec.eu).

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-415	1999	International Electrotechnical Vocabulary - Part 415: Wind turbine generator systems	-	-
IEC 61400-21-1	2019	Wind energy generation systems - Part 21-1: Measurement and assessment of electrical characteristics - Wind turbines	EN IEC 61400-21-1	2019
IEC 61400-27-1	-	Wind energy generation systems - Part 27-1: Electrical simulation models - Generic models	-	-

# INTERNATIONAL STANDARD



**Wind energy generation systems –  
Part 27-2: Electrical simulation models – Model validation**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2020 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

# INTERNATIONAL STANDARD



**Wind energy generation systems –  
Part 27-2: Electrical simulation models – Model validation**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 27.180

ISBN 978-2-8322-8506-0

**Warning! Make sure that you obtained this publication from an authorized distributor.**



## CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	10
2 Normative references .....	10
3 Terms, definitions, abbreviations and subscripts.....	11
3.1 Terms and definitions.....	11
3.2 Abbreviations and subscripts .....	15
3.2.1 Abbreviations.....	15
3.2.2 Subscripts .....	15
4 Symbols and units .....	15
4.1 General.....	15
4.2 Symbols (units).....	16
5 Functional specifications and requirements to validation procedures .....	18
5.1 General.....	18
5.2 General specifications.....	18
5.3 Wind turbine model validation .....	20
5.4 Wind power plant model validation .....	20
6 General methodologies for model validation .....	20
6.1 General.....	20
6.2 Test results .....	20
6.3 Simulations .....	21
6.4 Signal processing .....	21
6.4.1 General .....	21
6.4.2 Time series processing .....	21
6.4.3 Windows error statistics.....	23
6.4.4 FRT windows specification .....	24
6.4.5 Step response characteristics .....	25
7 Validation of wind turbine models .....	27
7.1 General.....	27
7.2 Fault ride through capability .....	27
7.2.1 General .....	27
7.2.2 Test requirements.....	28
7.2.3 Simulation requirements .....	29
7.2.4 Validation results .....	29
7.3 Active power control .....	29
7.3.1 General .....	29
7.3.2 Test requirements.....	29
7.3.3 Simulation requirements .....	30
7.3.4 Validation results .....	30
7.4 Frequency control .....	30
7.4.1 General .....	30
7.4.2 Test requirements.....	30
7.4.3 Simulation requirements .....	31
7.4.4 Validation results .....	31
7.5 Synthetic inertia control .....	31
7.5.1 General .....	31

7.5.2	Test requirements.....	31
7.5.3	Simulation requirements .....	32
7.5.4	Validation results .....	32
7.6	Reactive power reference control.....	32
7.6.1	General .....	32
7.6.2	Test requirements.....	32
7.6.3	Simulation requirements .....	33
7.6.4	Validation results .....	33
7.7	Reactive power – voltage reference control.....	33
7.7.1	General .....	33
7.7.2	Test requirements.....	33
7.7.3	Simulation requirements .....	33
7.7.4	Validation results .....	34
7.8	Grid protection.....	34
7.8.1	General .....	34
7.8.2	Test requirements.....	34
7.8.3	Simulation requirements .....	34
7.8.4	Validation results .....	35
8	Validation of wind power plant models .....	35
8.1	General.....	35
8.2	Active power control .....	35
8.2.1	General .....	35
8.2.2	Test requirements.....	36
8.2.3	Simulation requirements .....	36
8.2.4	Validation results .....	36
8.3	Reactive power reference control.....	36
8.3.1	General .....	36
8.3.2	Test requirements.....	37
8.3.3	Simulation requirements .....	37
8.3.4	Validation results .....	37
8.4	Reactive power – voltage reference control.....	37
8.4.1	General .....	37
8.4.2	Test requirements.....	38
8.4.3	Simulation requirements .....	38
8.4.4	Validation results .....	38
Annex A (informative)	Validation documentation for wind turbine model.....	39
A.1	General.....	39
A.2	Simulation model and validation setup information .....	39
A.3	Template for validation results .....	39
A.3.1	General .....	39
A.3.2	Fault ride through capability.....	40
A.3.3	Active power control .....	42
A.3.4	Frequency control.....	42
A.3.5	Synthetic inertia control .....	43
A.3.6	Reactive power reference control .....	43
A.3.7	Reactive power – voltage reference control .....	44
A.3.8	Grid protection.....	45
Annex B (informative)	Validation documentation for wind power plant model.....	46
B.1	General.....	46

