IEC 61400-27-1

Edition 1.0 2015-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Wind turbines –
Part 27-1: Electrical simulation models – Wind turbines

Eoliennes –
Partie 27-1: Modèles de simulation électrique – Eoliennes

IEC 61400-27-1:2015-02(en-fr)

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FOREWORD

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International Standard IEC 61400-27-1 has been prepared IEC Technical Committee 88: Wind turbines.

The text of this draft is based on the following documents:

Enquiry draft	Report on voting
88/510/FDIS	88/529/RVD

Full information on the voting for the approval of this technical specification 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 series, published under the general title *Wind turbines*, can be found on the IEC website.

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INTRODUCTION

The IEC 61400-27 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.

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 models developed by the wind turbine manufacturers reproduce the behaviour of their machines with a high level of detail. Such level of detail is not suitable for stability studies of large power systems with a huge number of wind power plants, firstly because the high level of detail increases the complexity and thus computer time dramatically, and secondly because the use of detailed manufacturer specific models requires a substantial amount of input data to represent the individual wind turbine types.

The purpose of this standard is to specify generic dynamic models, which can be applied in power system stability studies. The IEEE/CIGRE Joint Task Force on Stability Terms and Definitions has classified power system stability in categories according to Figure 1.

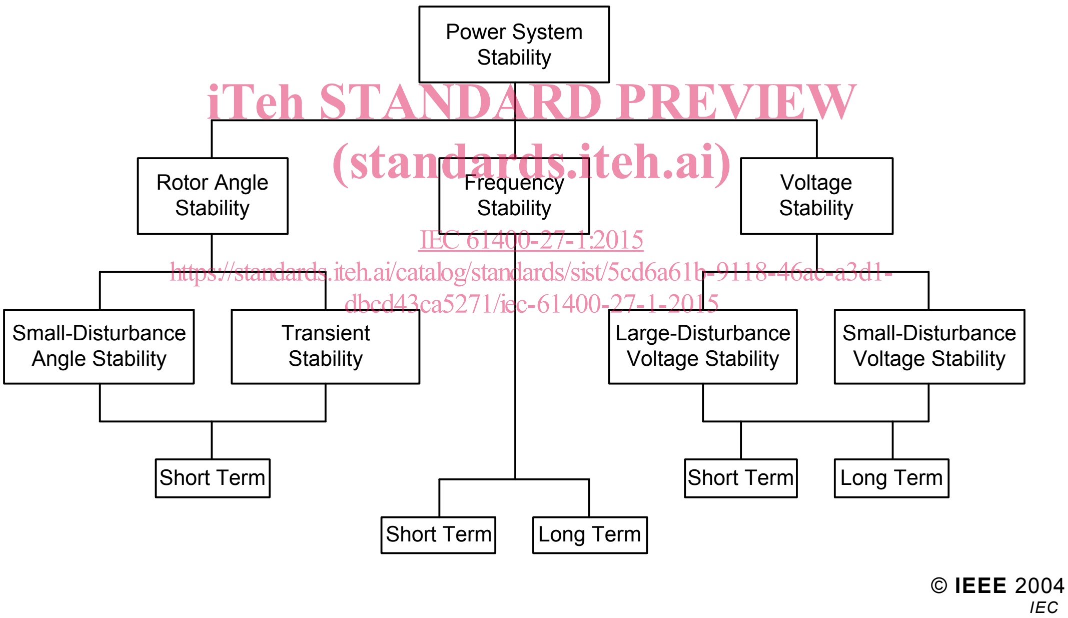

Figure 1 – Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions

Referring to these categories, the models are developed to represent wind power generation in studies of large-disturbance short term voltage stability phenomena, but they will also be applicable to study other dynamic short term phenomena such as rotor angle stability, frequency stability and small-disturbance voltage stability. 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 as specified in the scope.

The models have to be complete enough to represent the dynamic behaviour at the wind turbine terminals, but must also be suitable for large-scale grid studies. Therefore simplified wind turbine models are specified to perform the typical response of known wind turbine technologies.

The wind turbine models specified in this standard are for fundamental frequency positive sequence response[1]. The models have the following limitations:

– The models are not intended for long term stability analysis.
– The models are not intended for investigation of sub-synchronous interaction phenomena.
– The models are not intended for investigation of the fluctuations originating from wind speed variability in time and space. This implies that the models do not include phenomena such as turbulence, tower shadow, wind shear and wakes.
– The models do not cover phenomena such as harmonics, flicker or any other EMC emissions included in the IEC 61000 series.
– The models have not been developed explicitly with eigenvalue calculation (for small signal stability) in mind[2].
– The models specified here apply only to wind turbines, and therefore do not include wind power plant level controls and additional equipment such as SVCs, STATCOMs and other devices which will be covered by IEC 61400-27-2. The wind turbine models interface to the wind power plant controller models in IEC 61400-27-2.
– This standard does not address the specifics of short-circuit calculations.
– The models are not applicable to studies of extremely weak systems including situations where wind turbines are islanded without other synchronous generation.
– The models are limited by the technical specifications in 5.2.

