aeso
ALBERTA ELECTRIC SYSTEM OPERATOR

Wind Power Facility

Technical Requirements

REVISION 0

November 15, 2004

	Name	Signature	Date
Prepared:	J.H. Kehler D. McCrank, P.Eng.		Nov. 15, 2004
Reviewed:	F. Ritter, P.Eng.		Nov. 15, 2004
Approved:	N.A. Millar, P.Eng.		Nov. 15, 2004

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TABLE OF CONTENTS

List of Tables

List of Figures

1.0 INTRODUCTION

All Wind Power Facilities (**WPF**s) that connect to transmission system voltages on the Alberta Transmission System (**ATS**) are required to comply with the **Wind Power Facility Technical Requirements (WPFTR)**. The electrical behavior of **Wind Turbine Generators** (**WTG**) can be significantly different from the characteristics of synchronous generators (typically used in all other forms of generation). Therefore technical and performance requirements are defined which are applicable to **WPF**s interconnecting with the **ATS**.

The standard takes into consideration that some issues need to be further studied before implementing specific technical requirements arising from the variability of wind power. To facilitate continued development of wind power facilities and recognizing that more work and evaluation of wind power variability is required, this standard has some requirements that are planned to be reviewed by July 2005. Any technical requirements arising from the outcomes of the variability studies may require retroactive application to **WPF**s that connect under this standard dated November 15, 2004.

Marginal compliance with the voltage ride through requirements would be permitted up until January 1, 2006 as accepted by the AESO on a case by case basis. On acceptance of the marginal compliance the **WPF** is not subject to retroactivity.

Only **WPF**s are subject to this standard, all other forms of generation are subject to the AESO's interconnection requirements for generators.[1]

1.1 Purpose of the Wind Power Facility Technical Requirements

The purpose of this document is to define the required technical and performance requirements to ensure that wind power facilities contribute to continued safe and reliable operation of the Alberta Interconnected Electric System (**AIES**).

1.2 Limitations of the Wind Power Facility Technical Requirements

a) The **WPFTR** are not intended to be a design specification for the **WPF**s.

b) The technical requirements specified in this document may be subject to change in the event that North American Electric Reliability Council (**NERC**), Western Electricity Coordinating Council (**WECC**) requirements are specified requiring AESO compliance to such technical requirements or for other reasons as determined from time to time by the AESO.

[1] Technical Requirements for Connecting to the **AIES** Transmission System, Part 1: Technical Requirements for Connecting Generators December 2, 1999.

c) The **WPFTR** does not supersede other **WPF** requirements such as, but not limited to, contractual, tariff, energy market or operating agreements with the AESO.

d) Transmission Facility Owners (**TFO**s) may have additional or supplementary interconnection requirements to those specified by this **WPFTR**. The **WPF** should consult with the **TFO** regarding these requirements prior to proceeding with the interconnection.

e) The **WPFTR** are effective November 15, 2004 and apply to all new **WPF**s.

f) **WPF**s that were approved[2] for interconnection to the **ATS** prior to November 15, 2004 are subject to the previous generator standard.[3]

g) **WPF**s that were approved[2] for interconnection to the **ATS** prior to November 15, 2004 that go through any major refurbishment or any replacement are then required to meet this **WPFTR**.

2.0 OBJECTIVE

The primary objective of the **WPFTR** is to establish the technical rules, requirements and performance that a **WPF** must comply with in relation to their connection to and their operation on the Alberta Transmission System (**ATS**).

3.0 SCOPE

The **WPFTR** applies to **WPF**s only and involves **WPF** connection to the **ATS** and supersedes the AESO's "Technical Requirements for Connecting to the Alberta Interconnected Electric System (IES) Transmission System, Part 1: Technical Requirements for Connecting Generators December 2, 1999".

[2] A WPF is considered approved for interconnection when a customer has executed a Construction Commit Agreement (CCA) for the total estimated project cost.

[3] Technical Requirements for Connecting to the Alberta Interconnected Electric System (IES) Transmission System, Part 1: Technical Requirements for Connecting Generators December 2, 1999.

4.0 WIND POWER FACILITY DESCRIPTION AND DEFINITIONS

4.1 WPF Description

A **WPF** typically will have several **Wind Turbine Generators** (**WTG**s) connected to individual **WTG** step-up transformers. The **WTG** transformers will step-up voltages from a typical 600-volt level to a typical 25kV to 34.5 kV level called a collector. A **WPF** may have several collectors that will connect to the **Collector Bus**. The **Collector Bus** is connected to the low side of the transmission step-up transformer(s).

