DTU Library

Wind turbine standard models
Status of IEC 61400-27

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WIND TURBINE STANDARD MODELS

STATUS OF IEC 61400-27

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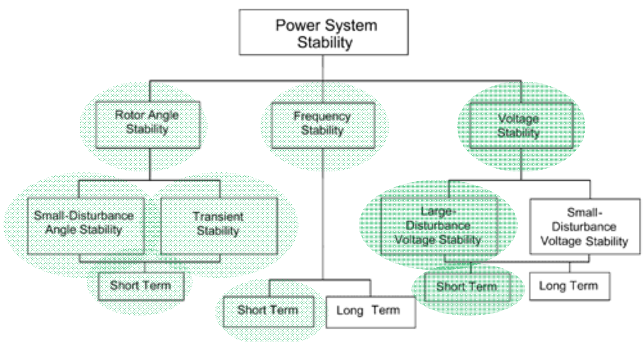
Purpose of models

- 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 plant models
- Specification a method to create models for wind power plants including wind turbines, auxcillary equipment and wind power plant controller.
- Specification of a method for validation of wind power plant simulation models

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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***.

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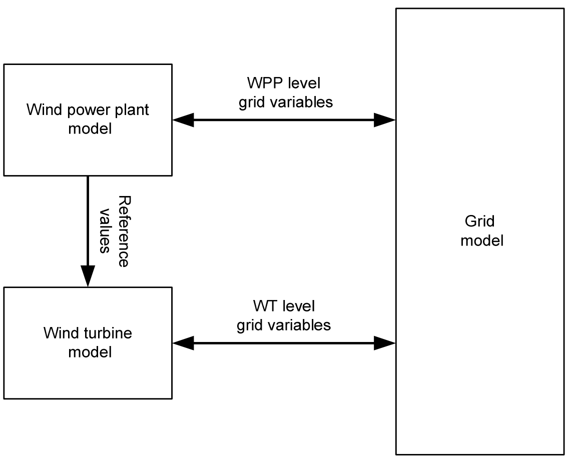
Interfaces between turbine, plant control and grid models

- Possible reference values:
  - Active power
  - Reactive power
  - Voltage
- Reference value symbols:
- p_{ref} (active power)
- x_{ref} (reactive power or voltage)



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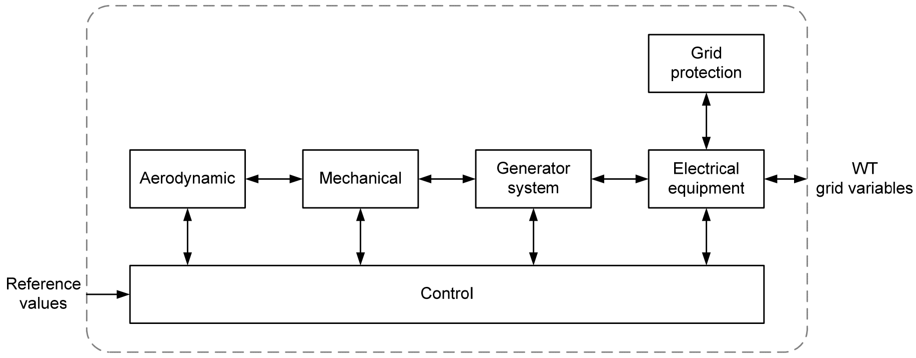
WT models block structure



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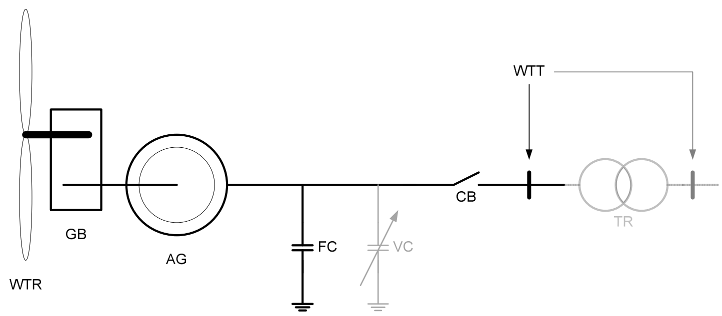
Type 1 wind turbine