The validation procedure specified in this standard is intended to be applied to standard models and other fundamental frequency wind turbine models. 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[3].
– The validation procedure does not specify test and measurement procedures, as it is based on tests specified in IEC 61400-21.
– The simulation model validation is not intended to justify compliance to any grid code requirement, power quality requirements or national legislation.
– The test and measurement procedures introduce errors which limit the possible accuracy as specified in the validation procedure.
– The validation procedure does not include steady state validation, but focuses on validation of the dynamic performance of the model.

The following stakeholders are potential users of the models specified in this standard:

– TSOs and DSOs are end users of the models, performing power system stability studies as part of the planning as well as the operation of the power systems.
– Wind plant owners are typically responsible to provide the wind power plant models to TSO and/or DSO prior to plant commissioning.
– wind turbine manufacturers will typically provide the wind turbine models to the owner.

———————

[1] This standard is dealing with balanced as well as unbalanced faults, but for unbalanced faults, only the positive sequence components are specified.

[2] These wind generation systems are highly non-linear and simplifications have been made in the development of the proposed models. Thus, linearisation for eigenvalue analysis is not trivial nor necessarily appropriate based on these simplified models.

[3] Clause 6 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 B describes limits to the possible accuracy of the models.

- Developers of modern software for power system simulation tools will use the standard to implement standard wind power models as part of the software library.
- Certification bodies in case of independent wind turbine model validation.
- Education and research communities, who can also benefit from the generic models, as the manufacturer specific models are typically confidential.

WIND TURBINES –

Part 27-1: Electrical simulation models –
Wind turbines

1 Scope

IEC 61400-27 defines standard electrical simulation models for wind turbines and wind power plants. The specified models are time domain positive sequence simulation models, intended to be used in power system and grid stability analyses. The models are applicable for dynamic simulations of short term stability in power systems. IEC 61400-27 includes procedures for validation of the specified electrical simulation models. The validation procedure for IEC 61400-27 is based on tests specified in IEC 61400-21.

IEC 61400-27 consists of two parts with the following scope:

– IEC 61400-27-1 specifies dynamic simulation models for generic wind turbine topologies/ concepts / configurations on the market. IEC 61400-27-1 defines the generic terms and parameters with the purpose of specifying the electrical characteristics of a wind turbine at the connection terminals. The models are described in a modular way which can be applied for future wind turbine concepts. The dynamic simulation models refer to the wind turbine terminals. The validation procedure specified in IEC 61400-27-1 focuses on the IEC 61400-21 tests for response to voltage dips, reference point changes and grid protection.

– IEC 61400-27-2 specifies dynamic simulation models for the generic wind power plant topologies / configurations on the market including wind power plant control and auxiliary equipment. In addition IEC 61400-27-2 specifies a method to create models for future wind power plant configurations. The wind power plant models are based on the wind turbine models specified in IEC 61400-27-1.

The electrical simulation models specified in IEC 61400-27 are independent of any software simulation tool.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050, *International electrotechnical vocabulary*

IEC 61400-21, *Wind turbines – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines*

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, as well as the following apply:

3.1.1
available aerodynamic power
maximum possible power taking into account wind speed, power rating, rotor speed limits and pitch angle constraints.

3.1.2
generic model
model that can be adapted to simulate different wind turbines or wind power plants by changing the model parameters

3.1.3
integration time step
simulation time interval between two consecutive numerical solutions of the model's differential equations

3.1.4
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:

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

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

Note 1 to entry: Negative sequence voltage or current components may be significant only when the voltages or currents, respectively, are unbalanced. For example, if phase voltage phasors are symmetrical $\underline{U}_{L1} = Ue^{j\theta}$, $\underline{U}_{L2} = Ue^{j(\theta+4\pi/3)}$ and $\underline{U}_{L3} = Ue^{j(\theta+2\pi/3)}$ then $\underline{U}_2 = (Ue^{j\theta} + e^{j4\pi/3}\,Ue^{j(\theta+4\pi/3)} + e^{j2\pi/3}\,Ue^{j(\theta+2\pi/3)})/3 = Ue^{j\theta}\,(1 + e^{j2\pi/3} + e^{j4\pi/3})/3 = 0$.

[SOURCE: IEC 60050-448:1995, 448-11-28, modified (addition of Note 1 to entry)]

3.1.5
nominal active power
nominal value of wind turbine active power, which must be stated by the manufacturer and is used as per-unit base for all powers (active, reactive, appearance)

3.1.6
nominal current
nominal value I_n of wind turbine current, which must be calculated from nominal active power P_n and nominal voltage U_n according to $I_n = \frac{P_n}{\sqrt{3}U_n}$

3.1.7
nominal frequency
nominal value of wind turbine frequency, which must be stated by the manufacturer

3.1.8
nominal voltage
nominal value of wind turbine voltage, which must be stated by the manufacturer