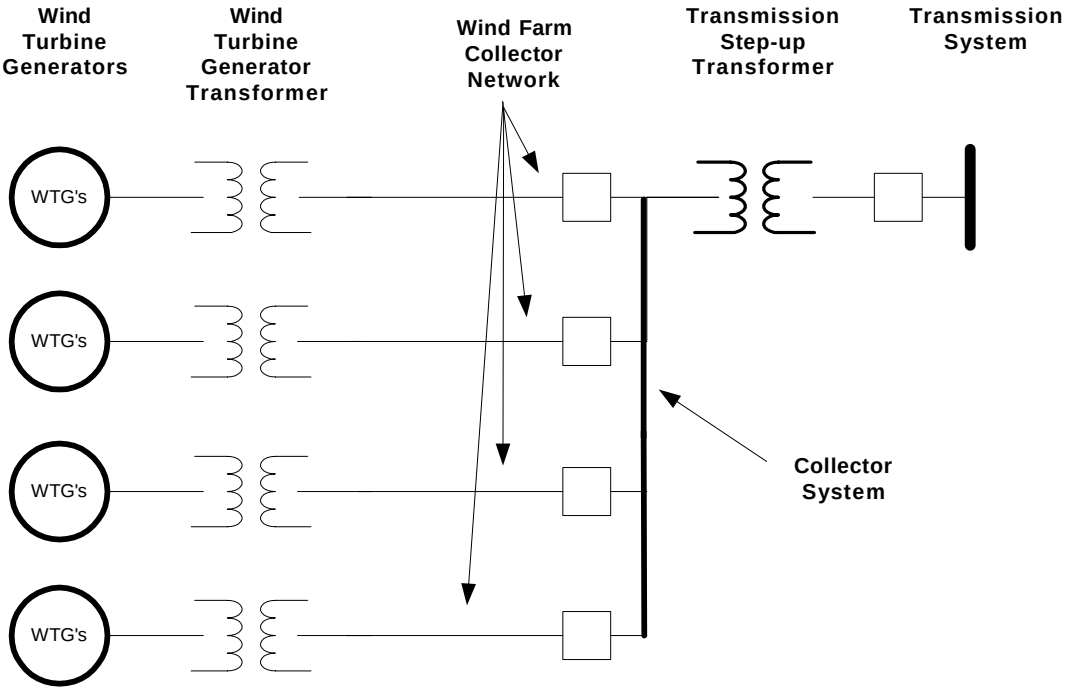

Figure 4.1 - Typical Wind Power Facility Configuration

4.2 Definitions and Terminology

In addition to definitions found in the ISO Rules, Part 1, General, the following is a list of terminology used in the wind power industry.

Alberta's Interconnected Electric System (AIES) means the "interconnected electric system" as defined by the Electric Utilities Act.

Alberta Transmission System (ATS) means all "transmission facilities" as defined by the Electric Utilities Act.

Asynchronous Generator means a type of electric generator that produces alternating current that matches an existing power source. The mechanical rotor of such a generator does not rotate in synchronism with system frequency, as is typically the case with all conventional synchronous generators.

Collector Bus means the low voltage side of the transmission systems step-up transformer which is the same as the medium voltage network or aggregate of medium voltage networks that connect to the low-voltage side of the transmission system transformer. The energy produced by **WTG**s is collected on this network and then transported to a station where the voltage is stepped up (by a transmission transformer) from the collector medium voltage level to the transmission system.

Doubly Fed Induction Generator is a type of **Asynchronous Generator** that operates with an alternating electrical supply connected to both the stator and rotor winding of the machine. The electric supply to the rotor circuit is modified via control circuitry.

Droop means the percent change in voltage that will result with a change in reactive power capability from minimum to maximum.

Induction Generator is a type of **Asynchronous Generator.** Typically, these are electrical machines with a short-circuited rotor winding. The magnetic flux within the machine is sustained by absorbing reactive power from the system.

Voltage Ride Through (VRT) means the capability to ride through a high and low voltage caused by a system disturbance.

Point of Connection means the highest voltage point at which electric energy is transferred between the customer's facility and the **ATS**. A **Point of Connection** may be a Point of Supply (POS), Point of Delivery (POD) or both.

Voltage Regulation System (VRS) means a centralized control system at a **WPF** that measures voltage compared to a set point voltage and will control reactive power devices such as **WTG**s, static var devices, capacitor banks etc.

Wind Power Facility (WPF) means any **Wind Power Facility** that connects to the **ATS**.

WPF Operator means the entity responsible to operate the **WPF** and respond to AESO System Controller voltage dispatch, energy dispatch and reliability directive instructions, or Transmission Facility Owner (**TFO**) instructions as may be required from time to time.

WPF Aggregated MW Capacity means the maximum real-power (MW) that may be transferred to the **Alberta Transmission System** (ATS) at 60 Hz as determined at the **Collector Bus(es)**.

WPF Aggregated MW Output means the real-power (MW) that is transferred to the **Alberta Transmission System** at 60 Hz as determined at the **Collector Bus(es)**.

Wind Turbine Generator (WTG) means a generator that converts mechanical energy to electrical energy, which can be either synchronous or asynchronous.

5.0 TECHNICAL REQUIREMENTS FOR WIND POWER FACILITIES

5.1 Wind Power Facility Aggregated MW Capacity

A **WPF** owner shall provide the AESO with the **WPF Aggregated MW Capacity** as determined at the **Collector Bus(es**). The **WPF Aggregated MW Capacity** shall be used to determine the **WPF** requirements associated with real and reactive power capability.

5.2 Voltage Ride Through (VRT) Requirements

a) **VRT** requirements are applicable to all transmission connected generating facilities where the **WPF Aggregated MW Capacity** is greater than 5 MW. The AESO will continue to monitor development of facilities 5 MW and less and may revise the MW threshold.

b) **WPF**s shall be capable of continuous operation between 90% to 110% of rated voltage at the **Point of Connection**.

c) A **WPF** shall not trip any loaded **WTG**s for voltage dips or post-transient voltage rises described in Figure 5.1 resulting from normally cleared transmission faults on any phase or combination of phases at or beyond the **Point of Connection**.

d) Voltages described in Figure 5.1 are based on the rated voltage level at the **Point of Connection**.

e) Exceptions:

i. **WPF**s are not required to ride through transmission system faults that cause a forced outage of a radial line to the **WPF**.

ii. **WPF**s are not expected to ride through faults that occur on the lower voltage networks of the **WPF.**[4]

iii. **WPF**s shall have **VRT** capability. Until January 1, 2006, **WPF**s that have **VRT** capability that does not fully comply with the AESO's **VRT** requirements will require AESO review and acceptance prior to **WPF** Owner or AESO application to the Alberta Energy Utility Board (AEUB) to connect the **WPF**.

iv. Effective January 1, 2006, **WPF**s are required to fully comply with the AESO **VRT** requirements.

