NEW BRUNSWICK SYSTEM OPERATOR

CONNECTION REQUIREMENTS GUIDE FOR WIND POWERED GENERATION IN NEW BRUNSWICK

NBSO-PSE-001

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Document Approval

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Table of Contents

Acronyms and Definitions

Acronyms

DFIG	Doubly Fed Induction Generator
FERC	Federal Energy Regulatory Commission
IEEE	Institute of Electrical and Electronics Engineers
LVRT	Low Voltage Ride-Through
NBSO	New Brunswick System Operator
NPCC	Northeast Power Coordinating Council
PCC	Point of Common Coupling
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SPS	Special Protection System
STATCOM	Static Synchronous Compensator
SVC	Static VAR Compensator
WPGF	Wind Powered Generation Facility
WTG	Wind Turbine Generator

Definitions

Collector System	The equipment and circuits within a *Wind Powered Generation Facility* that interconnect each wind turbine generator to the substation containing the *Step-Up Transformer*.
Generation Rejection	The process of deliberately removing pre-selected generation from a power system, or initiating HVDC runback, in response to a contingency or an abnormal system condition in order to maintain the integrity of the system.
Low Voltage Ride-Through	The capability of a wind turbine generator to stay connected to a transmission system during low voltage grid conditions (e.g. during system faults).
Market Participant	A person who is, subject to the New Brunswick Electricity Act, licensed by the Energy and Utilities Board of New Brunswick and accredited by NBSO to provide or convey, or to cause to be provided or conveyed, electricity or Ancillary Services into, though or out of the NBSO-controlled gird.
Point of Common Coupling	The high voltage side of the *Step-Up Transformer* connecting a *Wind Powered Generation Facility* to the NBSO-controlled grid.
Special Protection System	A protection system designed to detect abnormal system conditions and take corrective action other than the isolation of faulted elements.
Step-Up Transformer	The transformer that directly connects a *Wind Powered Generation Facility* to the NBSO-controlled grid.
Transmitter	The owner or operator of the transmission system element directly connected to a *Wind Powered Generation Facility's Point of Common Coupling*.
Wind Powered Generation Facility	All of the components that make up a generation facility that is powered by wind energy, including, but not limited to, Wind Turbine Generators, Collector System, Step-Up Transformers and voltage support equipment.

1 Introduction

1.1 Purpose

The purpose of the this document is to facilitate the development of wind powered generation in New Brunswick while ensuring system reliability by outlining the minimum mandatory requirements for connecting *WPGF*s to the NBSO-controlled grid.

1.2 Scope

This document is intended for any parties involved with the integration of *WPGF*s within the NBSO-controlled grid. The requirements outlined in this document are applicable to any *WPGF* with a net cumulative output of 5 MVA or more that is connected to, or planning to connect to, the NBSO-controlled grid as of July 13th, 2009.

Additional requirements for *WPGF*s not contained in this document will be enforced by NBSO. Such requirements may include, but not be limited to

- requirements arising from FERC, NERC or NPCC standards, criteria, guidelines and procedures,
- additional requirements in the NBSO Open Access Transmission Tariff not contained in this document, and
- additional requirements that are identified through a System Impact Study.

This document covers the following topics as they relate to each *WPGF* connected to the NBSO-controlled Grid:

- Frequency and Power
- Voltage, Reactive Power and Power Quality
- Modeling and Validation
- Operational Monitoring and Control
- Physical Connection Requirements

Links to documents that explain the connection application process are also provided in this document.

1.3 Legal Disclaimer

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2 Frequency and Power

2.1 Frequency Tolerance

Each *WPGF* connected to the NBSO-controlled grid shall operate continuously during under-frequency conditions as per NPCC Directory #2, Emergency Operations [1].

From NPCC Directory #2, section 5.4:

Generators should not be tripped for under-frequency conditions in the area above the curve in Figure 2.1.1.

