Hydro Québec TransÉnergie

# TECHNICAL REQUIREMENTS

# FOR THE CONNECTION OF GENERATION FACILITIES

# TO THE HYDRO-QUÉBEC TRANSMISSION SYSTEM

## SUPPLEMENTARY REQUIREMENTS FOR WIND GENERATION

**MAY 2003**

**(Revised October 2005)**

**Langue applicable:**

La version anglaise est pour le bénéfice de l'utilisateur seulement. Dans l'éventualité où une divergence intervient entre la version française et la version anglaise, la version française est la version originale et doit s'appliquer lorsqu'une question concernant l'interprétation de son contenu est soulevée.

**Governing language:**

The English version is for the user's convenience only. In the event of any discrepancies between the French version and the English version, the French version shall be the original and shall be the governing language in the event of any question concerning the meaning of its terms.

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# 1. Background

The document "Exigences techniques relatives à l'intégration des centrales au réseau de transport d'Hydro-Québec", issued by Hydro-Québec TransÉnergie in May 1999, states the requirements *power producers* must meet if they wish to connect a *generating plant* to the Hydro-Québec *transmission system*.

Since that document was published, wind power has become a rapidly evolving generating option. To cover supplementary technical characteristics specific to wind generation technology, specific requirements are needed to modify or complement those in the May 1999 document. The requirements set down herein take precedence over those in the May 1999 document.

This document includes all technical requirements contained in the document "Technical Requirements for the Connection of Generation Facilities to the Hydro-Québec Transmission System – Supplementary Requirements for Wind Generation Addendum 1, December 23, 2004" and thus supersedes the latter.

# 2. Definitions

Italicized terms herein are defined below.

***Disturbance***

A deviation from the normal operating conditions of a power system. In this document, the context generally designates deviations resulting from fortuitous incidents that are sudden and random, (e.g., faults, inadvertent operation of an automatic control or protection system, loss of generation or load, etc.). In other instances, the deviation may be more or less periodical and of lesser magnitude (e.g., harmonics, flicker, switching surges, power oscillations due to an inappropriate setting or to a regulation system failure, etc.).

***Facility***

A set of equipment and/or conductors, such as *generating units*, transformers, synchronous condensers or static var compensators, substations and lines, taken alone or as a whole. This also includes station services, control, monitoring and protection equipment, etc.

***Generating plant***

A site where electricity is produced, including any associated *switchyard* or part thereof. For the purposes of this document, *generating plant* denotes all *power producer facilities* located at a given generating site (e.g., at a hydro-electric generating station, thermal power plant or wind *generating plant*), and also includes any industrial customer *facilities* used to interconnect the *generating plant* whenever the case(see *facility*).

***Generating unit***

A unit that produces electricity. Usually comprised of a turbine/synchronous generator combination (synchronous *generating unit*) or a turbine/induction generator combination (asynchronous *generating unit*).

***Interconnection study***

An evaluation by the *transmission provider* of the adequacy of the Hydro-Québec *transmission system* to accommodate a request to connect a *generating plant* and of any *network upgrades* needed to do so.

***Network upgrades***

Modifications or additions to transmission-related *facilities* that are integrated with the *transmission provider*'s *transmission system*, carried out to accommodate a request to connect or modify a *generating plant*.

***Power producer***

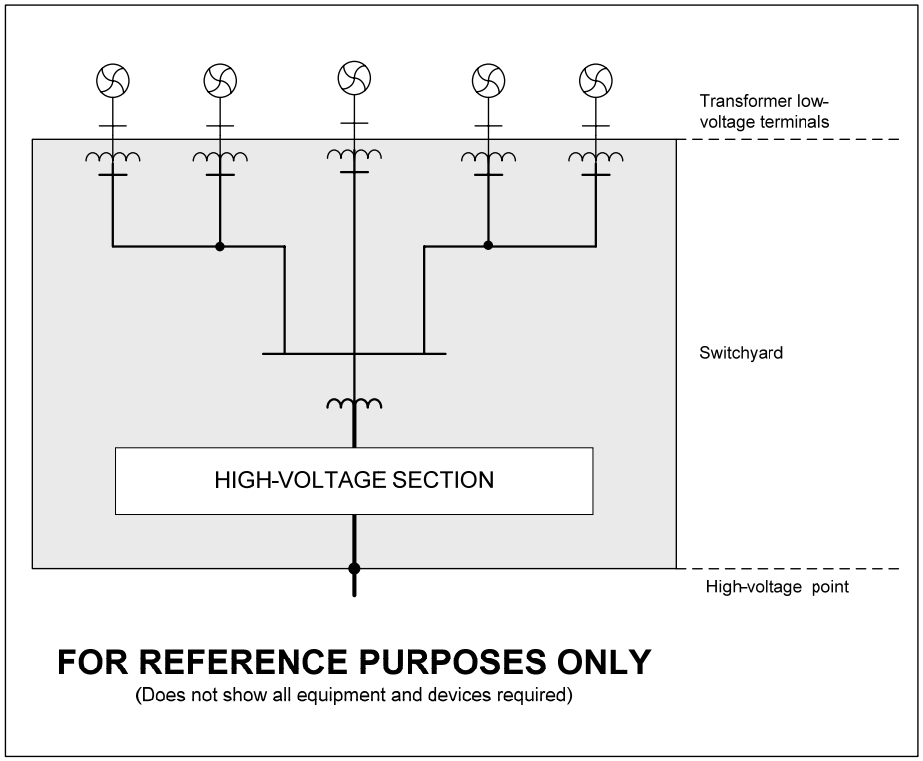
Any person or entity, including Hydro-Québec, when carrying on electric power generation activities.