[4] E.g. For faults on the low voltage side of the transmission step-up transformer, **Collector Bus**, collector systems, or **WTG**(s)**.**

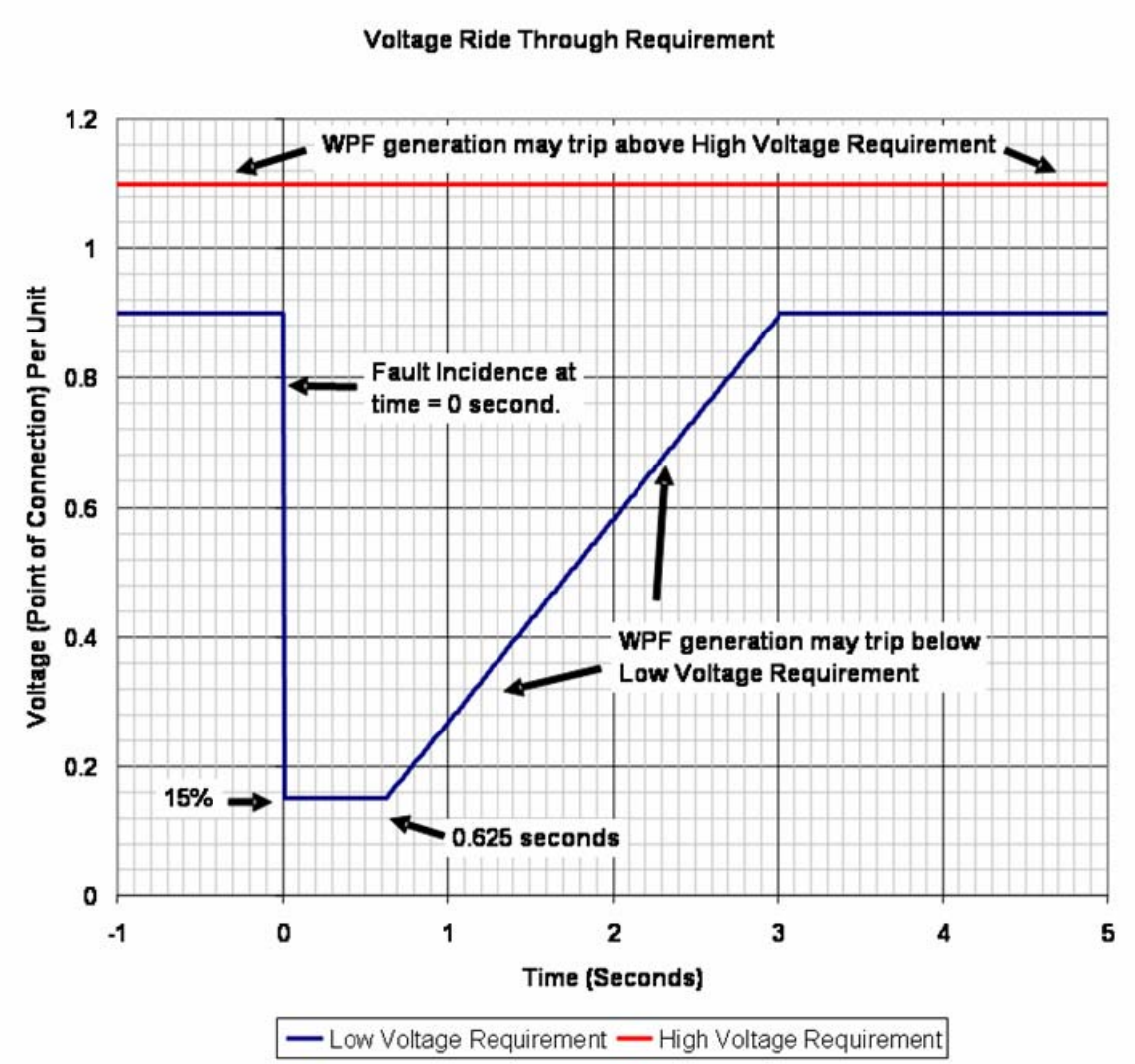

Figure 5.1 - Voltage Ride Through Requirement

5.3 Voltage Regulation / Reactive Power Requirements

Voltage regulation and reactive power capability from a **WPF** can vary with technology. Some **WPF**s may utilize reactive capability from the **WTG**s, other **WPF**s may use dynamic var devices, and some **WPF**s may be aggregated with synchronous generators.

Some **WPF**s may wish to connect to a common transmission substation and may wish to consider aggregating voltage regulation and reactive power from a single source for multiple **WPF**s. Such a proposal would be subject to review and approval of the AESO.

As voltage regulation requires some reactive power capability these two (2) requirements (regulation and reactive power) are specified in this section.

