Georgia Mountain Community Wind
WINTER OPERATING PROTOCOL (Revised)
(approved by PUC Order dated 1/13/12; supplement approved by Order dated 8/24/17)

A. Purpose:

The Vermont Public Service Board's Order of 5/31/11 in Docket No. 7508 includes as a condition of construction:

> GMCW shall prepare a winter operating protocol, subject to review by the parties and approval by the Board prior to commencement of construction, which shall require that the proposed turbines be placed in pause mode under any of the following circumstances:
>
> (a) installed ice monitoring device(s) or heated wind sensors (installation subject to reliability testing) detect if unsafe conditions are present due to icing conditions;
> (b) ice accretion is recognized by the site operator;
> (c) air temperature, relative humidity and other meteorological conditions at the site are conducive to ice formation;
> (d) air temperature is several degrees above 0 degrees Celsius after icing conditions; and
> (e) any other weather conditions that may result in the unsafe operation of the turbines.

The Winter Operating Protocol presented below is presented to meet the Board's requirements.

B. Control Methodologies:

1. The Winter Operating Protocol will curtail the operation of wind turbines in the event of icing and when extreme weather conditions present unsafe conditions for the general public.

2. The wind turbines will be monitored via the facility's Supervisory Control And Data Acquisition (SCADA) system 24 hours per day, seven days a week throughout the year. The turbines shall be subject to shutdown under the following conditions ("Icing Conditions"), as detected in accordance with Appendix A of this Protocol:

    a. The installed ice monitoring device(s) and heated wind sensors (installation and continued operations subject to reliability testing) detect that unsafe conditions are present due to icing conditions;
    b. Ice accretion is recognized by the site operator;
    c. Air temperature, relative humidity and other meteorological conditions at the site are conducive to ice formation;

d. Air temperature is several degrees above zero degrees Celsius after icing conditions; or
e. Other weather conditions at the project site create an unsafe operating environment.

3. A remote start-up procedure will be implemented after the turbine operation has been curtailed due to Icing Conditions. The turbines will not automatically be restarted until the operator performs a pre-startup inspection of the ice monitoring device(s) and other climatic conditions and/or visual inspection to ensure safe operating condition are present.

4. As an additional safeguard, GMCW will gate access roads and post signs warning of the potential for dangerous icing conditions in the vicinity of the turbines.

C. Safety of Personnel at the Project Site:

1. All personnel at the project site shall adhere to the site specific safety requirements required by the turbine manufacturer or operator before approaching the turbines during Icing Conditions.

D. Evaluation and Update:

1. On-site and remote monitoring will take place on a weekly basis during months when Icing Conditions may occur to evaluate effectiveness of the Winter Operating Protocol compared with recorded weather conditions at the project site.

2. This Winter Operating Protocol shall be subject to modification, upon Board approval, as necessary to ensure that unsafe conditions are minimized at the project site and that shut down of the turbines shall occur under the appropriate climatic conditions.

E. Reporting

1. GMCW shall file a report by July 1 for each of the five years following approval of this Revised WOP identifying any icing events and explaining any adjustments made to the thresholds used in the testing provided in Appendix A during the prior winter.

Appendix A: Supplement to Winter Operating Protocol
(approved by PUC Order dated 8/24/17)

Georgia Mountain Community Wind, LLC ("GMCW") has evaluated the performance of the Project's internal procedures used to implement the 2012 Board-approved Winter Operating Protocol ("WOP") at the GMCW Project over several winters of operational experience. Based upon that evaluation, GMCW proposes to implement a revised WOP to improve its performance and further ensure that unsafe conditions are minimized to the greatest extent possible. This updated WOP leverages the assessment of approximately four years of GMCW operational data which were not previously available at the time the WOP was first implemented. It is designed to enhance the sensitivity of GMCW's ice detection from on-site meteorological and turbine data.

