Wind turbine standard models
Status of IEC 61400-27

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Purpose of models

- IEC 61400-27 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:

Classification of power system stability according to IEEE/CIGRE Joint Task Force on Stability Terms and Definitions. (© IEEE 2004)
Potential users of the 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 turbine manufacturers** will typically provide the wind turbine models to the owner,
- **Wind plant owners** are typically responsible to provide the wind power plant models to TSO and/or DSO prior to plant commissioning,
- **Developers of power system simulation software** will use the standard to implement standard wind power models as part of the software library, and
- **Education and research** communities, who can also benefit from the generic models, as the manufacturer specific models are typically confidential.

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**IEC 61400-27 – content**

**Part 1 – wind turbines**
- Definition of generic terms and parameters for wind turbine models
- Specification of dynamic simulation models:
  - Standard models for generic wind turbine topologies/concepts/configurations on the market.
  - A method to create models for future wind turbine concepts.
- Specification of a method for validation of wind turbine simulation models

**Part 2 – wind power plants**
- Definition of generic terms and parameters for wind power models
- Specification a method to create models for wind power plants including wind turbines, auxiliary equipment and wind power plant controller.
- Specification of a method for validation of wind power plant simulation models
Key model specifications

- The models are for **fundamental frequency positive sequence** response.
- The models span the existing categories (**type 1-4**) of currently developed wind turbine generator technologies.
- The models are **modular** in nature to allow for the potential of augmentation in case of future technologies being developed, or future supplemental controls features.
- The typical simulation time frame of interest is from **10 to 30 seconds**. Wind speed is assumed to be constant during such a time frame.
- The models are specified to work with simulation **time steps up to ¼ cycle**. As a consequence, the smallest time constants which can be included are ½ cycle, and therefore the bandwidth of the model cannot be greater than 15 Hz.
- The models **initialize to a steady state** from power flow solutions at full or partial power.
- Wind turbine dynamics such as turbine-generator inertia and first shaft torsional mode is only taken into account where it has significant **influence on the power at the wind turbine terminals**.

Interfaces between turbine, plant control and grid models

- Possible reference values:
  - Active power
  - Reactive power
  - Voltage
- Reference value symbols:
  - $p_{ref}$ (active power)
  - $x_{ref}$ (reactive power or voltage)
**WT models block structure**

```
Aerodynamic ---- Mechanical ---- Generator system ---- Electrical equipment
```

Grid protection

WT grid variables

Reference values

Control

---

**Type 1 wind turbine**

```
AG ---- CB ---- FC ---- GB ---- TR ---- WTT
```

AG: asynchronous generator
CB: circuit breaker
FC: capacitor bank, which is not switched dynamically during voltage dips
GB: gearbox
TR: transformer
VC: variable capacitor bank, which is switched dynamically during voltage dips
WTR: wind turbine rotor
WTT: wind turbine terminals defined according to IEC 61400-21

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WT type 1 model blocks

Mechanical model – 2 mass

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Base unit</th>
<th>Description</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_{WTR}$</td>
<td>s</td>
<td>Inertia constant of wind turbine rotor</td>
<td>Type</td>
</tr>
<tr>
<td>$H_{gen}$</td>
<td>s</td>
<td>Inertia constant of generator</td>
<td>Type</td>
</tr>
<tr>
<td>$k_{drt}$</td>
<td></td>
<td>Drive train stiffness</td>
<td>Type</td>
</tr>
<tr>
<td>$c_{drt}$</td>
<td></td>
<td>Drive train damping</td>
<td>Type</td>
</tr>
</tbody>
</table>
Parameter categories

• The three parameter categories are defined as follows:
  • **Type dependent** parameters are characteristic to the specific wind turbine type. This is typically the case for mechanical and electrical parameters.
  • **Project dependent** parameters may be different for a specific wind turbine type, depending on the specific project. This is typically the case for control parameters set according to specific grid code requirements.
  • **Case dependent** parameters may vary depending on the specific steady state prior to the disturbance, e.g. depending on if the actual and / or possible power is nominal or partial. It is the responsibility of the wind turbine manufacturer to specify clearly how case dependent parameters depend on the specific simulation case.
  • It is the intention to **reduce the number of case dependent** parameters to a minimum, but also be clear in stating the limited application range for a specific set of parameters.