Voltage regulation is essential for reliable system operation and requires some reactive capability in order to perform. Voltage regulation and reactive power performance of a **WPF** will be assessed at the low voltage side of the transmission step-up transformer(s), which is the same as the **Collector Bus(es)** at a **WPF**. All reactive power requirements are based on the rated **Collector Bus(es)** voltage. The **WPF** must be able to regulate the system voltage both under system non-disturbance and system disturbance conditions.

The intent of voltage regulation requirements is to achieve reasonable response to disturbances as well as a steady-state regulation of +/- 0.5% of the controlled voltage.

The standard identifies a minimum requirement for dynamic vars and permits some controlled reactive devices such as capacitor banks to satisfy total reactive power requirements. Figure 5.2 illustrates the reactive power requirements for a **WPF**.

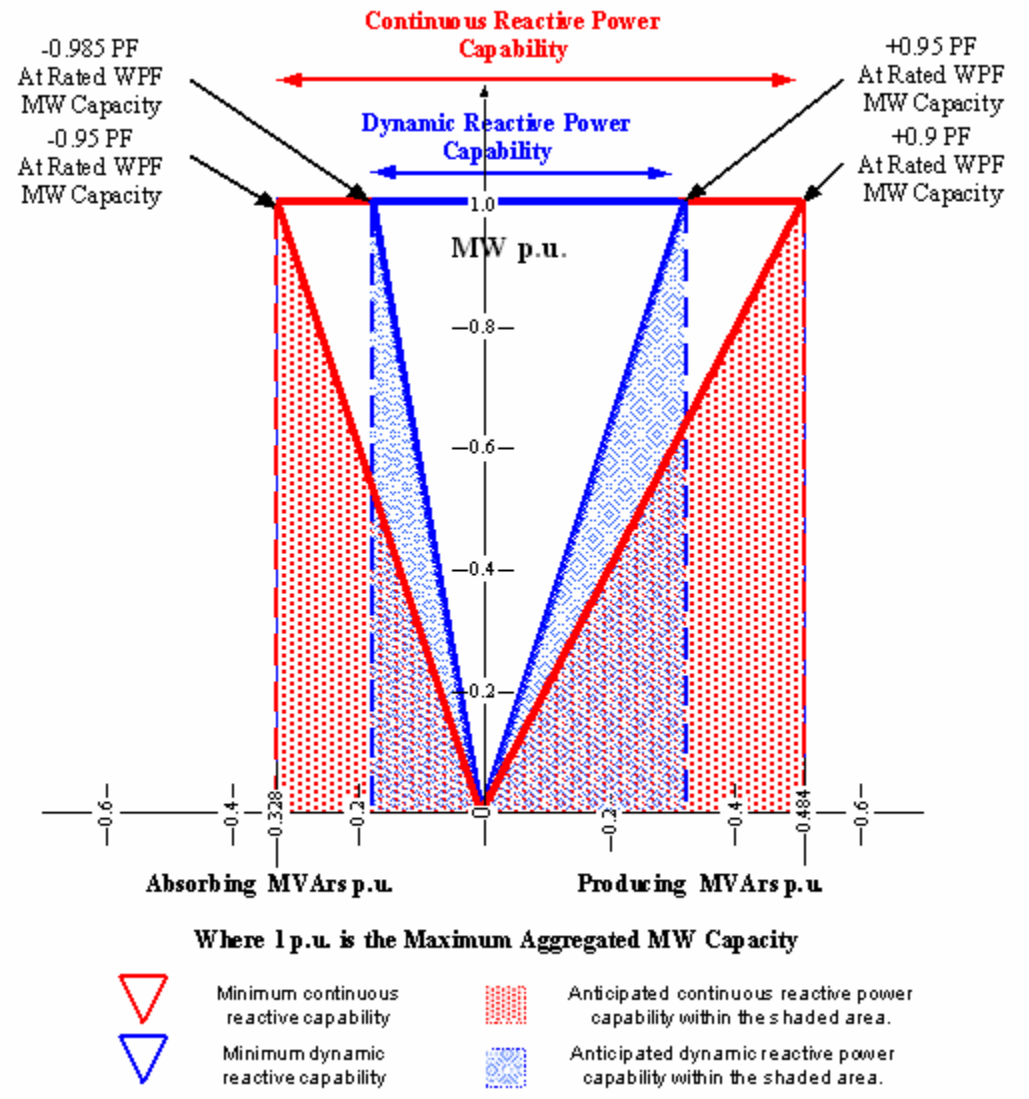

Figure 5.2 - Reactive Power Capability Curves

5.3.1 WPF Reactive Power Capability

a) A **WPF** reactive capability shall meet or exceed +0.9 Power Factor (PF) to -0.95 PF based on the **WPF Aggregated MW Output**.[5]

b) Continuous reactive power capability described in 5.3.2 and 5.3.3 can be aggregated to satisfy the +0.9 PF and the -0.95 PF requirement.

c) All reactive power devices used to vary the **WPF** reactive power within +0.9PF to -0.95 PF shall be under control of the **VRS** described in 5.3.4.

d) A **WPF** shall not intentionally reduce reactive power capability at MW output less than the **WPF Aggregated MW Capacity** from either the dynamic reactive devices described in 5.3.2 or the non-dynamic reactive devices described in 5.3.3.