I. Revised Protocol

Under the original WOP, the operating conditions of each wind turbine were analyzed by comparing its actual operations with its expected performance. These individual results caused the turbines to trigger "Pause Mode" *after* ice formation was detected. GMCW's revised protocol will detect the presence of trigger conditions earlier.

The updated protocol will incorporate site-specific meteorological ("MET") data from the on-site meteorological station ("MET Station") and wind turbine data monitored by the System Control and Data Acquisition (SCADA) system. The MET station has sensors for measuring wind speed, wind direction, temperature, and relative humidity.

When MET station temperature, relative humidity, or other meteorological conditions conducive to ice formation ("trigger conditions") are received by the SCADA system the wind turbines are automatically placed in Pause Mode.

Returning the wind turbines to operation will require the same steps as specified in the original WOP.

II. Explanation of Revision

Implementing an effective WOP at the GMCW Project has been an experience-based process. In early 2016, it was observed that the wind turbine manufacturer's icing shut down procedures were not sufficiently sensitive to cause a shutdown of the turbines under all conditions conducive to the formation of ice. GMCW began to work with the wind turbine manufacturer to update and implement a more robust WOP. Since there are no "off-the-shelf" WOP programs available, GMCW drew upon the experience of its team of consulting engineers, meteorologists, and managers, some of whom have over 30 years' experience in operating this equipment in mountain winter weather conditions. This Supplement to the WOP is the by-product of that work. Further refinements are likely as more experience is accumulated with actual icing events.

The Supplement increases the sensitivity of the procedures employed by the wind turbine manufacturer. It uses an on-site meteorological component in addition to the manufacturer-supplied procedure. The challenge is that wind and weather conditions are not precisely

predictable, and can change rapidly. As a result, the updated WOP relies upon an iterative approach, to determine the optimum set of rules and parameter values.

To integrate a meteorological component into the WOP, GMCW uses MET data collected at the on-site 80-meter meteorological station ("MET station"). The MET station has sensors at 80-meters above ground level which measure wind speed, wind direction, temperature, and relative humidity. The MET data output from these sensors are collected in a data logger and are received by the SCADA system which controls operation of the wind turbines at GMCW. The GMCW SCADA system was updated in February, 2017, to incorporate the meteorological component into the WOP. This SCADA update automatically places the wind turbines in Pause Mode if the MET data show that on-site conditions may be conducive to the accretion of ice. When the wind turbines are in Pause Mode, they do not produce power, although they may rotate slowly at speeds below one rotation per minute.[1] In addition to placing the wind turbines in Pause Mode, the SCADA system alerts the 24/7/365 Goldwind Remote Operations Center. A visual inspection of the wind turbines is required to take them out of Pause Mode and return the wind turbines to normal operation.

Humidity Test

The meteorological component of the WOP is intended to detect if on-site conditions are conducive to the formation of ice. To accomplish this, the SCADA system compares on-site meteorological conditions against threshold values which are likely to be conducive to the formation of ice ("test thresholds"). The meteorological conditions that adequately define periods when icing formation conditions are most likely to exist are when ambient temperatures are near or below the freezing point of water (0°C) and relative humidity is approaching saturation (100%). Implementing this meteorological component in the WOP requires an iterative learning process which evaluates the test thresholds in an operating environment. The first iteration of test thresholds being included in the humidity test includes a temperature threshold set at 1°C and relative humidity threshold set at 93%. As a conservative measure, these values have been adjusted to include the approximate standard error of the sensors measuring the temperature and relative humidity.

Wind Speed Sensor Test

In addition to the humidity test, there are wind speed sensor (anemometer) tests which compare values between heated and unheated anemometers when temperatures are at or below freezing. If the difference between the heated and unheated anemometers is "significant," this indicates ice is likely forming on the unheated anemometers. Due to the relatively small mass and surface area of these sensors, formation of ice will occur on anemometers before it does on objects with greater mass and surface area, such as wind turbine blades. The first iteration of test thresholds considers a significant wind speed difference as greater than 2 m/s for wind speeds at or below 8 m/s and a ratio of wind speeds (average heated anemometer wind speed/average unheated anemometer wind speed) greater than 1.3 for wind speeds above 8 m/s.