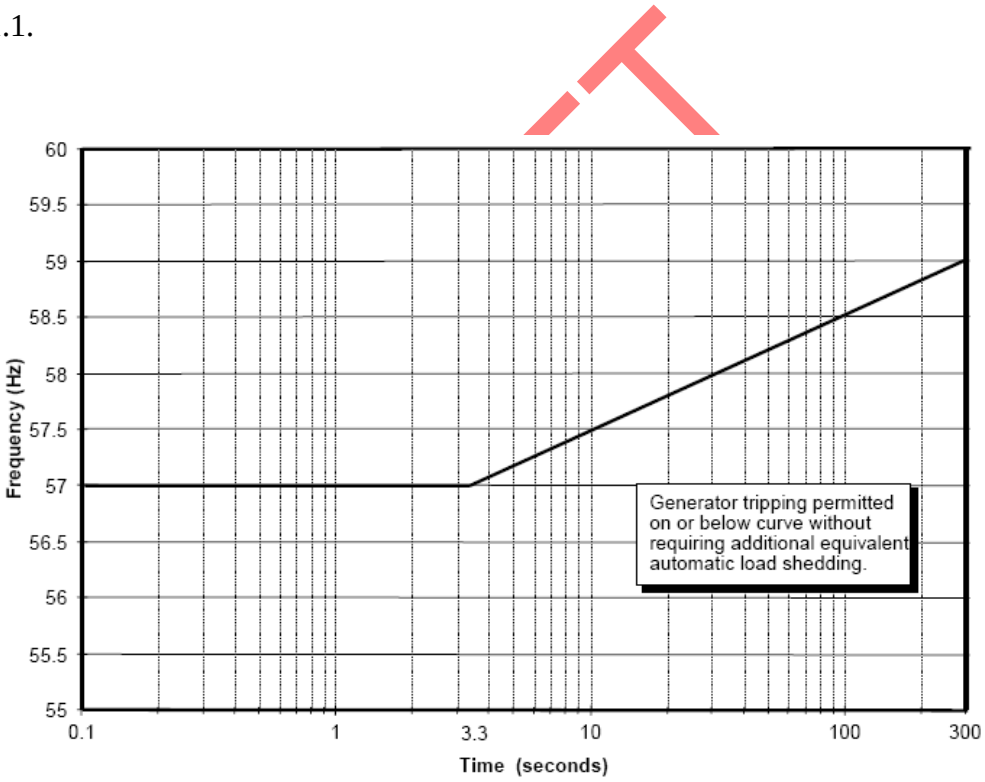

Figure 2.1.1 NPCC standards for setting under-frequency trip protection for generators

The NPCC Directory #2 can be found at:
http://www.npcc.org/documents/regStandards/Directories.aspx.

2.2 Power Control

There may be system conditions that require NBSO to limit the real power output of a *WPGF*.

Each *WPGF* connected to the NBSO-controlled grid shall be equipped with a *WPGF* management system that allows for the provision of real time power control. The power control component of the system shall be capable of

- responding to a MW set-point sent by the NBSO through the NBSO SCADA system; and
- limiting a *WPGF* MW output to the MW set-point established by NBSO.

The MW output of a *WPGF* shall not exceed the NBSO established MW set-point. A *WPGF* MW output may fall below the NBSO established MW set-point (e.g. during low wind conditions).

The power control component of the *WPGF* management system should operate in such a way that, where possible, WTGs are kept on-line or on stand-by instead of shut down in order to bring down and hold a *WPGF* MW output to the MW set-point established by NBSO.

2.3 Ramp-Rate Control

Each *WPGF* connected to the NBSO-controlled grid shall be equipped with a control system that allows for the provision of real power ramp-rate control in order to meet system operating requirements.

2.4 Frequency Response Control

The Maritimes area is susceptible to islanding from the Eastern Interconnection. Adequate frequency response capability from the Maritimes system during such islanding conditions is

critical to ensure reliability. Factors affecting frequency response include system inertia and the governing response of on-line generation.

WTGs, in general, have a negligible contribution to system inertia. In addition, the power generated by WTGs may displace conventional generation and thus reduce system inertia and governing response. System conditions may exist when system frequency response capability is unacceptable (e.g. during light load conditions with high levels of wind powered generation and limited on-line conventional generation).

NBSO may require that *WPGF*s connected to the NBSO-controlled grid be equipped with a control system that allows for the provision of frequency response control. The frequency response control shall be capable of the following:

- being activated and set by NBSO through the NBSO SCADA system;
- holding a *WPGF* MW output to an operator adjustable percentage of its calculated maximum MW output during pre-disturbance conditions; and
- responding to frequency disturbances with a frequency droop characteristic specified by NBSO.

3 Voltage, Reactive Power, and Power Quality

3.1 Voltage Operating Ranges

Each *WPGF* connected to the NBSO-controlled grid shall be able to operate continuously for all normal and emergency system operating voltages at the *PCC*.

The NBSO-controlled grid

- normal operating voltage range is between 0.95 pu to 1.05 pu; and
- emergency operating voltage range is between 0.90 pu to 1.10 pu.