5.3.2 Dynamic Reactive Power Capability

a) A **WPF**'s dynamic reactive power capability shall meet or exceed +0.95 Power Factor (PF) to -0.985 PF based on the **WPF Aggregated MW Output**.

b) Short term reactive power capability for periods up to 1 second qualifies for dynamic reactive power capability described above. Short term reactive power capability does not qualify for continuous reactive power described in 5.3.1.

c) A **WPF** shall have reactive power devices that are continuously-acting and continuously-variable under control of the **VRS** and able to respond to power system voltage fluctuations.

5.3.3 Non-Dynamic Reactive Power Capability

a) The MVAr size of the individual shunt reactive power devices under control of the **VRS** shall not be larger than the total range of the continuous capability of dynamic reactive power described in 5.3.2.

b) Once a shunt reactive power device has been switched off, it shall be capable of being switched on within 5 minutes.

5.3.4 Voltage Regulation System (VRS)

a) A **WPF** must have a continuously-variable, continuously-acting, closed loop control **VRS**.

b) The **VRS** set-point must be adjustable by the **WPF Operator** following an AESO System Controller dispatch or **TFO** instruction if authorized by the AESO System

[5] Positive (+) PF is where the **WPF** is producing (lagging) MVArs and negative (-) PF is where the **WPF** is absorbing (leading) MVArs.

Controller. The set-point shall be adjustable between 95% to 105% of rated voltage.

c) The **VRS** shall operate only in a voltage set point control mode. Other control modes or controllers such as Power Factor or VAR are not permitted.

d) The **VRS** shall measure voltage that represents the overall voltage response of the **WPF**.

e) The **VRS** shall be capable of adjustable **Droop** or adjustable gain. **VRS** that utilize **Droop** shall be adjustable from 0 to 10%.

f) The combined settings of **Droop** or gain are to achieve a steady-state voltage regulation of +/- 0.5% of the voltage controlled by the **VRS**.

g) If required by the AESO, the **VRS** shall be capable of reactive current compensation for the transmission system step-up transformer(s). The AESO will prescribe such setting to the **WPF** owner prior to commissioning of the **WPF**.

h) The **Droop**, gain or the reactive current compensation settings may be varied from time to time as requested by the AESO.

i) The **VRS** shall be calibrated such that a change in reactive power will achieve 95% of its final value no sooner than 0.1 seconds and no later than 1 second following a step change in voltage.

j) For **WPF**s that utilize shunt reactive devices, the **VRS** shall delay operation of these devices for 10 seconds.

5.3.5 External Voltage Regulation and Reactive Power

WPFs that use or rely on voltage regulation and reactive power that are external to the **WPF** shall require AESO review and approval prior to implementation.

5.3.6 WPF Operation of Voltage Regulation and Reactive Power

a) The **WPF VRS** must be in service at any time the **WPF** is electrically connected to the **ATS** regardless of MW output from the **WPF**.

b) A **WPF** with a **WPF Aggregated MW Capacity** greater than 5 MW shall provide a **WPF Operator** that can be contacted by the AESO System Controller on a 7x24 hour basis.

c) The **WPF Operator** is required to respond to voltage dispatches from the AESO System Controller or the **TFO** if authorized by the AESO System Controller.

5.4 Stability Control Requirements

WPFs that use synchronous generators connected directly to the **AIES** may require a Power System Stabilizer (PSS) as per Western Electricity Coordinating Council (**WECC**) policy.

5.5 Operating Voltage Requirements

5.5.1 Operating Voltage Range

The AESO will specify a transmission system voltage operating range (minimum through maximum) at the **Point of Connection** that the **WPF** shall be able to operate within.

5.5.2 Transmission System Step-Up Transformer(s)

WPF transmission system step-up transformer(s) voltage ratio, tap changer type (on-load/off-load), range and step size must be such that the reactive power requirements specified in Section 5.3 are fully available throughout the typical **ATS** operating voltage range described in Section 5.5.1.

The generator step-up transformer or transmission system step-up transformer connection shall be designed to provide:

a) A favorable circuit to block the transmission of harmonic currents, and

b) Isolation of transmission and generator side ground fault current contributions.

The preferred configuration is delta connection on the **WPF** side of the transmission system step-up transformer and solidly grounded wye connection on the transmission system side of the step-up transformer. Delta connection on the high side of the system step-up transformer is not permitted.

Alternative transformer configurations including wye-wye or wye-wye with a delta tertiary are also acceptable for the system step-up transformer.

5.6 Off Nominal Frequency Requirements

a) WPFs that need to protect equipment for off-nominal frequency operation shall ensure that protective relaying accommodates operation for the specified time frames. The trip setting of the relays shall not be set less than the minimum time prescribed in Table 5.1 with respect to the frequency setting.

Frequency (Hz)	Minimum Time Delay
>61.7 Hz	0 seconds
61.6 Hz to 61.7 Hz	30 seconds
60.6 Hz to <61.6 Hz	3 minutes
>59.4 Hz to <60.6 Hz	Continuous Operation
>58.4 Hz to 59.4 Hz	3 minutes
>57.8 Hz to 58.4 Hz	30 seconds
>57.3 Hz to 57.8 Hz	7.5 seconds
>57.0 Hz to 57.3 Hz	45 cycles
57.0 Hz or Less	0 seconds

Table 5.1 - Under/Over Frequency Limits

b) **WPF**s that do not meet the requirements in Table 5.1, must automatically trip load to match the anticipated generation loss and at comparable frequency levels.

c) Only solid state and/or microprocessor (numerical) frequency relays shall be used on a **WPF** to provide off-nominal frequency protection.

d) Frequency relays shall use the definite time characteristic and shall not be disabled for transmission system voltages that are 80% of nominal or higher.

e) A **WPF** shall seek AESO approval prior to permitting frequency relays to be automatically disabled if transmission system voltages fall below 80% of nominal.