***Switchyard***

The May 1999 document used the term "poste de raccordement" [connection substation], which has been replaced by *switchyard* to be in line with the document "Hydro-Québec Open Access Transmission Tariff".

As shown in Figure 1, the *switchyard* of a wind *generating plant* comprises: an initial transformation level originating at the low-voltage terminals near each wind generator, a medium-voltage system connecting to the second transformation level, one or more step-up transformers at that second level, and the high-voltage section.

**Figure 1: Boundaries of the *switchyard* for a wind *generating plant***




***Transmission provider***

Hydro-Québec when carrying on electric power transmission activities.

***Transmission system***

The set of *facilities* for carrying electricity, including step-up transformers on generating sites, transmission lines at 44 kV and over, transmission and transforming substations and any other *facility* for connecting generating sites to the distribution system.

***Tripping, reclosing***

The change in state of a circuit breaker by an automatic control.

# 3. General requirements for the design, construction and operation of *power producer facilities*

*Power producer facilities* connected to the Hydro-Québec *transmission system* must remain in service without *tripping* for as long as possible when *disturbances* occur. This is both so they can help restore voltage and frequency, and so they do not interfere with power system automatic controls.

To this end, *power producer facilities* must be designed, built and operated as to remain in service and not cause *tripping* of wind generators when subjected to the voltage and frequency variations given in the following subsections.

The *power producer* may meet these requirements by installing additional equipment in the *generating plant* (e.g., static var compensators, synchronous condensers, etc.).

## 3.1 Voltage conditions without wind generator tripping

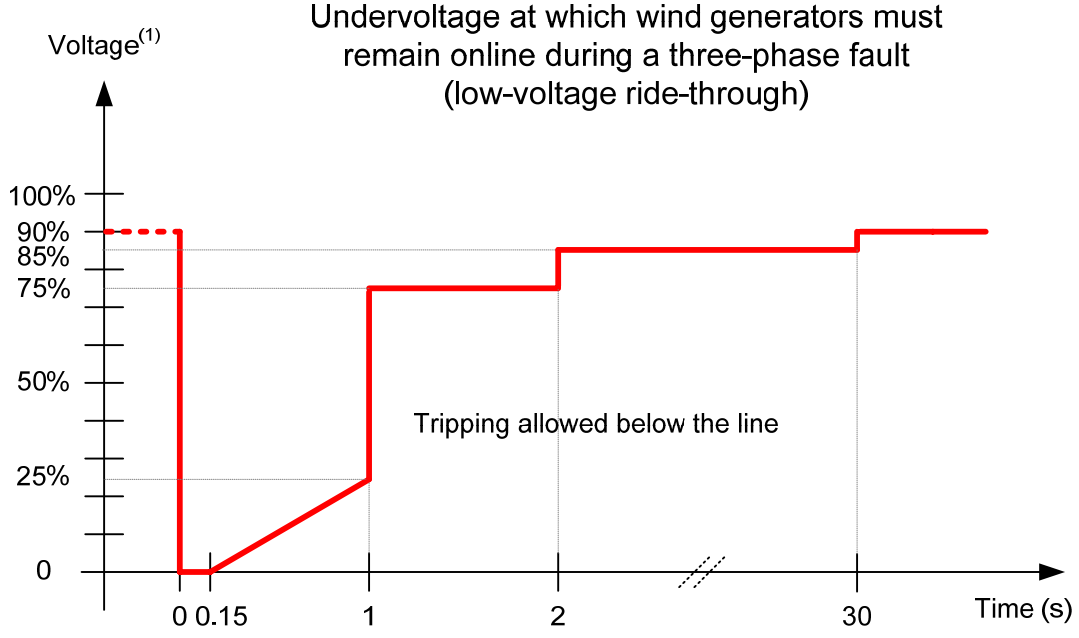
### 3.1.1 Undervoltage conditions and low-voltage ride-through

