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INTERNATIONAL STANDARD

Wind energy generation systems –
Part 27-1: Electrical simulation models – Generic models

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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.

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International Standard IEC 61400-27-1 has been prepared by IEC technical committee 88: Wind energy generation systems.

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

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

FDIS	Report on voting
88/762/FDIS	88/771/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.

This second edition cancels and replaces the first edition, published in 2015. This edition constitutes a technical revision and a restructure of the content into two parts. The new structure joins the models in part 27-1 and the validation procedures in part 27-2.

This edition includes the following significant technical changes with respect to the previous edition:

a) "Wind turbines" changed to "Generic models" because wind power plant models are also included, and the model validation is moved to IEC 61400-27-2;
b) specification of models for wind power plants including plant control, communication system model and aggregation procedure for power collection system in addition to the wind turbine models in the previous edition;
c) moving validation prodedures for wind turbine models from this edition to part 27-2;
d) a more detailed modular structure separating wind turbine control into pitch control and generator system control and extracting grid measurement modules from the control modules. Figures are revised accordingly;
e) inclusion of model for STATCOM;
f) inclusion of electrical components modules.

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.

INTRODUCTION

IEC 61400-27-1 specifies standard dynamic electrical simulation models for wind turbines and wind power plants. The specified wind turbine models can either be used in wind power plant models or to represent wind turbines without wind power plant relationships. Apart from the wind turbine models, the wind power plant model may include models for auxiliary equipment such as STATCOMs which are often used in 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 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 International 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 [11][1] has classified power system stability in categories according to Figure 1.

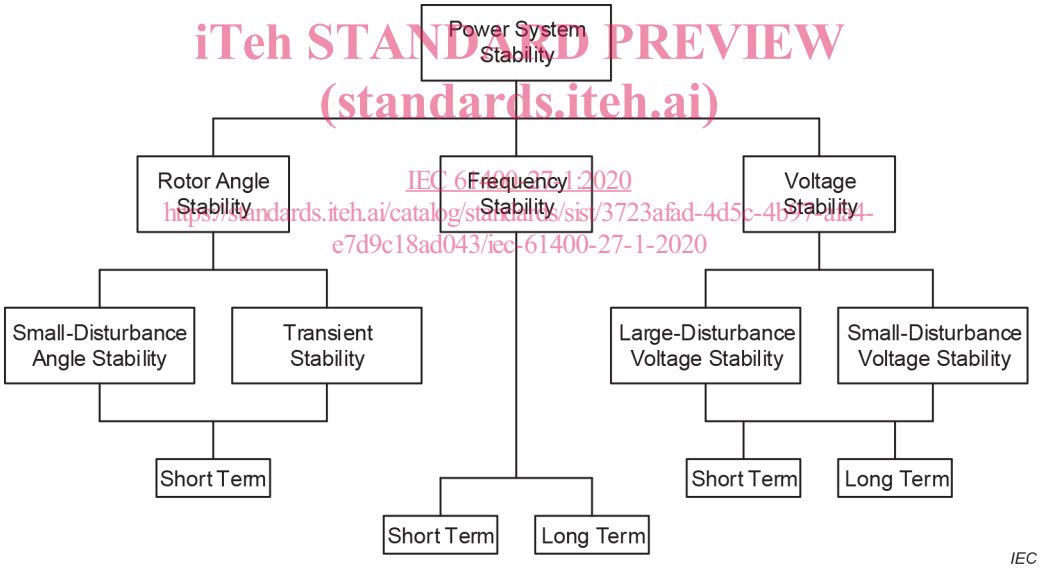

Figure 1 – Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions [11]

Referring to these categories, the models are 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 [12], and system separation of a synchronous system into more synchronous areas.

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1 The numbers in square brackets refer to the Bibliography.

The models shall be complete enough to represent the dynamic behavior of the wind power plant at the point of connection and of the wind turbine at the wind turbine terminals, but shall also be suitable for large-scale grid studies. Therefore, simplified models are specified to perform the typical response of known technologies.

The wind power plant models specified in this document are for fundamental frequency positive sequence response[2].

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 wind generation systems are highly non-linear and simplifications have been made in the development of the models. Thus, linearisation for eigenvalue analysis is not trivial nor necessarily appropriate based on these simplified models.
– This document does not address the specifics of short-circuit calculations.
– The models are not applicable to studies where wind turbines are islanded without synchronous generation.
– The models are not intended for studies of situations with short-circuit ratios less than 3. The short circuit limitation depends on wind turbine types, control modes and other settings. The WT manufacturer can specify a lower limit for the applicable short-circuit ratio provided that this application is validated according to part 27-2.
– The models are limited by the functional specifications in Clause 5.

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

– 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.
– 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.
– Consultants who use models on behalf of TSOs, DSOs and/or wind plant developers.
– Education and research communities, who can also benefit from the generic models, as the manufacturer specific models are typically confidential.

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2 This document is dealing with balanced as well as unbalanced faults, but for unbalanced faults, only the positive sequence components are specified.

WIND ENERGY GENERATION SYSTEMS –

**Part 27-1: Electrical simulation models –
Generic models**

1 Scope

This part of IEC 61400 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.

This document defines the generic terms and parameters for the electrical simulation models.

This document specifies electrical simulation models for the generic wind power plant topologies / configurations currently on the market. The wind power plant models include wind turbines, wind power plant control and auxiliary equipment. The wind power plant models are described in a modular way which can be applied for future wind power plant concepts and with different wind turbine concepts.

This document specifies electrical simulation models for the generic wind turbine topologies/concepts/configurations currently on the market. The purpose of the models is to specify the electrical characteristics of a wind turbine at the wind turbine terminals. The wind turbine models are described in a modular way which can be applied for future wind turbine concepts. The specified wind turbine models can either be used in wind power plant models or to represent wind turbines without wind power plant relationships.

The electrical simulation models specified in IEC 61400-27-1 are independent of any 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 61970-301, *Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*

IEC 61970-302, *Energy management system application program interface (EMS-API) – Part 302: Common information model (CIM) dynamics*

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
auxiliary equipment
STATCOM or other device supplementing wind turbines in wind power plant

3.1.2
available power
maximum possible power taking into account wind speed, power rating, rotor speed limits and pitch angle constraints

Note 1 to entry: The aerodynamic power cannot be greater than available power.

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
fault ride through
ability of a wind turbine or wind power plant to stay connected during voltage dips (under voltage ride through) and voltage swells (over voltage ride through)

3.1.5
generator sign convention
specification of signs for active and reactive components of current and power e.g. from a wind turbine or a reactive power compensation component

Note 1 to entry: The active current and power are positive if power is generated and negative if power is consumed. Likewise, the reactive current and reactive power are positive if reactive power is generated as in the case of a capacitor and negative if reactive power is consumed as in the case of a reactance.

3.1.6
generic model
model that can be adapted to simulate different wind turbines or wind power plants by changing the model parameters

3.1.7
grid variable
voltage, current or frequency

3.1.8
hook
input to or output from a module which is not used in the generic models specified in this standard but may be used to expand generic models beyond the IEC 61400-27-1 scope e.g. to match manufacturer specific models or to match specific national grid connection requirements

3.1.9
integration time step
simulation time interval between two consecutive numerical solutions of the model's differential equations

3.1.10
module
part of a model which has a modular structure