5.7 Supplemental Over Frequency Control Requirements

This section is subject to review pending the outcome of further studies associated with wind power variability, which is expected to be completed by July 2005. If specific control requirements for **WPF**s are determined as a result of the studies, such requirements may be applied retroactively to **WPF**s approved for interconnection under this standard dated November 15, 2004.

Should an over frequency condition occur, the AESO System Controller may issue a directive to the **WPF Operator** or **TFO** to curtail the **WPF**.

5.8 Wind Power Facility Disconnection

a) A **WPF** may be required by the AESO System Controller to electrically disconnect from the **ATS** for reasons of reliability.

b) The **WPF** owner shall provide equipment and controls to electrically disconnect the **WPF** at the **Point of Connection,** or alternatively the **Collector Bus** feeder breakers, from the **ATS**.

c) The interconnecting **TFO** shall be provided with the functionality and remote control to "trip open only" the interconnecting breaker(s), either at the **Point of Connection** or the **Collector Bus** feeder breakers, of the **WPF**.

d) Once a **WPF** interconnecting breaker or breakers have been tripped by a **TFO**, the **WPF** shall not automatically re-connect the **WPF** to the **ATS**. **WPF** connection is done upon authorization by the AESO System Controller.

5.9 Operational Requirements for WPFs

This section is subject to review pending the outcome of further studies associated with wind power variability, which is expected to be completed by July 2005. If specific control requirements for **WPF**s are determined as a result of the studies, such requirements may be applied retroactively to **WPF**s approved for interconnection under this standard dated November 15, 2004.

Most of the time the **AIES** operates normally and with no constraints on **WPF**s. On occasions, transmission outage(s) or abnormal operating conditions can occur that will require electric disconnection or partial curtailment of a **WPF**. A **WPF** that can be partially curtailed during a constraint condition may remain electrically connected to the **ATS** as determined by the AESO System Controller.

A **WPF Operator** may be permitted to re-connect the **WPF** to the **ATS** during an operating constraint upon permission to do so from the AESO System Controller and subject to requirements identified in the following sections.

5.9.1 WPF Connection Requirements During Constrained Operating Conditions

a) **WPF**s that are not equipped to manage the wind facility MW loading will remain disconnected from the **ATS** during the period of the system operating constraint as declared by the AESO System Controller.

b) **WPF**s that have wind management controls described in Section 5.9.2 and 5.9.3 may be permitted to operate on the **ATS** system during operating constraints subject to AESO System Controller instruction.

5.9.2 Response Time for Curtailment of a WPF During A Constrained Operating Condition

WPF having a 7x24 **WPF Operator** that can reduce MW output and MW capability to AESO System Controller reliability directives within 10 minutes may not be required to electrically disconnect during an operating constraint.

5.9.3 WPF Power Limiting During Constrained System Operation

The following are MW limiting requirements for a **WPF** to remain connected to the **ATS** during constrained system operating conditions subject to AESO System Controller instruction:

a) **WPF** shall have the capability of limiting the power output from the **WPF** to the

curtailment level directed by the AESO System Controller. The **WPF** MW output shall not exceed the MW directive limit.

b) The maximum power ramp rate of the **WPF** for power output shall not exceed 10% of **WPF Aggregated MW Capacity** in MW / Minute.

5.10 Protection Requirements

All **WPF**s are required to comply with the AESO **AIES** Protection Standard. The AESO **AIES** Protection Standard requires the **WPF** to protect the **ATS** against faults originating in the **WPF**. This includes but is not limited to the wind turbine, generator, WTG step-up transformer, collector facilities, transmission step-up transformer and any transmission equipment required to interconnect the **WPF** to the **ATS**.

Basic requirements are:

a) Shall protect the **AIES** from all electrical faults originating on the **WPF**.

b) Shall protect the **AIES** from abnormal operating conditions originating on the **WPF**.

c) Shall protect the **WPF** from all faults originating on the **AIES**.

d) Shall protect the **WPF** from abnormal operating conditions originating on the **AIES**.

e) With exception of breaker fail on the high voltage breaker of the **WPF** transmission step-up transformer, cascade tripping for any fault is not permitted.

f) The **WPF** shall coordinate the protection requirements with the interconnecting **TFO**.

5.11 Power Quality

The **WPF** shall comply with industry standards and guidelines for power quality including but not limited to the following.

5.11.1 Voltage Flicker

Any **WPF** flicker shall be lower than either the maximum permissible voltage flicker limits as defined in figure 5.3 or as defined in IEC 61000-3-7.