Wind generators must remain in service and not trip when the positive sequence voltage on the high-voltage side of the *switchyard* is:

- Less than 1.0 p.u. but greater than 0.9 p.u.
- Less than 1.0 p.u. but greater than 0.85 p.u. for less than 30 s
- Less than 1.0 p.u. but greater than 0.75 p.u. for less than 2 s

Wind generators must remain in service and not trip during a three-phase fault cleared normally (9 cycles) that occurs on the *transmission system* (including on the high-voltage side of the *switchyard*), and during the period required to restore voltage after the fault is cleared, if the positive sequence voltage on the high-voltage side of the *switchyard* does not fall below the line plotted in Figure 2.

Figure 2
Undervoltage at which wind generators must remain online during a three-phase fault (low-voltage ride-through)




(1) Positive sequence voltage on the high-voltage side of the switchyard

Wind generators must remain in service and not trip during a double phase-to-ground fault or a phase-to-phase fault cleared normally (9 cycles) that occurs on the *transmission system* (including on the high-voltage side of the *switchyard*), and during the period required to restore voltage after the fault is cleared.

Wind generators must remain in service and not trip during a single-phase-to-ground fault with delayed clearing (15 cycles) that occurs on the *transmission system* (including on the high-voltage side of the *switchyard*), and during the period required to restore voltage after the fault is cleared.

Furthermore, wind generators must remain in service and not trip during a remote fault cleared by a slow protective device (up to 45 cycles), and during the period required to restore voltage after the fault is cleared, be it:

- A three-phase fault, if the positive sequence voltage on the high-voltage side of the *switchyard* does not fall below 0.25 p.u.

- A double phase-to-ground fault, if the positive sequence voltage on the high-voltage side of the *switchyard* does not fall below 0.5 p.u.

- A phase-to-phase fault, if the positive sequence voltage on the high-voltage side of the *switchyard* does not fall below 0.6 p.u.

*Power producer facilities* must also help restore the power system to normal operating conditions after a *disturbance*.

### 3.1.2 Overvoltage conditions

Wind generators must remain in service and not trip under the overvoltage conditions given in Table 1.

*Power producer facilities* must also help restore the power system to normal operating conditions after the *disturbance*.

**Table 1** **Overvoltage threshold vs. minimum time wind generators must remain in service without tripping**

| Overvoltage (p.u) note 1 | Minimum time |
|---|---|
| ≤ 1.10 | Unlimited |
| > 1.10 | 300 seconds |
| > 1.15 | 30 seconds |
| > 1.20 | 2 seconds |
| > 1.25 note 2 | 0.10 seconds |
| > 1.40 note 2 | 0.03 seconds |

Note 1: Positive sequence voltage on the high-voltage side of the *switchyard*

Note 2: Temporary blocking is allowed for *facilities* using power electronics when the voltage exceeds 1.25 p.u. Normal operation must, however, resume immediately once the voltage drops below 1.25 p.u. again.

## 3.2 Frequency conditions without wind generator tripping

Wind generators must remain in service and not trip under the frequency conditions given in Table 2.

This requirement also applies to wind *generating plants* connected to the distribution system.

**Table 2** **Frequency deviation range vs. minimum time wind generators must remain in service without *tripping***

| Overfrequency | Underfrequency | Minimum time |
|---|---|---|
| $60.0 \leq F \leq 60.6$ | $59.4 \leq F \leq 60.0$ | Unlimited |
| $60.6 < F \leq 61.5$ | $58.5 \leq F < 59.4$ | 11 minutes |
| $61.5 < F < 61.7$ | $57.5 \leq F < 58.5$ | 1.5 minutes |
| | $57.0 \leq F < 57.5$ | 10 seconds |
| | $56.5 \leq F < 57.0$ | 2 seconds |
| | $55.5 \leq F < 56.5$ | 0.35 seconds |
| $F \geq 61.7$ | $F < 55.5$ | Instantaneous |

# 4. Voltage regulation

Voltage regulation is essential for maintaining *transmission system* stability and reliability. To be effective, a large majority of *generating plants* must help assume this function.