3.2 Voltage Control

Each *WPGF* connected to the NBSO-controlled grid shall be equipped with a *WPGF* management system that allows for the provision of automatic voltage regulation. The automatic voltage regulation scheme shall be capable of automatically

- responding to a kV set-point sent by the NBSO through the NBSO SCADA system, and
- setting and holding the voltage at a *WPGF PCC* to the kV set-point established by the NBSO.

Planned outages of a *WPGF* automatic voltage regulation scheme must be authorized by NBSO.

3.3 Reactive Power Capability

Each *WPGF* connected to the NBSO-controlled grid shall meet the minimum *WPGF* reactive power capability requirements at the *PCC* as specified in Figure 3.3.1 and Table 3.3.1. These requirements apply for all *WPGF* real power output levels at the *PCC*.

The total reactive power capability of each *WPGF* connected to the NBSO-controlled grid shall be comprised of the following:

- a dynamic portion that meets the requirements outlined in Figure 3.3.1 and Table 3.3.1; and
- a dynamic or non-dynamic portion that, in combination with the required dynamic portion, meets the requirements outlined in Figure 3.3.1 and Table 3.3.1.

The dynamic reactive power capability of each *WPGF* connected to the NBSO-controlled grid shall:

- be continuously acting;
- be continuously variable; and
- have a time response similar to that of a conventional synchronous generator.

The dynamic reactive power requirement may be met by:

- WTGs capable of injecting or absorbing reactive power in accordance with the requirements outlined in this section, or
- the installation of equipment that meet the requirements outlined in this section (SVC, STATCOM, etc.).

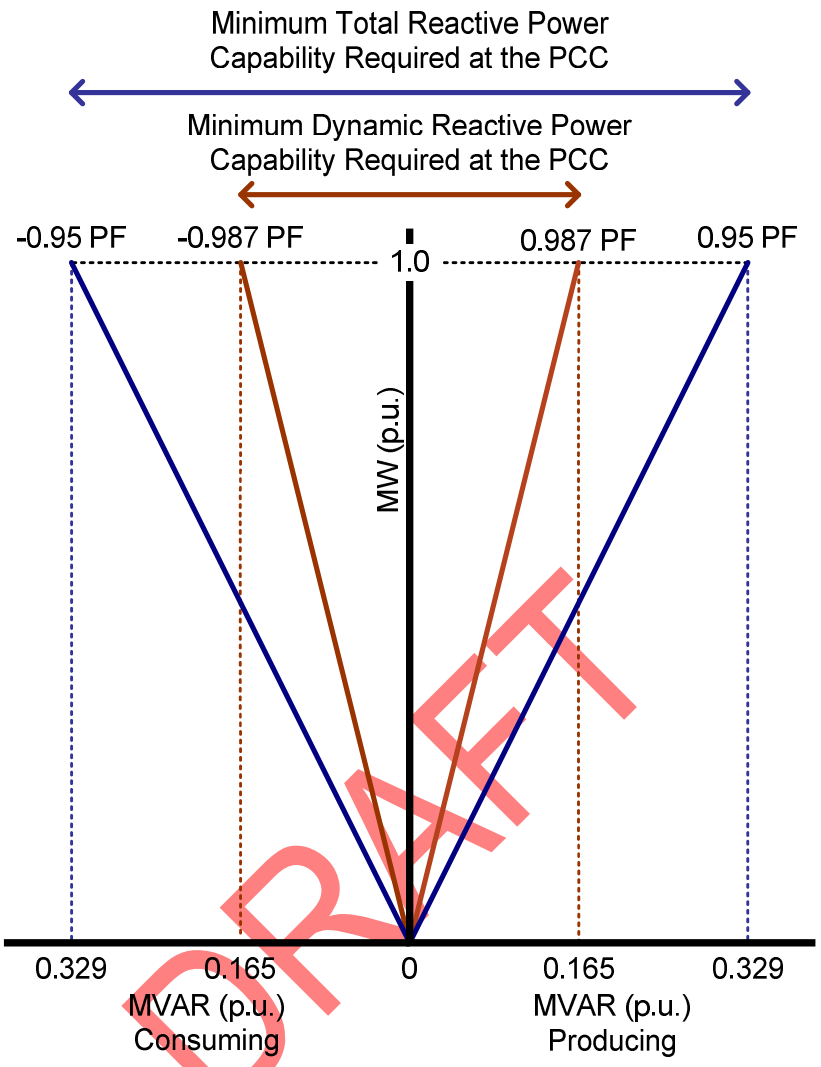

Figure 3.3.1 Minimum WPGF Reactive Power Capability Requirements
(PCC voltage = 1 pu)