B.2	Simulation model and validation setup information .....	46
B.3	Template for validation results .....	46
B.3.1	General .....	46
B.3.2	Active power control .....	47
B.3.3	Reactive power reference control .....	47
B.3.4	Reactive power – voltage reference control .....	48
Annex C (informative)	Reference grid for model-to-model validation .....	49
Annex D (informative)	Model validation uncertainty .....	50
D.1	General .....	50
D.2	Simulation uncertainties .....	50
D.3	Measurement uncertainties .....	50
D.4	Impact of model validation uncertainties .....	51
Annex E (normative)	Digital 2 <sup>nd</sup> order critically damped low pass filter .....	52
Annex F (informative)	Additional performance based model validation methodology for active power recovery in voltage dips .....	53
F.1	General .....	53
F.2	Active power recovery criterion .....	53
F.3	Active power oscillation criterion .....	53
Annex G (informative)	Generic software interface for use of models in different software environments .....	55
G.1	Description of the approach .....	55
G.2	Description of the software interface .....	56
G.2.1	Description of data structures .....	56
G.2.2	Functions for communication through the ESE-interface .....	58
G.2.3	Inputs, outputs, parameters .....	59
Bibliography	.....	60
Figure 1 – Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions [1] .....		8
Figure 2 – Signal processing structure with play-back simulation approach applied .....		22
Figure 3 – Signal processing structure with full-system simulation approach applied .....		22
Figure 4 – Voltage dip windows [12] .....		24
Figure 5 – Step response characteristics .....		26
Figure 6 – Measured and simulated settling time with inexpedient choice of tolerance band .....		27
Figure A.1 – Time series of measured and simulated positive sequence voltage .....		40
Figure A.2 – Time series of measured and simulated positive sequence active current .....		40
Figure A.3 – Time series of measured and simulated positive sequence reactive current .....		40
Figure A.4 – Time series of calculated absolute error of positive sequence active and reactive current .....		40
Figure A.5 – Time series of measured and simulated negative sequence voltage .....		41
Figure A.6 – Time series of measured and simulated negative sequence active current .....		41
Figure A.7 – Time series of measured and simulated negative sequence reactive current .....		41
Figure A.8 – Time series of calculated absolute error of negative sequence active and reactive current .....		41

Figure A.9 – Time series of active power reference, available active power, measured active power and simulated active power .....	42
Figure A.10 – Time series of frequency reference value and measured input to WT controller .....	43
Figure A.11 – Time series of available active power, measured active power and simulated active power .....	43
Figure A.12 – Time series of frequency reference value and measured input to WT controller .....	43
Figure A.13 – Time series of available active power, measured active power and simulated active power .....	43
Figure A.14 – Time series of reactive power reference, measured reactive power and simulated reactive power .....	44
Figure A.15 – Time series of measured active power and simulated active power .....	44
Figure A.16 – Time series of measured and simulated reactive power .....	44
Figure B.1 – Time series of active power reference, available active power, measured active power and simulated active power .....	47
Figure B.2 – Time series of reactive power reference, measured reactive power and simulated reactive power .....	47
Figure B.3 – Time series of measured active power and simulated active power .....	47
Figure B.4 – Time series of measured and simulated reactive power .....	48
Figure C.1 – Layout of reference grid .....	49
Figure F.1 – Voltage dip active power performance validation parameters .....	54
Figure G.1 – Sequence of simulation on use of ESE-interface .....	59
Table 1 – Windows applied for error calculations .....	25
Table A.1 – Required information about simulation model and validation setup .....	39
Table A.2 – Additional information required if full-system method is applied .....	39
Table A.3 – Positive sequence validation summary for each voltage dip and voltage swell validation case .....	41
Table A.4 – Negative sequence validation summary for each voltage dip and voltage swell validation case .....	42
Table A.5 – Validation summary for active power control .....	42
Table A.6 – Validation summary for reactive power control .....	44
Table A.7 – Validation summary for grid protection .....	45
Table B.1 – Required information about simulation model and validation setup .....	46
Table B.2 – Additional information required if full-system method is applied .....	46
Table B.3 – Validation summary for active power control .....	47
Table B.4 – Validation summary for reactive power control .....	47
Table C.1 – Line data for the WECC test system in per-unit .....	49
Table C.2 – Transformer data for the WECC test system .....	49

# INTERNATIONAL ELECTROTECHNICAL COMMISSION

## WIND ENERGY GENERATION SYSTEMS –

### Part 27-2: Electrical simulation models – Model validation

#### FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users shall ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61400-27-2 has been prepared by IEC technical committee 88: Wind energy generation systems.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
88/763/FDIS	88/772/RVD

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

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

A list of all parts in the IEC 61400, 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 publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