[1] The wind turbines "pinwheel" (slowly rotate below 1 rpm) when in Pause Mode or otherwise not producing power. This slow rotation is by design and occurs for many reasons, including lubrication of mechanical components and reduction of mechanical loads.

Wind Direction Sensor Test

The wind direction sensor (wind vane) test compares the average change in wind direction (standard deviation) against a test threshold when temperatures are at or below freezing. Like the anemometers, the formation of ice will occur on wind vanes (due to their relatively small mass and surface area) before forming on objects with greater mass and surface area, such as wind turbine blades. In the first iteration of test thresholds, if the wind direction standard deviation equals zero (0), this indicates ice is likely forming on the wind vane.

Note: The numeric test threshold values indicated above for temperature, humidity, wind speed, and wind direction were used in the first iteration of testing which was implemented in the winter of 2016-2017. The test threshold values included in the meteorological component of the WOP are subject to change based on the results of further testing.

If the SCADA system determines that on-site conditions meet or exceed any of the test thresholds described above, it automatically places the wind turbines in Pause Mode.

The results of this past winter's testing indicated that the test threshold values were generally appropriate, albeit overly conservative, i.e., there were instances when the turbines shut down prematurely, without ice formation occurring. In one case, a programming error was identified, which was corrected. In another, the overly conservative specification of the threshold values placed the turbines in Pause Mode. Implementing this innovative technique will be an on-going iterative process, due to the complexity of the defining test thresholds and the relatively short amount of applicable meteorological conditions in a given year in which they can be tested. Through further testing, starting in the winter of 2017-2018, GMCW will refine threshold values or ranges which are best suited to achieve the goal of the updated WOP. As GMCW gathers additional data and experience, it will iteratively update the SCADA system to incorporate the test results.

Georgia Mountain Community Wind
WINTER OPERATING PROTOCOL (Revised)
(approved by PUC Order dated 1/13/12; supplement approved by Order dated 8/24/17)

A. Purpose:

The Vermont Public Service Board's Order of 5/31/11 in Docket No. 7508 includes as a condition of construction:

> GMCW shall prepare a winter operating protocol, subject to review by the parties and approval by the Board prior to commencement of construction, which shall require that the proposed turbines be placed in pause mode under any of the following circumstances:
>
> (a) installed ice monitoring device(s) or heated wind sensors (installation subject to reliability testing) detect if unsafe conditions are present due to icing conditions;
> (b) ice accretion is recognized by the site operator;
> (c) air temperature, relative humidity and other meteorological conditions at the site are conducive to ice formation;
> (d) air temperature is several degrees above 0 degrees Celsius after icing conditions; and
> (e) any other weather conditions that may result in the unsafe operation of the turbines.

The Winter Operating Protocol presented below is presented to meet the Board's requirements.

B. Control Methodologies:

1. The Winter Operating Protocol will curtail the operation of wind turbines in the event of icing and when extreme weather conditions present unsafe conditions for the general public.

2. The wind turbines will be monitored via the facility's Supervisory Control And Data Acquisition (SCADA) system 24 hours per day, seven days a week throughout the year. The turbines shall be subject to shutdown under the following conditions ("Icing Conditions"), as detected in accordance with Appendix A of this Protocol:

   a. The installed ice monitoring device(s) and heated wind sensors (installation and continued operations subject to reliability testing) detect that unsafe conditions are present due to icing conditions;
   b. Ice accretion is recognized by the site operator;
   c. Air temperature, relative humidity and other meteorological conditions at the site are conducive to ice formation;

d. Air temperature is several degrees above zero degrees Celsius after icing conditions; or
e. Other weather conditions at the project site create an unsafe operating environment.