Table 3.3.1 Minimum WPGF Reactive Power Capability Requirements

	Minimum WPGF Reactive Power Capability Requirements			
PCC Voltage (pu)	**Total Leading Power Factor**	**Total Lagging Power Factor**	**Dynamic Leading Power Factor**	**Dynamic Lagging Power Factor**
1.05	0.95	0.95*	0.987	0.987*
1.00	0.95	0.95	0.987	0.987
0.95	0.95*	0.95	0.987*	0.987

* Will be reviewed by NBSO on a case by case basis

3.4 Harmonics

The harmonic content of the voltage and current waveforms at the *PCC* of a *WPGF* shall be within the limits set by IEEE Standard 519-1992 [2].

Harmonic problems will be addressed on a complaint basis. If a *WPGF* is determined to be the cause of a harmonic problem, then that *WPGF* shall be removed from the NBSO-controlled grid until the condition is resolved. All costs associated with research and corrective action, including settlements paid to other customers, will be at the *WPGF* owner's expense.

3.5 Flicker

Each *WPGF* connected to the NBSO-controlled grid shall not exceed the HV-EHV P_{st} and P_{lt} planning levels at the *PCC* for more than 1% of the time, as outlined in IEEE Standard 1453-2004 [3].

Each *WPGF* connected to the NBSO-controlled grid shall not cause a voltage drop or rise of 3% or more at the *PCC* during non-faulted conditions. Events that may cause such a voltage drop or rise include the following:

- the start-up or shut-down of any number of WTGs in a WPGF;
- non-fault tripping of WTGs in a WPGF; and
- power surges due to wind gusts.

Flicker problems will be addressed on a complaint basis. If a *WPGF* is determined to be the cause of a flicker problem, then that *WPGF* shall be removed from the NBSO-controlled grid until the condition is resolved. All costs associated with research and corrective action, including settlements paid to other customers, will be at the *WPGF* owner's expense.

3.6 Voltage Unbalance

The magnitude of voltage unbalance shall not exceed 2% between phases at the *PCC* for any *WPGF* connected to the NBSO-controlled grid.

3.7 Low Voltage Ride-Through Requirements

Each *WPGF* connected to the NBSO-controlled grid shall comply with the Post-Transition Period *LVRT* Standard outlined in Appendix G of FERC Order 661-A (Dec 2005) [4].

FERC Order 661-A (Dec 2005) can be found at:
http://www.ferc.gov/EventCalendar/Files/20051212171744-RM05-4-001.pdf

4 Modeling and Validation

4.1 Provision of Physical Specifications and Data

The NBSO requires complete and accurate data to enable the proper modeling of *WPGF*s in load flow, transient stability and fault studies. Specifications and data shall be provided for the following:

- WPGF layout (one-line diagram and description).
    - *WPGF* geographical location
    - *WPGF* equipment (total number of WTGs, capacitors, STATCOM, etc.)
    - Layout of *Collector System* and WTG connections/groupings

- WTG specifications
    - Make and model
    - MVA and MW ratings
    - Nominal operating voltage
    - Generator type (induction, DFIG, etc.)
    - Generator MW/MVAR capability curves/data
    - Protection specifications (frequency, voltage, *LVRT*, etc.)

- WTG transformer specifications
    - High-side and low-side kV
    - Reactance (%, specify base)
    - R/X ratio
    - Tap specifications

- WPGF Step-Up Transformer data
    - Nameplate drawings
    - High-side and low-side kV

- Reactance (%, specify base)
- R/X ratio
- Tap specifications, if applicable

- WPGF Collector System data
  - Resistance, reactance and shunt admittance (%, specify base) for each *WPGF* collector circuit

Additional data may be required by NBSO.

4.2 Provision of PSS®E Models and Data

Complete and accurate PSS®E models and associated data are required for all applicable equipment within each *WPGF* connected to the NBSO-controlled grid. These PSS®E models enable the proper modeling of *WPGF*s for load flow, transient stability and fault studies. Applicable equipment includes, but is not limited to, WTGs and dynamic reactive power devices (SVC, STATCOM, etc…). Appropriate and complete documentation shall be provided with each required model.

The performance of the supplied PSS®E models and associated data shall be validated against the results from laboratory and/or field tests. The *WPGF* owner shall be responsible for providing the evidence of this validation

Any required models shall be compatible with PSS®E versions 30.3.X.