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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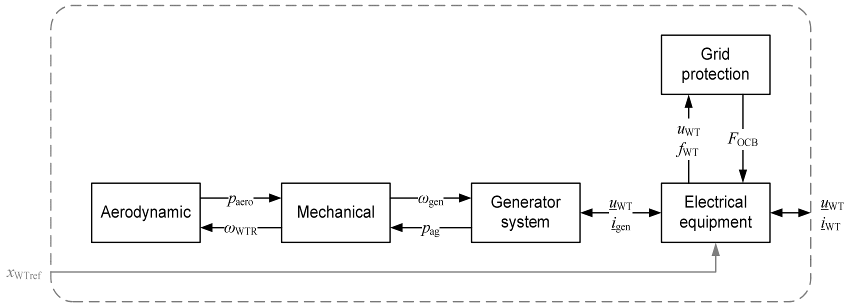
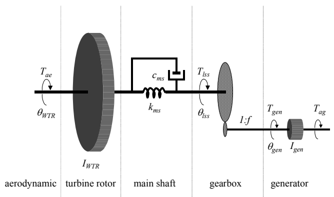
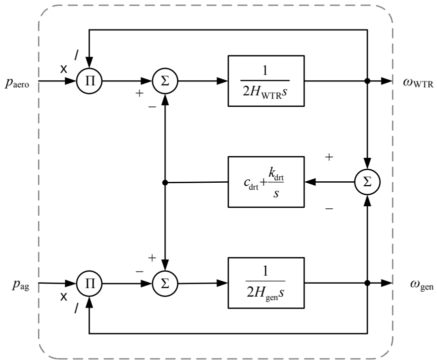
WT type 1 model blocks



Mechanical model – 2 mass



Physical model



Symbol	Base unit	Description	Category
H_{WTR}	s	Inertia constant of wind turbine rotor	Type
H_{gen}	s	Inertia constant of generator	Type
k_{drt}	T_{base}	Drive train stiffness	Type
c_{drt}	T_{base} / ω_{base}	Drive train damping	Type

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 intension 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.

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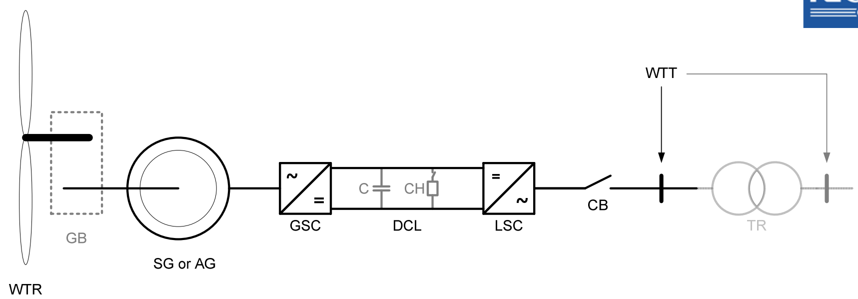
Type 4 wind turbines



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

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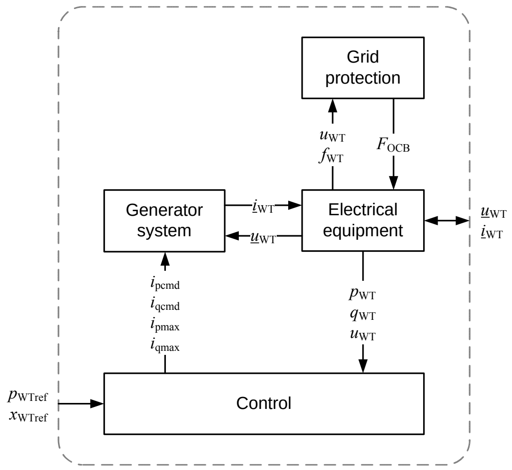
WT type 4A model blocks