3. A remote start-up procedure will be implemented after the turbine operation has been curtailed due to Icing Conditions. The turbines will not automatically be restarted until the operator performs a pre-startup inspection of the ice monitoring device(s) and other climatic conditions and/or visual inspection to ensure safe operating condition are present.

4. As an additional safeguard, GMCW will gate access roads and post signs warning of the potential for dangerous icing conditions in the vicinity of the turbines.

C. Safety of Personnel at the Project Site:

1. All personnel at the project site shall adhere to the site specific safety requirements required by the turbine manufacturer or operator before approaching the turbines during Icing Conditions.

D. Evaluation and Update:

1. On-site and remote monitoring will take place on a weekly basis during months when Icing Conditions may occur to evaluate effectiveness of the Winter Operating Protocol compared with recorded weather conditions at the project site.

2. This Winter Operating Protocol shall be subject to modification, upon Board approval, as necessary to ensure that unsafe conditions are minimized at the project site and that shut down of the turbines shall occur under the appropriate climatic conditions.

E. Reporting

1. GMCW shall file a report by July 1 for each of the five years following approval of this Revised WOP identifying any icing events and explaining any adjustments made to the thresholds used in the testing provided in Appendix A during the prior winter.

Appendix A: Supplement to Winter Operating Protocol
(approved by PUC Order dated 8/24/17)

Georgia Mountain Community Wind, LLC ("GMCW") has evaluated the performance of the Project's internal procedures used to implement the 2012 Board-approved Winter Operating Protocol ("WOP") at the GMCW Project over several winters of operational experience. Based upon that evaluation, GMCW proposes to implement a revised WOP to improve its performance and further ensure that unsafe conditions are minimized to the greatest extent possible. This updated WOP leverages the assessment of approximately four years of GMCW operational data which were not previously available at the time the WOP was first implemented. It is designed to enhance the sensitivity of GMCW's ice detection from on-site meteorological and turbine data.

I. Revised Protocol

Under the original WOP, the operating conditions of each wind turbine were analyzed by comparing its actual operations with its expected performance. These individual results caused the turbines to trigger "Pause Mode" *after* ice formation was detected. GMCW's revised protocol will detect the presence of trigger conditions earlier.

The updated protocol will incorporate site-specific meteorological ("MET") data from the on-site meteorological station ("MET Station") and wind turbine data monitored by the System Control and Data Acquisition (SCADA) system. The MET station has sensors for measuring wind speed, wind direction, temperature, and relative humidity.

When MET station temperature, relative humidity, or other meteorological conditions conducive to ice formation ("trigger conditions") are received by the SCADA system the wind turbines are automatically placed in Pause Mode.

Returning the wind turbines to operation will require the same steps as specified in the original WOP.

II. Explanation of Revision

Implementing an effective WOP at the GMCW Project has been an experience-based process. In early 2016, it was observed that the wind turbine manufacturer's icing shut down procedures were not sufficiently sensitive to cause a shutdown of the turbines under all conditions conducive to the formation of ice. GMCW began to work with the wind turbine manufacturer to update and implement a more robust WOP. Since there are no "off-the-shelf" WOP programs available, GMCW drew upon the experience of its team of consulting engineers, meteorologists, and managers, some of whom have over 30 years' experience in operating this equipment in mountain winter weather conditions. This Supplement to the WOP is the by-product of that work. Further refinements are likely as more experience is accumulated with actual icing events.

The Supplement increases the sensitivity of the procedures employed by the wind turbine manufacturer. It uses an on-site meteorological component in addition to the manufacturer-supplied procedure. The challenge is that wind and weather conditions are not precisely

predictable, and can change rapidly. As a result, the updated WOP relies upon an iterative approach, to determine the optimum set of rules and parameter values.