*Power producer facilities* must take part in regulating *transmission system* voltage continuously, dynamically and rapidly. They must be equipped with an automatic voltage regulation system that can supply or absorb reactive power corresponding to an overexcited or underexcited power factor equal to or less than 0.95 on the high-voltage side of the wind *generating plant switchyard*. Available reactive power must at least correspond to a power factor equal to 0.95 of the rated capacity of the wind generators in service.

If the *interconnection study* shows that reactive power from the wind *generating plant* cannot be completely used on the *transmission system*, the *transmission provider* may accept a power factor greater than 0.95 though never exceeding 0.97.

Voltage regulation for a wind *generating plant* may be provided by the wind generators or by other equipment installed by the *power producer* in the *generating plant* (e.g., synchronous condensers, static var compensators, etc.). Voltage regulation performance of a wind *generating plant* must however be comparable to that of a *generating plant* equipped with conventional synchronous generators.

The *transmission provider* may allow a wind *generating plant* with installed capacity of less than 10 MW to have no automatic voltage regulation system, for instance when the short-circuit level at the high voltage point is much greater than the installed capacity of the *generating plant*. In such instances, the *power producer facilities* must supply sufficient reactive power to keep the power factor at 1.0 on the high-voltage side of the *switchyard*.

# 5. Frequency control

The *facilities* of a wind *generating plant* whose rated output is greater than 10 MW must be designed to be able to be equipped with a frequency control system. The manufacturer must design this system and install it as soon as it is available. This frequency control system shall help reduce large (> 0.5 Hz), short-term (< 10 s) frequency deviations on the power system.

The frequency control system must reduce large, short-term frequency deviations at least as much as does the inertial response of a conventional generator whose inertia (H) equals 3.5 s. This target performance is met, for instance, when the frequency control system varies the real power dynamically and rapidly by about 5% for 10 s when a large, short-term frequency deviation occurs on the power system.

# 6. Requirements regarding protection systems

As indicated in Section 3, *power producer facilities* connected to the Hydro-Québec *transmission system* must remain in service without *tripping* for as long as possible when *disturbances* occur.

Systems protecting *power producer facilities* must be selective enough to avoid inadvertent *tripping* when such disturbances occur. No protection system must thus result in *tripping* of the wind generator, directly or indirectly, for the voltage and frequency variations given in Sections 3.1 and 3.2.

## 6.1 Voltage protection

Voltage protection comprises an undervoltage function and an overvoltage function. Such protection must be selective enough to avoid inadvertent *tripping* of wind generators when *disturbances* occur.

Voltage protection must thus meet Section 3.1 requirements. The times specified in Section 3.1 set minimum time-lags that the voltage protection system must meet. Referring to Table 1, for instance, overvoltage protection with an operating threshold set to a voltage of 1.17 p.u. must have a minimum time-lag of 30 seconds.

Voltage protection must be coordinated with other existing protection systems and initiate *tripping* of the *generating plant*, when required, to avoid its operation under unacceptable voltage conditions.

## 6.2 Frequency protection

Frequency protection comprises an underfrequency function and an overfrequency function. Such protection must be set to sufficiently selective thresholds and time-lags to avoid inadvertent wind generator *tripping* when *disturbances* occur. Such protection settings must in no instance interfere with the means implemented by the *transmission provider* to restore the frequency of the power system during a *disturbance*.

Frequency protection must thus meet Section 3.2 requirements. Times specified in Table 2 set minimum time-lags that the protection must meet for given frequency ranges. Referring to Table 2, for instance, frequency protection with an operating threshold set in the frequency range ($58.5 \leq F < 59.4$) must have a minimum time-lag of 11 minutes.

Frequency protection must be coordinated with other existing protection systems and initiate *tripping* of the *generating plant*, when required, to avoid its operation under unacceptable frequency conditions.

## 6.3 Telecommunication system for teleprotection functions

The *transmission provider* will supply, install and maintain the equipment required for transmitting teleprotection signals.

The kind of equipment required, interface points and other characteristics relevant to providing the required services will be specified to the *power producer* at the preliminary project or engineering study stage.

The *power producer* must provide adequate secure space for installing the equipment and any needed junction boxes and ductwork.

# 7. Electric power quality

Section 4.3 of the May 1999 document deals with *disturbances* to power quality by *power producer facilities* connected to the *transmission system*.