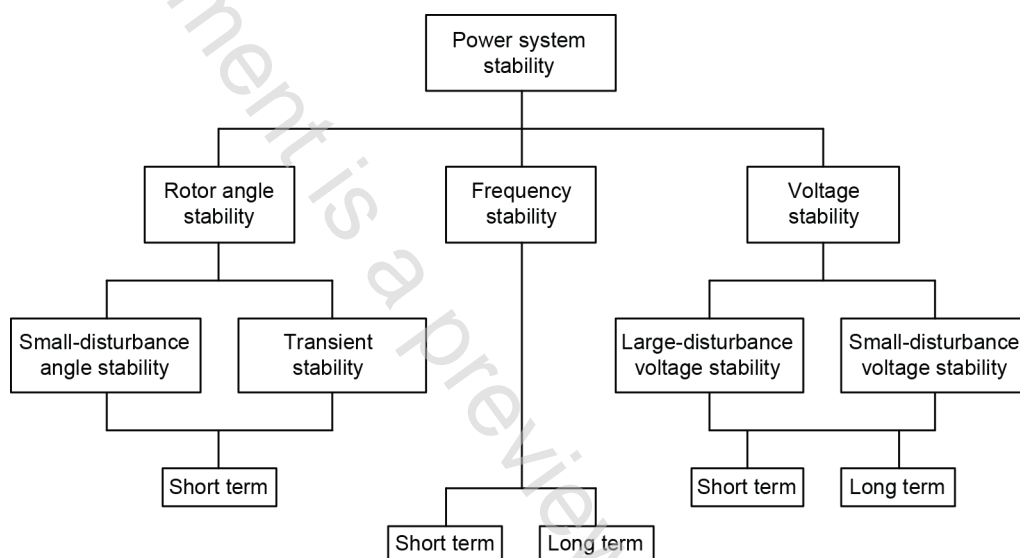
**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

## INTRODUCTION

IEC 61400-27-2 specifies model validation procedures for electrical simulation models of wind turbines and wind power plants.

The increasing penetration of wind energy in power systems implies that Transmission System Operators (TSOs) and Distribution System Operators (DSOs) need to use dynamic models of wind power generation for power system stability studies.

The purpose of this International Standard is to specify validation procedures for dynamic models, which can be applied in power system stability studies. The IEEE/CIGRE Joint Task Force on Stability Terms and Definitions [1]<sup>1</sup> has classified power system stability in categories according to Figure 1.



IEC

**Figure 1 – Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions [1]**

Referring to these categories, the models to be validated have been developed to represent wind power generation in studies of large-disturbance short term stability phenomena, i.e. short term voltage stability, short term frequency stability and short term transient stability studies referring to the definitions of IEEE/CIGRE Joint Task Force on Stability Terms and Definitions in Figure 1. Thus, the models are applicable for dynamic simulations of power system events such as short-circuits (low voltage ride through), loss of generation or loads, and system separation of one synchronous area into more synchronous areas.

The validation procedure specified in this document assesses the accuracy of the fundamental frequency response of wind power plant models and wind turbine models. This includes validation of the generic positive sequence models specified in IEC 61400-27-1 and validation of positive sequence as well as negative sequence response of more detailed models developed by the wind turbine manufacturers.

<sup>1</sup> Figures in square brackets refer to the Bibliography.

The validation procedure has the following limitations:

- The validation procedure does not specify any requirements to model accuracy. It only specifies measures to quantify the accuracy of the model<sup>2,3</sup>.
- The validation procedure does not specify test and measurement procedures, as it is intended to be based on tests specified in IEC 61400-21-1 and IEC 61400-21-24.
- The validation procedure is not intended to justify compliance to any grid code requirement, power quality requirements or national legislation.
- The validation procedure does not include validation of steady state capabilities e.g. of reactive power, but focuses on validation of the dynamic performance of the models.
- The validation procedure does not cover long term stability analysis.
- The validation procedure does not cover sub-synchronous interaction phenomena.
- The validation procedure does not cover investigation of the fluctuations originating from wind speed variability in time and space.
- The validation procedure does not cover phenomena such as harmonics, flicker or any other EMC emissions included in the IEC 61000 series.
- The validation procedure does not cover eigenvalue calculations for small signal stability analysis.
- This validation procedure does not address the specifics of short-circuit calculations.
- The validation procedure is limited by the functional specifications in Clause 5.

The following stakeholders are potential users of the validation procedures specified in this document:

- TSOs and DSOs need procedures to validate the accuracy of the models which they use in power system stability studies;
- wind plant owners are typically responsible to provide validation of their wind power plant models to TSO and/or DSO prior to plant commissioning;
- wind turbine manufacturers will typically provide validation of the wind turbine models to the owner.
- developers of modern software for power system simulation tools may use the standard to implement validation procedures as part of the software library;
- certification bodies in case of independent model validation;
- education and research communities, who can also benefit from standard model validation procedures.

---

<sup>2</sup> Specification of requirements to model accuracy is the responsibility of TSOs e.g. in grid codes. The scope of IEC 61400-27-2 is to provide a standard for how to measure accuracy and this way remove indefiniteness.

<sup>3</sup> Clause 7 specifies a large number of measures for model accuracy. The importance of the individual measure depends on the type of grid and type of stability study. Annex D describes limits to the possible accuracy of the models.

<sup>4</sup> Under consideration.