To integrate a meteorological component into the WOP, GMCW uses MET data collected at the on-site 80-meter meteorological station ("MET station"). The MET station has sensors at 80-meters above ground level which measure wind speed, wind direction, temperature, and relative humidity. The MET data output from these sensors are collected in a data logger and are received by the SCADA system which controls operation of the wind turbines at GMCW. The GMCW SCADA system was updated in February, 2017, to incorporate the meteorological component into the WOP. This SCADA update automatically places the wind turbines in Pause Mode if the MET data show that on-site conditions may be conducive to the accretion of ice. When the wind turbines are in Pause Mode, they do not produce power, although they may rotate slowly at speeds below one rotation per minute.[1] In addition to placing the wind turbines in Pause Mode, the SCADA system alerts the 24/7/365 Goldwind Remote Operations Center. A visual inspection of the wind turbines is required to take them out of Pause Mode and return the wind turbines to normal operation.

Humidity Test

The meteorological component of the WOP is intended to detect if on-site conditions are conducive to the formation of ice. To accomplish this, the SCADA system compares on-site meteorological conditions against threshold values which are likely to be conducive to the formation of ice ("test thresholds"). The meteorological conditions that adequately define periods when icing formation conditions are most likely to exist are when ambient temperatures are near or below the freezing point of water (0°C) and relative humidity is approaching saturation (100%). Implementing this meteorological component in the WOP requires an iterative learning process which evaluates the test thresholds in an operating environment. The first iteration of test thresholds being included in the humidity test includes a temperature threshold set at 1°C and relative humidity threshold set at 93%. As a conservative measure, these values have been adjusted to include the approximate standard error of the sensors measuring the temperature and relative humidity.

Wind Speed Sensor Test

In addition to the humidity test, there are wind speed sensor (anemometer) tests which compare values between heated and unheated anemometers when temperatures are at or below freezing. If the difference between the heated and unheated anemometers is "significant," this indicates ice is likely forming on the unheated anemometers. Due to the relatively small mass and surface area of these sensors, formation of ice will occur on anemometers before it does on objects with greater mass and surface area, such as wind turbine blades. The first iteration of test thresholds considers a significant wind speed difference as greater than 2 m/s for wind speeds at or below 8 m/s and a ratio of wind speeds (average heated anemometer wind speed/average unheated anemometer wind speed) greater than 1.3 for wind speeds above 8 m/s.

[1] The wind turbines "pinwheel" (slowly rotate below 1 rpm) when in Pause Mode or otherwise not producing power. This slow rotation is by design and occurs for many reasons, including lubrication of mechanical components and reduction of mechanical loads.

Wind Direction Sensor Test

The wind direction sensor (wind vane) test compares the average change in wind direction (standard deviation) against a test threshold when temperatures are at or below freezing. Like the anemometers, the formation of ice will occur on wind vanes (due to their relatively small mass and surface area) before forming on objects with greater mass and surface area, such as wind turbine blades. In the first iteration of test thresholds, if the wind direction standard deviation equals zero (0), this indicates ice is likely forming on the wind vane.

Note: The numeric test threshold values indicated above for temperature, humidity, wind speed, and wind direction were used in the first iteration of testing which was implemented in the winter of 2016-2017. The test threshold values included in the meteorological component of the WOP are subject to change based on the results of further testing.

If the SCADA system determines that on-site conditions meet or exceed any of the test thresholds described above, it automatically places the wind turbines in Pause Mode.

The results of this past winter's testing indicated that the test threshold values were generally appropriate, albeit overly conservative, i.e., there were instances when the turbines shut down prematurely, without ice formation occurring. In one case, a programming error was identified, which was corrected. In another, the overly conservative specification of the threshold values placed the turbines in Pause Mode. Implementing this innovative technique will be an on-going iterative process, due to the complexity of the defining test thresholds and the relatively short amount of applicable meteorological conditions in a given year in which they can be tested. Through further testing, starting in the winter of 2017-2018, GMCW will refine threshold values or ranges which are best suited to achieve the goal of the updated WOP. As GMCW gathers additional data and experience, it will iteratively update the SCADA system to incorporate the test results.