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| AMERICAN TRANSMISSION COMPANY® | **Guide** | **Department:** | **Interconnection Services** |
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| **Title:** **WIND ISLANDING** | | **Issue Date:** | **11-24-2014** |
| | | **Previous Date:** | **N/A** |

## Contents



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# 1 PURPOSE

There is a next contingency operational concern when a wind farm is interconnected with two transmission elements and one is out due to planned maintenance or a forced outage. Under this scenario, the next forced outage may result in the development of an island with wind power as its sole energy source. Since wind turbines do not control frequency, this situation could lead to an unstable island and subject connected load to significant voltage and frequency variations. Additional information is found in Appendix A and B. This business practice describes ATC's practice to prevent development of such an island.

# 2 SCOPE AND APPLICABILITY

This guideline applies to all wind farms without the ability to control frequency interconnected to ATC's facilities.

ATC will continue to work with its customers from a joint-planning perspective, in order to accommodate their planned generation. ATC will plan, construct, operate, and maintain its facilities in accordance to Good Utility Practice, and all FERC, MISO, and NERC Standards.

# 3 ROLES AND RESPONSIBILITIES

Generator Interconnection studies are completed under the MISO tariff; however, ATC participates in these studies in the role of the affected Transmission Owner and in many cases, works as a consultant to MISO to perform the studies. ATC Planning and Interconnection Services will be members of the study team. In the situation when Wind Islanding concerns are present, ATC Operations will be a party to the discussion of possible operational restrictions.

# 4 Wind Islanding

ATC will review the unique characteristics of an interconnector's request, as well as application of ATC's Generating Facility Interconnection Guide and Interconnection Agreement. Such characteristics may include the following:

- System configuration at the point of interconnection
- Future transmission plans
- Transmission system operational concerns

## 4.1 Actions to Prevent Wind Islanding

Upon identification of a potential wind islanding scenario, ATC will develop an ATC Operator Instruction specifying the actions the ATC System Control Operator will take to prevent the development of an electrical island with wind power as its sole energy source. These Operating Instructions may be shared will MISO on an "as needed" basis. Unless operating steps can be developed to avoid the creation of a wind island for the next contingency (see Appendix B), ATC will require the wind farm operator to curtail wind farm real power output to zero.

## 4.2 Optional Additional Facilities

Upon review of the system characteristics, application of the Generating Facilities Interconnection Guide, the outcome of MISO planning process and the Generator Interconnection Agreement, ATC will present the customer with its proposed interconnection design and operational restrictions. Based on the customer's review of the operational restrictions, the customer may request a study and an estimate for an alternate upgraded configuration to remove the operational restrictions (likely needing an additional transmission outlet interconnected to the substation). ATC will provide an estimate of the cost of additional studies needed for the alternate upgraded configuration design.

If the customer elects to proceed with the alternate upgraded design, the following requirements must be met prior to final design, procurement and construction:

1. Execution of an Elective Interconnection Facilities Upgrade Agreement
2. Public Service Commission of Wisconsin approval (if needed)
3. Federal Energy Regulatory Commission FPA Section 205 authorization (if needed)
4. Deposit for estimated cost of upgraded configuration

Upon completion of the Interconnection Facilities, ATC will reconcile the construction charges and review with the interconnecting customer the estimated cost difference versus the actual cost difference. Based on the outcome of the reconciliation, ATC will refund or invoice the interconnected customer accordingly. Once this reconciliation is complete, ATC will record the net value of these assets.

*Note: The cost to be paid by the customer will include a gross-up for income taxes incurred by ATC as a result of the additional facilities. The tax gross-up will be calculated based on the weighted average of ATC's owners' tax rates and ATC's customer discount rate.

ATC will be responsible for any of the on-going maintenance or operational expenses of the upgraded assets. This will include any replacement costs that may be incurred once the useful life has expired, or in the event of equipment failure.

### 4.2.1 Supporting Information and Documents

It is ATC's intent to meet its duty as a public utility by planning, constructing, operating and maintaining its transmission system in such a manner that all customers receive reliable, cost-effective, and nondiscriminatory service. The following documents provide support and direction as to ATC's obligations, practices, procedures and design standards:

1. Generation Interconnection Agreement
2. Forming Party Agreement Regarding System Operating Procedures
3. Generating Facility Interconnection Guide

# 5 ADDITIONAL INFORMATION

Additional technical information can be found in Appendix A and B.

# 6 DOCUMENT REVIEW

This guideline will be reviewed and revised as necessary no less than every three years.

# 7 RECORDS RETENTION

System planning studies required are retained through ATC Planning Records Retention Guidelines. The Interconnection Agreement and future revisions will remain active throughout the life of the generator.