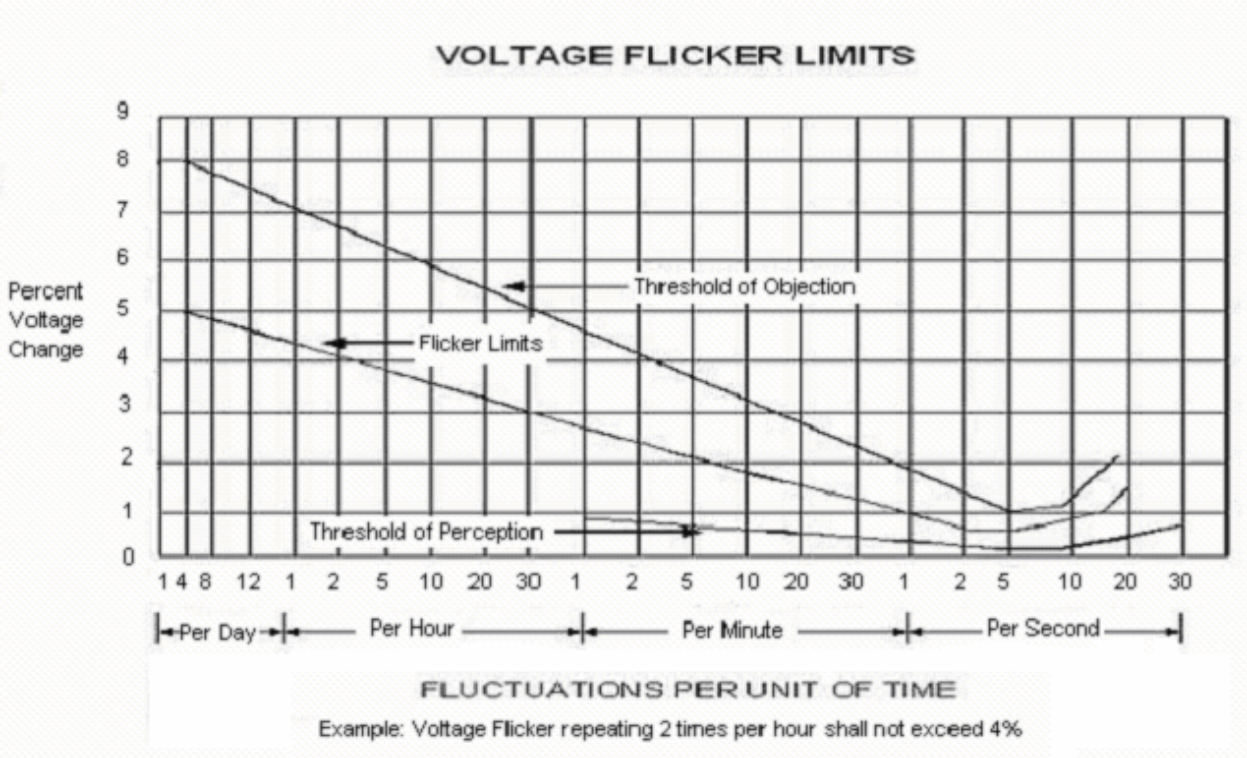

Figure 5.3 - Flicker Curve

The **WPF** owner shall be required to carry out corrective action if the power system or other facilities are affected by voltage depressions caused by the **WPF** in excess of the maximum permissible voltage flicker limits as defined in Figure 5.3 or defined in IEC 61000-3-7IEC.

5.11.2 Harmonics

Harmonic limits are as specified in IEEE Standard 519-1992 "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems".

a) Upon request from the **WPF** owner, the AESO will provide the **WPF** owner with information describing the specific harmonic-impedance envelope at the proposed **Point of Connection**.

b) The **WPF** owner is required to mitigate harmonic currents resulting from non-compliance with IEEE Standard 519-1992 "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems".

5.11.3 Voltage Unbalance

A **WPF** shall not cause voltage unbalance to exceed 3%. Where voltage unbalance expressed in percent is determined as:

The voltage unbalance on the electrical system under normal operating conditions may reach 3%. The voltage unbalance is calculated using the following formula:

Unbalance (%) = $\frac{100 \times (\text{deviation from average})}{(\text{average})}$

The calculation is derived from NEMA MG1-14.33.

5.11.4 Resonance

The **WPF** owner must design the facility to avoid introducing undue resonance into the **AIES**. Of particular concern are self-excitation of induction machines, transformer ferroresonance, and the resonant effects of capacitor additions and the capacitance of the **WPF** collector cables.

5.12 Grounding

The **ATS** is operated as an effectively (solidly) grounded electric system. This shall be taken into account in the design of the **WPF**.

5.13 Lightning (Surge) Protection

a) The lightning (surge) protection for substation facilities shall be designed taking into account the average isokeraunic level (thunderstorm days per year) for the particular site location. IEEE P998 provides further background on direct stroke lightning protection.

b) Lightning protection shall be coordinated with the interconnecting **TFO** to ensure coordination of BIL levels.

5.14 Clearances and Access

Energized parts shall be maintained at safe vertical and horizontal clearances as dictated by the following standards, regulations and code requirements:

a) The **TFO**'s portion of the interconnection facilities shall comply with The Alberta Electrical and Communication Utility Code (AECUC).

b) The **WPF** owner portion of the interconnection facilities shall comply with the Canadian Electrical Code Part I.

5.15 Interrupting and Isolation Devices

5.15.1 Fault Interrupting Devices

The design of the interconnection facility shall consider the fault contributions from both the transmission system and the proposed facility. The interconnection facility must have fault interrupting and momentary withstand ratings that are adequate to meet the maximum expected fault levels, with appropriate margin for future growth.

The choice between circuit breakers or circuit interrupters will depend on the required fault interrupting capability, clearing and reclosing requirements.

Due to the reduced reliability, increased outage times, single phasing and the possibility of ferroresonance, the application of high voltage fuses on the transmission system is not acceptable at voltages 69 kV and higher.