Type 4 wind turbines

AG asynchronous generator
C DC link capacitor
CB circuit breaker
CH chopper
DCL DC link
GB gearbox
GSC generator side converter
LSC line (grid) side converter
SG synchronous generator
TR transformer
WTR wind turbine rotor
WTT wind turbine terminals defined according to IEC 61400-21
WT type 4A model blocks

WT type 4B model blocks
WT type 4A control model blocks

Q-control

- The Q control is shared between type 4 and type 3
- Q-control model support four different wind turbine normal operation modes:
  - Voltage control
  - Reactive power control
  - Open loop reactive power control (only applicable with closed loop at plant level)
  - Power factor control
- Q-control model support three different wind turbine LVRT operation modes:
  - Voltage dependent reactive current injection
  - Reactive current injection controlled as the pre-fault value plus an additional voltage dependent reactive current injection during fault, and as the pre-fault value plus an additional constant reactive current injection post fault
Validation procedure

- The validation procedure is based on wind turbine tests according to IEC 61400-21.
- The validation procedure includes the following wind turbine functional characteristics:
  - Validation of the simulation model response to voltage dips.
  - Validation of the simulation model response to changes in reference values.
  - Validation of the simulation model grid protection functionality.
- The model and test must refer to the same wind turbine terminals to ensure that measurements and simulations refer to the same point. According to IEC 61400-21, the wind turbine terminals are defined by the manufacturer and thus can be either:
  - the low voltage side of the generator step-up transformer, or
  - the high voltage side of the generator step-up transformer.
- To comply with the validation procedure, simulated positive sequence values shall be validated against the measured positive sequence values.

Validation - Signal processing

\[ x_{\text{mea}}(n) = x_{\text{mea}}(n) - x_{\text{sim}}(n) \]
## IEC 61400-27 – timeline

### Part 1: wind turbines
- 2008-12: NP
- 2009-04: 88/347/RVN
- 2012-01: 88/424/CD
- 2013-08: 88/463/CC
- 2013-11: 88/464/CDV
- 2014-08: FDIS
- 2014-11: Publication date

### Part 2: wind power plants
- 2012-04: 88/431/NP
- 2012-08: 88//RVN
- 2014-06: CD
- 2015-03: CC
- 2015-06: CDV
- 2016-03: FDIS
- 2016-06: Publication date

NP: New (work item) Proposal  
RVN: Result of voting from National committees  
CD: Committee Draft  
CC: Compilation of Comments from National committees  
CDV: Committee Draft for Voting  
FDIS: Final Draft International Standard

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## Application Note

- The **scope** of the Application Note is to provide a **Benchmark** to support the implementation of dynamic simulation models for wind turbines being developed by the WG27 and fully documented in IEC 61400-27-1.  
- The dynamic model of all types of wind turbines will be **implemented in** the following power system simulation platforms:  
  - DIgSILENT PowerFactory  
  - Eurostag  
  - Dymola  
  - Matlab Simulink  
- **A set of generic data is used.** This data is not proprietary from any wind turbine manufacturer.  
- The **external network** layout is based on the **WECC** proposal of typical diagram of a typical wind power plant.
Summary

- **Part 1 (wind turbines):**
  - Wind turbine models for type 1-4 are at CDV stage, **standard expected 2014**
  - Models:
    - Type 1, type 3 and type 4 models are validated by manufacturers
    - Type 2 model adapted from WECC
  - Validation procedure based on test standard IEC 61400-21
- **Part 2 (wind power plants):**
  - **Standard expected 2016**
  - Work on wind power plant models started, presently **plant control model available**
  - Validation procedure relies on new test standard IEC 61400-21-2 for plant level tests

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