# 8 REVISION INFORMATION

| Version | Author | Date | Section | Description |
|---|---|---|---|---|
| 01 | Heather Andrew | 11-24-2014 | | New |

# Appendix A
# Technical Notes

The development of wind farms in the ATC footprint creates the potential for load/generation islanding scenarios where wind farms are the only generation on-line in the island. Individual wind turbines implement both over/underfrequency tripping and over/undervoltage tripping and are unable to control system frequency. However, the withstand capability of the wind turbines can be rather robust (i.e. wide frequency excursion for many hundreds of seconds). The following pages contain two tables, Table 1 and Table 2, providing typical wind turbine capabilities according to voltage and frequency.

Multiple wind farms within the ATC footprint are located near system load. In these cases, a single forced outage or a maintenance/construction outage can result in a configuration where the next contingency may island a wind farm with some system load. Examples of these configurations are: Forward Energy Center, Cedar Ridge, and Butler Ridge. Figure 1 shows a simplified one-line representation of a typical configuration where this potential exists.

Although the probability of an island forming with the right balance of generation and load is low, some wind turbine manufacturers and industry papers indicate that the wind turbine machines can be self-excited and a stable island could exist until a sufficient load or generation mismatch occurs. Due to the lack of frequency control, small changes in the load/generation mismatch of a stable island will produce frequency fluctuations within the limits of the over/underfrequency tripping characteristics of the wind turbines.

ATC has worked with its interconnected Load Distribution Companies to identify that the potential frequency deviations and voltage deviations are unacceptable for end-use load.