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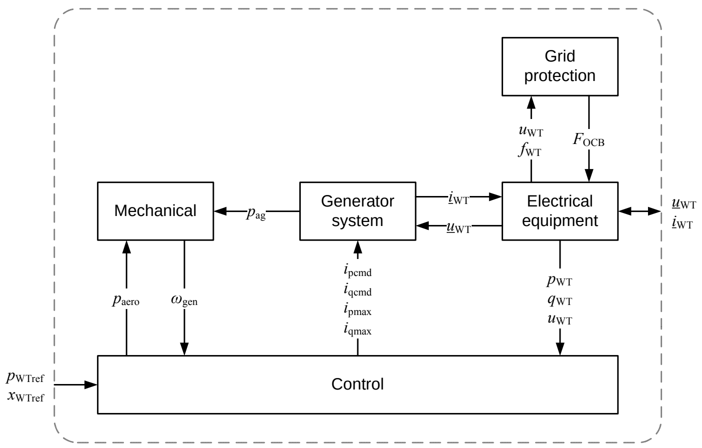
WT type 4B model blocks



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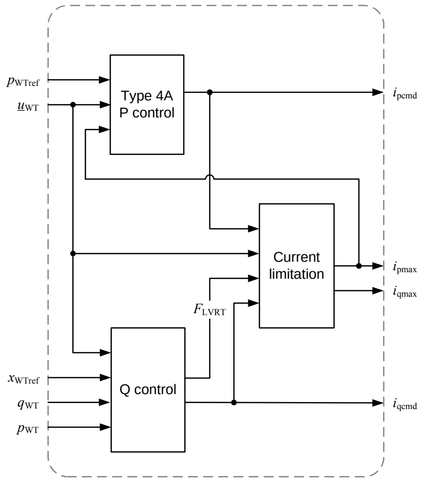
WT type 4A control model blocks



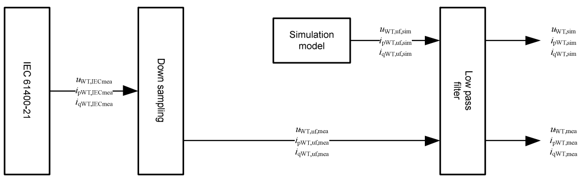
Q-control

- 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
  - 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

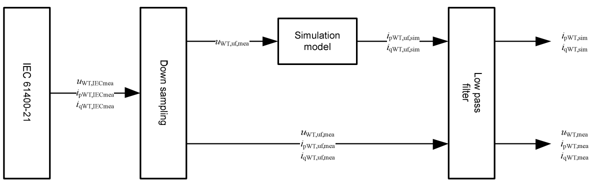
- The validation procedure is based on wind turbine tests according to IEC ***61400-21***.
- The validation procedure includes the following wind turbine functional characteristics:
  - Validation of the simulation model response to ***voltage dips***.
  - Validation of the simulation model response 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



Full grid simulation

$$x_{\mathrm{error}}(n) = x_{\mathrm{mea}}(n) - x_{\mathrm{sim}}(n)$$



Play-back

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: Compolation of Comments from National committees
CDV: Committee Draft for Voting
FDIS: Final Draft International Standard

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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- Yongning Chi, CEPRI (CN)
- Martin Brennecke, FGH (DE)
- Jeferson Marques, Enercon (DE)
- Angelo Mendonca, Enercon (DE)
- Frank Fischer, PowerWind (DE)
- Frank Martin, Germanischer Lloyd (DE)
- Jens Fortmann, RePower (DE)
- Anatoli Semerow, Friedrich Alexander Univercity (DE)
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- Emilio Gómez Lázaro, UCLM (ES)
- Javier Pérez-Jacoiste, Gamesa (ES)
- Francisco Jiménez Buendia, Gamesa (ES)
- Ana Morales, DIgSILENT Spain (ES)
- Montserrat Mata, ECOTÈCNIA / ALSTOM (ES)
- Alberto Molina Martín, Energy to Quality (ES)
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