5 Operational Monitoring and Control

5.1 SCADA Capability

Each *WPGF* connected to the NBSO-controlled grid shall have the capability to transmit data and receive instructions from the SCADA systems at the NBSO primary and back-up control centres.

Each *WPGF* owner is responsible for the cost to install and maintain continuous SCADA communications between the *WPGF* and the NBSO primary and back-up control centres.

Each *WPGF* connected to the NBSO-controlled grid is required to have 7 days-per-week, 24 hours-per-day repair capability for all SCADA circuits.

5.2 Control Authority

NBSO shall have direct control over the following:

- opening of the *WPGF* breaker at the *PCC;*
- *WPGF* MW production set-point limits;
- voltage control kV set-point; and
- arming of *WPGF*s for *Generation Rejection*.

The *WPGF* owner shall have direct control over the operation of the *WPGF* breaker at the *PCC*. At no time shall this breaker be operated without the explicit consent of the NBSO power system operator. The *WPGF* owner will take necessary actions, without prior approval of NBSO, when the urgent removal from service or de-rating of equipment is necessary to prevent an actual failure that could jeopardize safety, the environment, or the equipment itself. When such actions are necessary, the *WPGF* owner will notify NBSO as soon as practicable following the action.

5.3 Data Communication Requirements

An RTU is required for the transmittal of data between a *WPGF* and the NBSO primary and back-up control centres. The communications protocol to be used by any RTU shall be specified by the NBSO.

Data shall be carried on leased telephone company provided circuits or on private infrastructure. The Internet shall not be used for telemetry or control. Existing *Transmitter* owned data communication networks may be used. In this case the *WPGF* owner is responsible for the incremental costs associated with accessing that network.

The availability of the communication link and the RTU shall be no less than 99.98%

5.4 Monitoring and Control Signals

NBSO requires that all non-meteorological *WPGF* monitoring and control signals shall have an update time of two seconds.

In addition, NBSO requires that all analog non-meteorological *WPGF* monitoring and control signals shall adhere to the following minimum resolutions:

- 1 MW/MVAR for all signals representing MW/MVAR quantities.
- 0.5 kV for all signal representing voltage quantities at 100 kV and above.
- 0.1 kV for all signal representing voltage quantities below 100 kV.

All of the non-meteorological *WPGF* monitoring and control signals required by NBSO are listed in Table 5-A.

5.5 Meteorological Data

NBSO requires that meteorological data at a *WPGF* be transmitted to the NBSO primary and back-up control centres and have a minimum update time of one minute.

Table 5-B lists all of the meteorological *WPGF* data required by NBSO.

5.6 Coordination with SPSs

SPSs exist in the NBSO-controlled grid that rejects pre-selected generation during specific disturbances experienced under certain system operating conditions.

NBSO may require *WPGF*s to be available for selection for *Generation Rejection*. Such *Generation Rejection* would be initiated by *SPS* action. *WPGF*s will not be compensated by the NBSO for costs incurred due to tripping by *SPS* action.

5.7 System Disturbance Monitoring

The installation of a disturbance recording device with clock synchronization is required for all *WPGF*s connected to the NBSO-controlled grid. The disturbance recording devices will be used to monitor and record the responses of *WPGF*s to disturbances on the NBSO-controlled grid in order to verify the dynamic response of *WPGF* equipment.

5.8 References to Operational Documentation

The following documents are useful for understanding the requirements outlined in this chapter and any other requirements and practices not covered in this document.

- Template of the Common Operating Practices between the NBSO and the *WPGF* owner.
- Attachment J (Generator Connection Agreement) of the NBSO Open Access Transmission Tariff: http://www.nbso.ca/Public/en/op/transmission/tariff.aspx

Table 5-A: Required WPGF Monitoring and Control Signals

WPGF Monitoring and Control Signals	**Units**	**Monitor**	**Control**	**Notes**
WPGF Total Output Power	MW	X		On the HV side
WPGF Total Output Reactive Power	MVAR	X		On the HV and LV sides
WPGF Voltage	kV	X		On the HV and LV sides
Step-up Transformer Tap Position	Tap	X		
WPGF Production Set-Point Limits	MW	X	X	
Voltage Regulation Control Status	On/Off/Mode	X		
Voltage Control Set-Point	kV	X	X	
Dynamic Reactive Power Device(s) Status	On/Off	X		
Dynamic Reactive Power Devices Output	MVAR	X		
WPGF HV Circuit Breaker(s) Status	Open/Close	X	X	Open control only
WPGF HV Circuit Breaker(s) Reclosure/Restoration Status	On/Off	X		
WPGF Substation Breakers Status	Open/Close	X		