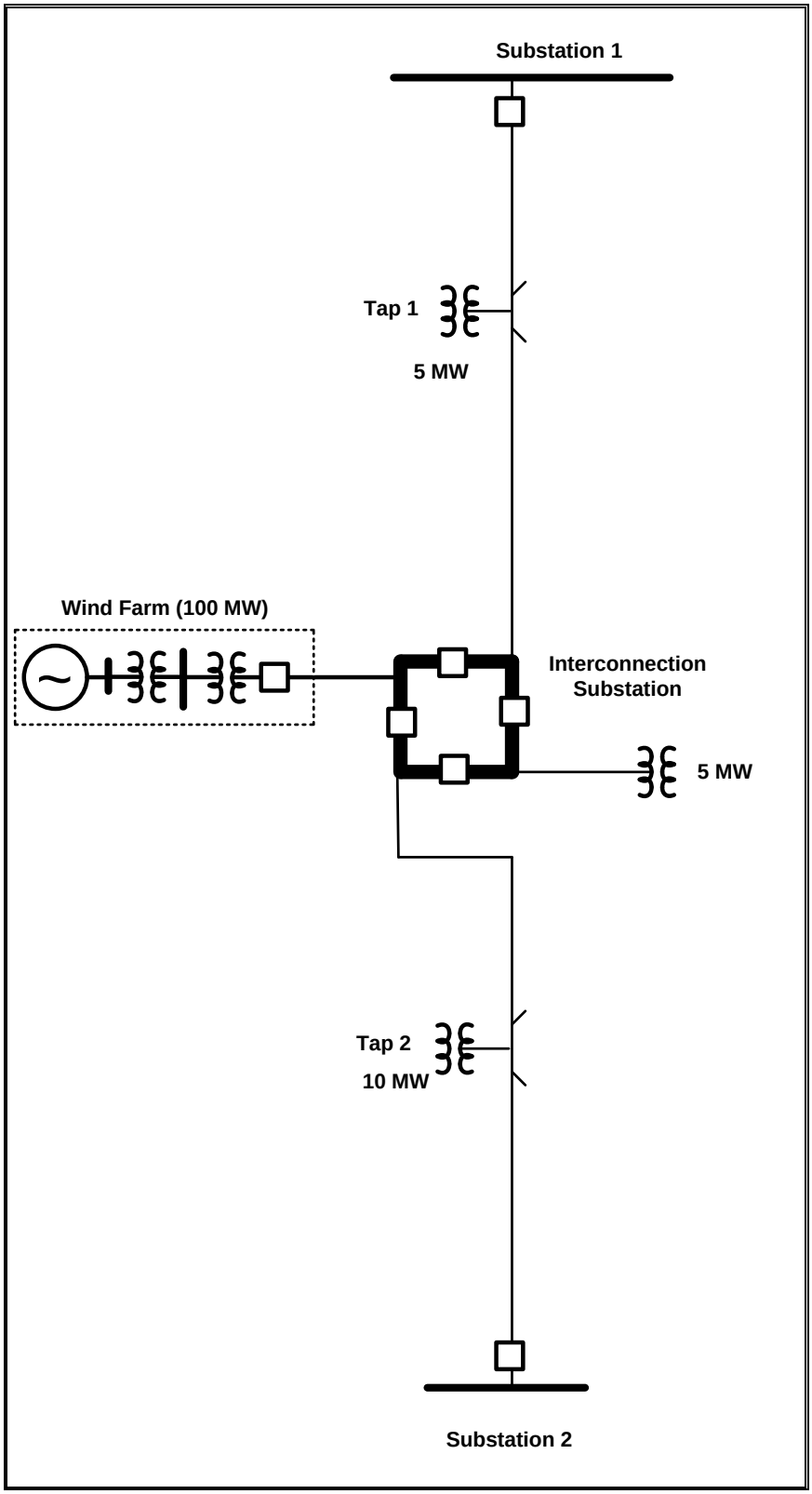


**Figure 1 Simplified One-line of Potential Wind Islanding Configuration**

**Table 1 Typical Wind Turbine Tripping Characteristics-Frequency***

| Frequency | Time in Seconds | | | | | |
|---|---|---|---|---|---|---|
| | Variable Rotor Resistance | Variable Rotor Resistance | Various types of Doubly Fed Induction Generators | | | |
| Over frequency trip time delay if frequency rises above value | | | | | | |
| 63.2 | | | | 0.2 | | |
| 63 | | 0.2 | 5 | | | 0.02 |
| 62.5 | | | | | 0.02 | |
| 62.2 | 0.1 | | | | | |
| 62 | 1 | | | | | |
| 61.5 | 6 | | | | 30 | 30 |
| 61.25 | 50 | | | | | |
| 61 | 300 | | | | | |
| Under frequency time delay if frequency falls below value | Continuous | Continuous | Continuous | Continuous | Continuous | Continuous |
| 57.5 | | | | | 10 | 10 |
| 57 | 0.1 | 0.2 | 5 | | | |
| 56.5 | | | | | 0.02 | 0.02 |
| 56.4 | | | | 0.2 | | |

*Characteristics are from typical generators installed on the ATC system of various manufacturers

**Table 2 Typical Wind Turbine Tripping Characteristics-Voltage***

| Voltage | Time in Seconds | | | | | |
|---|---|---|---|---|---|---|
| | Variable Rotor Resistance | Variable Rotor Resistance | Various types of Doubly Fed Induction Generators | | | |
| Over voltage trip time delay if voltage rises above value | | | | | | |
| 1.3 | | | | | 0.02 | 0.02 |
| 1.2 | | 0.08 | | 0.12 | | |
| 1.15 | | 60 | 1 | | 0.1 | 0.1 |
| 1.135 | | Continuous | Continuous | 0.2 | | |
| 1.125 | 0.1 | | | | | |
| 1.1 | 60 | | | 60 | 1 | 1 |
| Under voltage time delay if voltage falls below value | Continuous | | | Continuous | Continuous | Continuous |
| 0.9 | 60 | 60 | 15 | 60 | 600 | 600 |
| 0.85 | | | 1 | 0.4 | 10 | 10 |
| 0.8 | 3 | 2.8 | 0.5 | | | |
| 0.75 | | | | 0.0001 | 2.375 | 1.9 |
| 0.7 | 2.643 | | | | 2.25 | |
| 0.65 | | | | | 2.125 | |
| 0.6 | 2.2877 | 1.6 | | | 1.875 | |
| 0.55 | | | | | 1.75 | |
| 0.5 | 1.9315 | | | | 1.625 | 1.2 |
| 0.45 | | | | | 1.5 | |
| 0.4 | 1.5754 | 0.7 | | | 1.25 | |
| 0.35 | | | | | 1.125 | |
| 0.3 | 1.2192 | | | | 1 | 0.7 |
| 0.25 | | | | | 0.875 | |
| 0.2 | 0.8631 | | | | 0.625 | |
| 0.15 | 0 | 0.08 | 0.25 | | 0.5 | 0.2 |
| 0.1 | | | | | 0.375 | |
| 0.05 | | | | | 0.25 | |
| 0 | | | | | 0.2 | |

*Characteristics are from typical generators installed on the ATC system of various manufacturers

# Appendix B

Summary Notes

**Detection of and Tripping for an Electrical Island Condition as Associated with Interconnection of Wind Generation**

Integrating certain generation with the networked transmission system poses certain risks, especially to interconnected load under islanding conditions. Failure to trip certain islanded generators may lead to safety, degraded power quality, and reclosing issues.

**The Issue:**

Given the following conditions:

- A generating facility has no governor controls.
- A generating facility could potentially be isolated with transmission system load (an "island") for the outage of two transmission elements.

Load interconnected within the island may be exposed to the following risks:

1. *Off-nominal frequency operation for an extended and indefinite duration*. For example, the frequency deviations may extend down to 57 Hz and up to 62.5 Hz without wind generation tripping.

2. *Over- and under-voltage operation for duration likely not to exceed one minute.* For example, the voltage may decline to 80% of nominal for one minute before generation tripping occurs. If the generating facility is controlling system voltage, whether through wind turbine controls or additional dynamic reactive power compensation, there is a lower risk of over- and under-voltage operation.

