IEC 61400-27-2

Edition 1.0 2020-07

INTERNATIONAL STANDARD

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colour inside

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

Systèmes de génération d'énergie éolienne –
Partie 27-2: Modèles de simulation électrique – Validation des modèles

IEC 61400-27-2:2020-07(en-fr)

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WIND ENERGY GENERATION SYSTEMS –

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

FOREWORD

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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

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- amended.

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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][1] has classified power system stability in categories according to Figure 1.

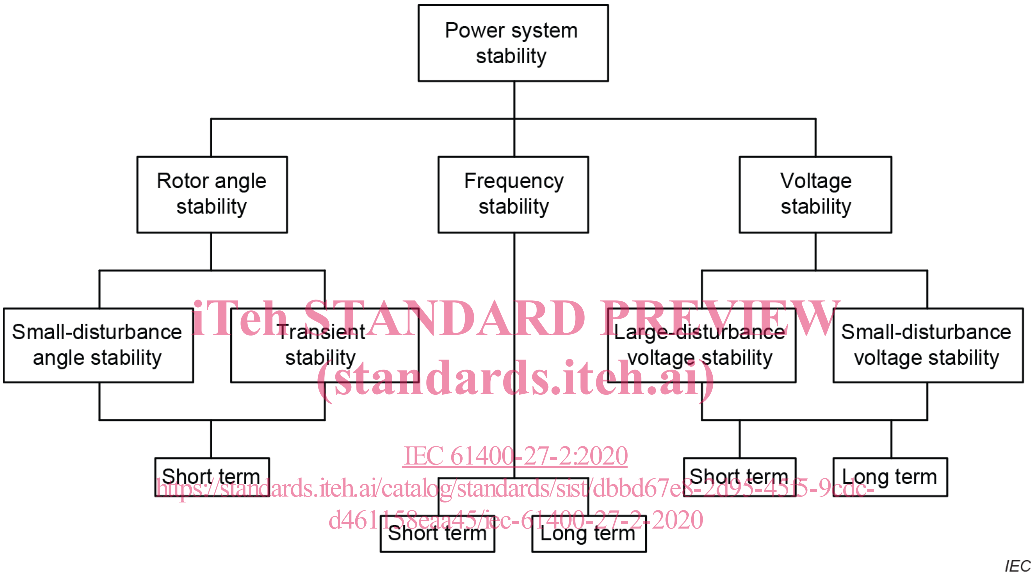

Figure 1 – Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions [1]

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.

1 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[2],[3].
- 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 61400-21-2[4].
- 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.

2 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.

3 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.

4 Under consideration.

WIND ENERGY GENERATION SYSTEMS –

Part 27-2: Electrical simulation models – Model validation

1 Scope

This part of IEC 61400 specifies procedures for validation of electrical simulation models for wind turbines and wind power plants, intended to be used in power system and grid stability analyses. The validation procedures are based on the tests specified in IEC 61400-21 (all parts). The validation procedures are applicable to the generic models specified in IEC 61400-27-1 and to other fundamental frequency wind power plant models and wind turbine models.

The validation procedures for wind turbine models focus on fault ride through capability and control performance. The fault ride through capability includes response to balanced and unbalanced voltage dips as well as voltage swells. The control performance includes active power control, frequency control, synthetic inertia control and reactive power control. The validation procedures for wind turbine models refer to the tests specified in IEC 61400-21-1. The validation procedures for wind turbine models refer to the wind turbine terminals.

The validation procedures for wind power plant models is not specified in detail because IEC 61400-21-2 which has the scope to specify tests of wind power plants is at an early stage. The validation procedures for wind power plant models refer to the point of connection of the wind power plant.

The validation procedures specified in IEC 61400-27-2 are based on comparisons between measurements and simulations, but they are independent of the choice of software simulation tool.

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 (IEV) – Part 415: Wind turbine generator systems* (available at www.electropedia.org)

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

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

3 Terms, definitions, abbreviations and subscripts

3.1 Terms and definitions

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
application range
specification of the boundaries for the situations where the electrical simulation model is applicable

3.1.2
available active power
predicted optimal active power of wind turbine or wind power plant, either based on power curves and measured wind speeds or as an output from wind turbine controller or wind power plant controller, where more parameters are taken into the calculation

3.1.3
base unit
unit of parameter values, which is the per-unit base value if the parameter is given in per-unit or the physical unit if the value is given in a physical unit

3.1.4
generic model
model that can be adapted to simulate different wind turbines or wind power plants by changing the model parameters

3.1.5
integration time step
simulation time interval between two consecutive numerical solutions of the model's differential equations