Table 5-A: Required WPGF Monitoring and Control Signals (Continued)

WPGF Monitoring and Control Signals	Units	Monitor	Control	Notes
Reactive Power Device(s) Circuit Breaker(s) Status	Open/Close	X		For both static and dynamic devices
WPGF Substation Motor Operated Disconnects Status	Open/Close	X		
WPGF Total Available Power	MW	X		
WPGF Total Available Reactive Power	MVAR	X		
WPGF WTG On-Line	# of WTG	X		Shall be known for each associated grid connected transformer
WPGF WTG Availability	# of WTG	X		Shall be known for each associated grid connected transformer
WPGF WTG Shutdown by High Winds	# of WTG	X		Shall be known for each associated grid connected transformer
WPGF WTG Shutdown by Cold Temperature	# of WTG	X		Shall be known for each associated grid connected transformer
System Disturbance Monitor Status	On/Off	X		

Table 5-B: Required Meteorological Data

Meteorological Signals	Units	Notes
Wind Speed	m/s	One minute average
Wind Direction	Degrees	One minute average
Air Temperature	ºC	

6 Physical Connection Requirements

6.1 Physical Connection to the NBSO-Controlled Grid

Each *WPGF* connected to the NBSO-controlled grid shall follow the physical connection standards of the *Transmitter*. Such physical connection standards may include, but not be limited to, standards for the following:

- tapping transmission lines;
- breaker requirements and arrangement;, and
- isolation switch requirements and placement.

If a *WPGF PCC* is connected to a transmission element that is shared between multiple *Transmitters* (e.g. an interconnecting transmission line) then the most stringent of all the Transmitter physical connection standards will be applied to that *WPGF*.

The *WPGF* System Impact Study will outline the appropriate *Transmitter* physical connection standards, as well as any other necessary physical connection requirements. The final design of a *WPGF* physical connection to the NBSO-controlled grid shall be approved by the NBSO.

6.2 Step-Up Transformer

*WPGF*s shall connect to the NBSO-controlled grid through a *Step-Up Transformer* of adequate MVA rating and proper voltage rating for conversion from the *WPGF Collector System* voltage to the transmission system voltage. The high voltage side of the *Step-Up Transformer* shall be solidly grounded and in a wye configuration. As a minimum, *Step-Up Transformers* shall have tap settings that span ±5% of the nominal voltage at 2.5% intervals.

The NBSO shall direct the setting of the taps for WPGF *Step-Up Transformers*.

6.3 Protection Equipment and Characteristics

Each *WPGF* connected to the NBSO-controlled grid shall design, install, maintain and operate appropriate protection systems. The *Transmitter* shall approve the specific relays, connection equipment and protection settings of a *WPGF* before it can connect to the NBSO-controlled grid.

6.4 Substation Equipment

WPGF station grounds shall be designed and installed in accordance with the *Transmitter's* substation standards. The NBSO and the *Transmitter* shall approve a *WPG* substation design before that *WPGF* can connect to the NBSO-controlled grid.

7 Facility Connection Process

7.1 Facility Connection Process

NBSO approval is required for all *WPGF* projects connecting to the NBSO-controlled grid. NBSO is responsible for ensuring that the connection and operation of any generator does not compromise the reliability of the NBSO-controlled grid or have any negative impact on existing transmission customers.

Further information on facility connection can be found on the NBSO website at: http://www.nbso.ca/Public/en/op/transmission/connecting/default.aspx.

The NBSO grid Connection Assessment process is outlined in NBSO Market Procedure 21 which can be accessed on-line at:
http://www.nbso.ca/Public/en/op/market/procedures/document.aspx?id=5287663c-dccc-4024-9694-bc652d8f4f50

8 References

[1] "Regional Reliability Reference Directory #2: Emergency Operations", Northeast Power Coordinating Council, NPCC, October 21, 2008. http://www.npcc.org/documents/regStandards/Directories.aspx

[2] "IEEE Standard 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems".

[3] "IEEE Standard 1453-2004, IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems"

[4] "Federal Energy Regulatory Commission - Grid Interconnection for Wind Energy", Docket No. RM05-4-001, Order No. 661-A, December 12, 2005. http://www.ferc.gov/EventCalendar/Files/20051212171744-RM05-4-001.pdf