**Mitigation:**

ATC continues to research and consider appropriate solutions for mitigating this issue. Such measures include both operational and technical solutions:

Operational Solutions:

ATC has established formal operating instructions to operationally mitigate this issue for generating facilities presently interconnected to ATC's system.

The following operational actions are used to mitigate wind islanding at Forward Energy Center, Butler Ridge Wind Farm, and Cedar Ridge Wind Farm (i.e. substation configurations where the breakers cannot be pre-positioned to avoid islanding for the next most probable outage).

- In advance of a planned outage, ATC will instruct the affected generator owner(s) to curtail all generation output during the outage of any of the transmission element(s) where the next outage could result in an electrical island condition. ATC will try to coordinate as best feasible with the generator owner to minimize the impact of this outage.
- In the event of a forced outage to the same equipment, ATC will instruct the affected generator owner to immediately curtail all generation output.

The following operational actions are used to mitigate wind islanding at Glacier Hills Wind Farm (i.e. substation configurations where pre-positioning of breakers avoids an island for the next most probable contingency).

- During the switching for any planned outage, ATC will reconfigure the transmission ring bus to which the generator is connected such that the wind generation will be curtailed immediately for loss of the next transmission line that could result in an

electrical island condition. This solution does not protect against the unlikely scenario of a bus fault occurring during the planned outage while generation and load are sufficiently matched.

- In the event of a forced outage to the same equipment, the ATC Operator will reconfigure the system as described above, according to the applicable Operator Instruction.

The following operational actions are used to mitigate wind islanding at all wind generators where an island could form.

- For double contingencies (N-2), or two single contingencies occurring prior to curtailment of generation output (N-1-1) that result in a formed electrical island, the ATC System Control Operator will immediately open transmission system circuit breakers to separate generation output from connected load in the electrical island, resulting in an outage to each.

Technical Solutions:

ATC is seeking to develop technical solutions that may be employed for interconnected generator owners affected by this issue. The following solutions have been considered to date.

- ATC's present Generator Interconnection Guide[1] provides a transmission ring bus for new generator interconnections. The ring bus configuration provides the advantage of being able to perform circuit breaker maintenance at the interconnection substation without curtailing wind generation for the next most probable forced outage (i.e. a transmission line fault). However, this solution only mitigates the electrical island issue for certain outages at the generator interconnection substation.

- ATC has evaluated the potential application of transfer trip schemes, but to date does not consider them as a preferable solution due to the following risks:

  - Transfer trip schemes are classified as "special protection systems" (SPS) under NERC reliability standards. These standards require additional regulatory attention and administration by the owner of the SPS including 1) approval of the SPS by the relevant NERC-recognized regional entity (i.e. MRO or RFC) prior to installation, 2) quarterly reporting, 3) review every five years and 4) functional modification approval by the regional entity prior to any necessary changes due to permanent transmission system configuration changes.

  - The transfer trip schemes necessary to mitigate the electrical island issue would have a level of complexity that increases the risk of mis-operation or operation when not intended. This increased risk is due to the relatively high number of transmission elements that would need to be monitored (e.g. circuit breakers and disconnects) at multiple locations remote from the generating facility. New redundant equipment such as contact logic, relaying and communication equipment would need to be installed and maintained at each remote location (some presently without control buildings).

- ATC has evaluated the potential application of a generator owner's under- and over-frequency protection systems to mitigate the electrical island issue. This type of protection is already a part of many generating facilities in the Eastern Interconnection and

[1] http://www.atcllc.com/wp-content/uploads/2014/04/04-11-14-Version-5-0-GIC-Guide-final-signed.pdf

ATC believes it may not be classified as an SPS. However, the settings of the under-frequency tripping would need to be consistent with the under-frequency and time delay settings set by the applicable regional entity to ensure coordination with the underfrequency load shedding programs of the local distribution companies. ATC is not recommending this approach at this time for two reasons:

- It is unclear if under-frequency and time delay settings set by the applicable regional entity are acceptable to the load distribution companies for the potential electrical island conditions. These under-frequency settings were developed for the very rare instance of islanding a significant portion of the Wisconsin, Michigan, Illinois or regional systems. The use of these settings for this new electrical island issue may not be acceptable.
- The regional entity requirements for frequency and time delay do not specify over-frequency settings. Therefore, it is unknown what the appropriate settings for over-frequency would be.

- ATC is investigating the potential of a generator owner's application of anti-islanding protection. However, such anti-islanding protection could potentially be classified as a generator protection system, although this would need to be reviewed with the regional entities.

ATC continues to actively engage affected generator owners, load interconnection customers, balancing authorities, the Midwest ISO and its members, the North American Transmission Forum, regional entities, and NERC in order to develop effective alternatives to the operational solutions noted above.