The allowable limits to *disturbances* of power quality are specified in the July 2002 document "Emission Limits for Customer Facilities Connected to the Hydro-Québec Transmission System", which is available on the Hydro-Québec website at:

http://www.hydroquebec.com/transenergie/fr/commerce/pdf/limites_emission_en.pdf

# 8. Requirements for *transmission system* operation

## 8.1 Data required

The *transmission provider* requires real-time data from each *generating plant* for effective operation of the Hydro-Québec *transmission system*. This data must be provided in a form compatible with *transmission provider* equipment. The real-time data required for all types of *generating plants* depends on their capacity and is specified in Appendix A, Table A1.

Note that wind *generating plants* are also required to provide the following meteorological data [Note 1]:

- Wind speed and direction
- Dry-bulb temperature
- Wet-bulb temperature
- Dew point
- Type of precipitation
- Atmospheric pressure

The *power producer* must equip its *facilities* with all sensors needed to transmit the required information to the *transmission provider*. At the request of the *transmission provider*, it must take part in tests two months before the *generating plant* is commissioned or at a date agreed to with the *transmission provider* to check that data acquisition is working properly.

The equipment used by the *power producer* to provide the required data to the *transmission provider* must be accepted by the latter.

## 8.2 Telecommunication system for operation functions

The *transmission provider* will supply, install and maintain on the *power producer*'s premises the communication equipment needed to transmit from *power producer facilities* data enabling it to operate the *transmission system*.

The kind of equipment required, interface points and other characteristics relevant to providing the required services will be specified at the preliminary project or engineering study stage.

The *power producer* must provide adequate secure space for installing the equipment and any needed junction boxes and ductwork.

[Note 1] Acquisition rate: Wind data – 30 seconds
Temperature and pressure data – 10 minutes

# 9. *Power producer* responsibility for technical information to be submitted to the *transmission provider*

The *power producer* is responsible for the validity of information (data, models and associated settings) that it or its supplier submits to the *transmission provider* so the latter can conduct the studies required to assess the impact of connecting the wind *generating plant* to the *transmission system*.

## 9.1 IEEE-based modeling

Besides the information specified in Appendix B of the May 1999 document, the *power producer* must provide detailed models for the wind *generating plant* based on IEEE models and associated generator and converter settings. The models must be compatible with Siemens PTI's PSS/E software, which the *transmission provider* uses for its studies of dynamic behaviour.

For projects under a connection agreement between the *power producer* and *transmission provider*, the latter may, as a member of power system reliability organizations (NPCC, NERC), be called upon to share some of this information with other transmission providers.

## 9.2 Non-IEEE-based modeling

If no IEEE model is available, the *power producer* must provide a complete "black-box" model, including the required technical documentation, data and settings. The model must be able to represent all *generating plant* wind generators as a single generator. This model must also be compatible with Siemens PTI's PSS/E software, which the *transmission provider* uses for its studies of dynamic behaviour.

For projects under a connection agreement between the *power producer* and *transmission provider*, the latter may, as a member of power system reliability organizations (NPCC, NERC), be called upon to share some of this information with other transmission providers.

The *power producer* must provide compliance tests demonstrating that the "black-box" model behaves like the real wind generator.

Given that technology used in wind *generating plants* is diverse and rapidly evolving, the *transmission provider* further requires that the *power producer* provide test results

demonstrating that the wind generator meets the voltage and frequency requirements described in Sections 3.1 and 3.2 herein.

If wind generator behaviour does not conform to the model, the *power producer* is responsible for any additional costs for interconnection with the *transmission system*.

## 9.3 Information required for EMTP modeling

The *transmission provider* also requires that it be provided with the information needed to conduct studies of electromagnetic phenomena, as specified in Appendix B herein.

The EMTP model is required no later than one month after the selected project(s) are announced in the case of a call for tenders by the Distributor. In other instances, the model must be provided to the *transmission provider* when the *interconnection study* agreement is signed. The manufacturer may, once the *transmission provider* so approves, lock certain components of the wind generator model.

# 10. Other considerations

To meet *transmission system* operating requirements, the *transmission provider* may request that:

- The raising and lowering of wind *generating plant* output stay below maximum ramp rates set by the *transmission provider*
- A control system be added to receive control signals for such functions as limiting maximum real power
- A control system be added to receive a signal that gradually shuts down the wind generators in extremely cold weather
- Generating *facilities* be able to be equipped with a stabilizer.