3.1.6
negative (sequence) component (of a three-phase system)
one of the three symmetrical sequence components which exists only in an unsymmetrical three-phase system of sinusoidal quantities and which is defined by the following complex mathematical expression:

$$\underline{X}_2 = \frac{1}{3}\left(\underline{X}_{\mathrm{L1}} + \underline{a}^2 \underline{X}_{\mathrm{L2}} + \underline{a}\underline{X}_{\mathrm{L3}}\right)$$

where $\underline{a}$ is the 120 degree operator, and $\underline{X}_{\mathrm{L1}}$, $\underline{X}_{\mathrm{L2}}$ and $\underline{X}_{\mathrm{L3}}$ are the complex expressions of the phase quantities concerned, and where $\underline{X}$ denotes the system current or voltage phasors

[SOURCE: IEC 60050-448:1995, 448-11-28]

3.1.7
nominal active power
nominal value of active power, which is stated by the manufacturer and is used as a per-unit base for all powers (active, reactive, apparent)

[SOURCE: IEC 61400-21-1:2019, 3.15, modified – Removed “wind turbine” from definition]

3.1.8
nominal voltage
nominal value of line-to-line voltage, which is stated by the manufacturer and is used as a per-unit base

3.1.9
overshoot
difference between the maximum value of the response and the steady-state final value

Note 1 to entry: Overshoot is defined by the response to a step change of a controller reference variable, see Figure 5.

[SOURCE: IEC 61400-21-1:2019, 3.47, modified – The note to entry has been changed]

3.1.10
phasor
complex RMS value
representation of a sinusoidal integral quantity by a complex quantity whose argument is equal to the initial phase and whose modulus is equal to the RMS value

Note 1 to entry: For a quantity $a(t) = \hat{A}\cos(\omega t + \vartheta_0)$ the phasor is $\underline{A} = A\exp(j\vartheta_0)$ where $A = \frac{\hat{A}}{\sqrt{2}}$ is the RMS value and ϑ_0 is the initial phase. A phasor can also be represented graphically.

Note 2 to entry: Electric current phasor $\underline{I}$ and voltage phasor $\underline{U}$ are often used.

Note 3 to entry: The similar representation with the modulus equal to the amplitude is sometimes also called "phasor".

[SOURCE: IEC 60050-103:2017 103-07-14]

3.1.11
point of connection
reference point on the electric power system where the user’s electrical facility is connected

[SOURCE: IEC 60050-617:2009, 617-04-01]

3.1.12
positive (sequence) component (of a three-phase system)
one of the three symmetrical sequence components which exists in symmetrical and unsymmetrical three-phase system of sinusoidal quantities and which is defined by the following complex mathematical expression:

$$\underline{X}_1 = \frac{1}{3}\left(\underline{X}_{L1} + \underline{a}\underline{X}_{L2} + \underline{a}^2\underline{X}_{L3}\right)$$

where $\underline{a}$ is the 120 degree operator, and $\underline{X}_{L1}$, $\underline{X}_{L2}$ and $\underline{X}_{L3}$ are the complex expressions of the phase quantities concerned, and where $\underline{X}$ denotes the system current or voltage phasors

[SOURCE: IEC 60050-448:1995, 448-11-27]

3.1.13
power system stability
capability of a power system to regain a steady state, characterized by the synchronous operation of the generators after a disturbance due, for example, to variation of power or impedance

Note 1 to entry: IEEE/CIGRE Joint Task Force on Stability Terms and Definitions: Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.

[SOURCE: IEC 60050-603:1986, 603-03-01, modified – addition of Note 1 to entry]

3.1.14
quasi steady state of a system
short-term steady state, for instance during a voltage dip or voltage swell which is long enough to include a period where the system state variables can be considered sensibly constant

3.1.15
reaction time
elapsed time from test command issued until the change in amplitude reaches 10 % of the measured output variable of the step height

Note 1 to entry: Reaction time is defined by the response to a step change of a controller reference variable, see Figure 5.

[SOURCE: IEC 61400-21-1:2019, 3.48, modified – The note to entry has been changed]

3.1.16
reference variable
input variable to a comparing element in a controlling system, which sets the desired value of the controlled variable and is deducted from the command variable

[SOURCE: IEC 60050-351:2013, 351-48-02, modified – The note to entry and the figure have been deleted]

3.1.17
response time
elapsed time from the start of a step change or start of event until the observed value first time enters the predefined tolerance band of the target value

Note 1 to entry: Response time is defined by the response to a step change of a controller reference variable, see Figure 5.

[SOURCE: IEC 61400-21-1:2019,3.44, modified – The note to entry has been changed]

3.1.18
rise time
time from when the observed value reaches 10 % of the step change until the observed value reaches 90 % of the step change

Note 1 to entry: Rise time is defined by the response to a step change of a controller reference variable, see Figure 5.

[SOURCE: IEC 61400-21-1:2019, 3.46, modified – The note to entry has been changed]

3.1.19
settling time
elapsed time from the start of a step change event until the observed value continuously stays within the predefined tolerance band of the target value

Note 1 to entry: Settling time is defined by the response to a step change of a controller reference variable, see Figure 5.

[SOURCE: IEC 61400-21-1:2019, 3.45, modified – The note to entry has been changed]