5.15.2 Isolating Devices

The AESO, in consultation with **TFO**s, will define electrical point or points of isolation. The **WPF** owner shall provide manually operable isolation switches at all points of isolation. The switches shall permit visual verification of electrical isolation. The isolation switch shall have the capability of being locked open with multiple locks. The isolating device shall be under the control of a single control authority, as agreed between the **WPF** owner and the **TFO**.

5.16 Special Interconnection Protections

In some cases special **WPF** specific protection and controls may be required. Similarly special interconnection and system protection such as Remedial Action Schemes or Special Protection Schemes may be required to provide additional protection on some facilities. These requirements shall be developed, in consultation with the AESO, at the time of **WPF** design.

5.17 Revenue Metering

a) The **WPF** owner shall install a revenue electric meter installation to measure active energy and reactive energy flowing from the **WPF** to the **ATS**.

b) Metering data shall be submitted to the AESO in the format specified in the AESO Measurement System Standard, which can be found at www.aeso.ca. Metering equipment shall conform to the AESO Measurement System Standard.

c) The AESO will determine metering requirements for any load to be served at the **WPF**, per the EUA definitions.

d) Metering equipment includes (but is not limited to) the instrument transformers (voltage transformers, current transformers), secondary wiring, test switches, meters and communication interface. Unless otherwise agreed to, the instrument transformers shall be dedicated for metering purposes only.

e) The **WPF** shall provide MW Metering Import MW at the **Point of Connection**.

f) The **WPF** shall provide MW Metering Export MW at the **Point of Connection**.

5.18 Supervisory Control and Data Acquisition (SCADA)

To ensure reliable and secure operation of the **AIES**, the AESO requires **WPF**s to comply with AESO SCADA requirements as outlined in OPP-003.1, "Electric Facility Data and Data for the Alberta Control Area" as well as the additional **WPF** SCADA requirements described below.

a) **Voltage Regulation System** set-point.

b) Wind Speed (from a single point of measurement at the **WPF**).

c) Wind Direction (from a single point of measurement at the **WPF**).

6.0 MONITORING REQUIREMENTS

a) A **WPF** may be required to make provisions for the installation of a system disturbance monitor that complies with the AESO Requirements for Phasor Measurement Units (PMU). The AESO will make such determination, and if required, request the TFO to coordinate with the **WPF** Owner the installation of the PMU.

b) The monitoring system, when required by the AESO, will measure 3 phase voltages and currents on the transmission system and **WPF** collector system.

i. All collector bus voltages, phase to ground measurement.

ii. All collector currents, or currents on the low side of the transmission step-up transformer(s) if current transformers unavailable on individual feeders.

iii. Transmission system voltage(s), phase to ground measurement.

iv. Transmission system current(s).

v. Transmission system frequency, measured on the transmission system side of the transmission step-up transformer.

7.0 MODELING AND VALIDATION REQUIREMENTS

7.1 Provision of Modeling Information

a) The **WPF** owner shall provide all pertinent data to the AESO to allow the modeling of the **WTG**s, transformers, collector system(s) and control systems at the **WPF**.

b) Where an appropriate model is not available within PSS/E, the **WPF** Owner shall supply a working user written PSS/E model.

c) **WPF** Owners that provide user written model(s) shall provide compiled code of the model and are responsible to maintain the user written model compatible with current and new releases of PSS/E until such time a standard model is provided.

d) The AESO must be permitted by the **WPF** Owner to make available **WPF** models to WECC members for interconnected system studies.

e) The **WPF** owner shall provide the AESO with power system studies which demonstrate the **WPF**'s capability to meet the **VRT** requirements specified in section 5.2.

f) The **WPF** owner shall provide the AESO with power system studies which demonstrate the **WPF**'s capability to meet the reactive power requirements specified in section 5.3.

7.2 Provision of Validated Model

a) The **WPF** owner shall provide a **WTG** model with validated data demonstrated by a physical performance test of at least one **WTG** for every type / model of **WTG** used at the facility.

b) The **WPF** owner shall provide a voltage regulation model with validated data demonstrated by a physical performance test of at least one voltage regulation device used at the **WPF**.

c) The **WPF** owner shall re-validate the model data from time to time as requested by the AESO or as required by **WECC** / **NERC** requirements.

8.0 TESTING REQUIREMENTS

WPF owners are required to test to ensure performance and compliance to the **WPFTR**.

a) Following connection of a **WPF** to the **ATS**, the **WPF** owner shall conduct the following tests described below and provide the test results to the AESO within 30-days following appropriate wind speed conditions to conduct the appropriate tests.

b) A **WPF** owner will be required to re-conduct the following tests described below upon written request from the AESO.

c) A **WPF** owner will be required to retest the **WPF** as may be required by **WECC** / **NERC** requirements.

d) The following tests shall be completed by the **WPF** owner immediately following commissioning of the **WPF**:

i. Voltage Regulation / Reactive Power Response Test: This test will demonstrate the ability of the **WPF** to control the collector and transmission system voltage in a stable manner. The test will consist of injecting a test signal to the voltage reference point of the **Voltage Regulation System**.

ii. Reactive Power Capability: This test will demonstrate the ability of the **WPF** to provide continuous reactive power as per requirements of this standard.

iii. Voltage Set-point Capability: This test will demonstrate the ability of the **WPF** to

adjust the voltage set-point of the **VRS** to the requirements of the standard.

iv. Harmonic test: This test will confirm that harmonic levels are within the limits of IEEE 519.

v. Flicker Tests: This test will confirm that flicker levels are within the limits specified by the AESO.