# APPENDIX A

## INFORMATION REQUIRED BY THE *TRANSMISSION PROVIDER* TO OPERATE THE *TRANSMISSION SYSTEM*

# Information required by the *transmission provider* to operate the *transmission system*

**Table AI:** **Connection of *generating plants* to the Hydro-Québec *transmission system* – Information required by the Telecontrol Centre (CT) and System Control Centre (CCR) (Notes a and b)**

| | CAPACITY < 50 MW | | CAPACITY ≥ 50 MW | |
|---|---|---|---|---|
| **INFORMATION REQUIRED** | **CT** | **CCR** | **CT** | **CCR** |
| **Total *generating plant* capacity MW and Mvar** | | **Measurement** Except if impact on power system deemed negligible | | **Measurement** |
| ***Generating unit* breaker** | **Status** If required for power system operation | | **Status** | **Status** If reserve service contract or Generation rejection or Regulation |
| ***Generating unit* disconnect switch** | **Status** If required for power system operation | | **Status** | **Status** If reserve service contract or Generation rejection or Regulation |
| ***Generating unit* MW, Mvar, kV, A** | **Measurement** If required for local power system operation | | **Measurement** | **Measurement** If reserve service contract or Generation rejection or Regulation |
| **Connection breaker** | **Measurement** Except if impact on power system deemed negligible | | **Status** | **Status** If connected to line under CCR responsibility |
| **Connection point MW, Mvar, kV, A** | **Measurement** Except if impact on power system deemed negligible | | **Measurement** | **Measurement** If connected to line under CCR responsibility |
| **Water level (upstream and downstream)** | | | | If reserve service contract or Generation rejection or Regulation |
| **Generation rejection, Regulation Other network protection systems** | | | When under automatic control, transmission of: **Status signals, measurements and commands** To be specified, if applicable | When under automatic control, transmission of: **Status signals, measurements and commands** To be specified, if applicable |
| **Acquisition unit** | **Status** | | **Status** | **Status** |
| **Telephone link (voice)** | **Note d** | | **Note d** | |
| **Breaker or disconnect switch for the station service supply point** | | | **Status** | |
| **Status signals and alarms (Note c)** | **Status** | | | |
| **Stabilizer** | | | **Status** Where applicable (Note e) | **Status** Where applicable (Note e) |

Note a Requirements for remote control of the *generating plant* are not included, nor those for power dispatch.
Note b Information for the CCR may go through a CT.
Note c Certain status or alarm signals may be required to indicate the state of tone units or the operation of some protections (such as back-up protection) that can affect the *transmission system*.
Note d Link for contacting the operator of the *generating plant* 24/24 x 7/7 (directly without dialing, e-mail or voice mailbox).
Note e Signaling the status of the stabilizer is required whenever one is installed (See Section 5.3.2).

# APPENDIX B

## INFORMATION REQUIRED BY THE *TRANSMISSION PROVIDER* FOR EMPT MODELING OF THE WIND *GENERATING PLANT*

## Information required by the *transmission provider* for EMPT modeling of the wind *generating plant*

In order to conduct studies of transient phenomena, essential for the detailed analysis of power system behaviour, the *power producer* or manufacturer must provide a model of the wind generator and equipment equipped with a control system (SVC, STATCON, etc.) that can be readily usable with EMPTWorks© (distributed by TransÉnergie Technologies: www.emtp.com).

The detailed model must be unlocked and have the following characteristics:

- Include technical documentation used to develop the model
- Support representation of a single wind generator or of an entire wind farm including the collector system (the *power producer* may provide the equivalent collector system separately)
- Represent variable-speed rotating machines using a multimass model for blades and rotor
- Represent blades by their aerodynamic equivalent under wind conditions, including variable pitch where applicable. The wind generator must be able to work across its entire range of output
- Include an adequate representation of any power electronics with which the wind generator is equipped (for instance, an IGBT may be represented by a controlled switch)
- Represent any filters with which the wind generator is equipped
- Represent any capacitors with which the wind generator is equipped, and the mechanism that triggers them
- Completely represent control systems, including the physical limits of components. Any adjustable regulator gain on the wind generator must be clearly accessible in the model (for instance, voltage regulator gain)
- Adequately represent harmonics produced by the wind generator
- Provide an exact representation of the wind generator behaviour under fault conditions (current, voltage and dynamic)

The EMTP model is required no later than one month after the selected project(s) are announced in the case of a call for tenders by the Distributor. In other instances, the model must be provided to the *transmission provider* when the *interconnection study* agreement is signed. The manufacturer may, once the *transmission provider* so approves, lock certain components of the wind generator model.