OP-14 Appendix H -   
Solar Plant Operator Guide

**Effective Date: Draft**

**Review By Date: Month day, year**

**References:**

|  |  |
| --- | --- |
|  | ISO New England Inc. Transmission, Markets, and Services Tariff, Section I – General Terms and Conditions (Section I) |
|  | ISO New England Inc. Transmission, Markets, and Services Tariff, Section II – Open Access Transmission Tariff (OATT) |
|  | ISO New England Inc. Transmission, Markets, and Services Tariff, Section III – Market Rule 1 – Standard Market Design (Market Rule 1) |
|  | ISO New England Operating Procedure No.5 – Resource Maintenance and Outage Scheduling (OP-5) |
|  | ISO New England Operating Procedure No.14 - Technical Requirements for Generators, Demand Response Resources, Asset Related Demands and Alternative Technology Regulation Resources (OP-14) |
|  | ISO New England Operating Procedure No. 18 - Metering and Telemetering Criteria (OP-18) |
|  | ISO New England Operating Procedure No. 18 Appendix C - Minimum Accuracy Standards for New and Upgraded Metering, Recording and Telemetering Installations And For Calibration of Existing Equipment (OP-18C) |
|  | ISO New England Operating Procedure No. 18 Appendix F - ISO Communications Front End (CFE) Interface Specifications (Confidential) (OP-18F) |

**Attachments:**

|  |  |
| --- | --- |
|  | Attachment A – Solar Plant-Static Data Information Form Exemplar |
|  | Attachment B - RTHOL and SHL Calculation Examples |
|  | Attachment C – Solar Plant Power Generation Diagram |

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# Introduction

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|  | This Appendix H describes Solar Plant operating requirements and the data reporting requirements that Solar Plant Operators shall submit to ISO New England (ISO). The submittal of such data supports the operation of a centralized regional power forecasting system and therefore, the reliable and efficient integration of solar power into the ISO New England Balancing Authority Area (BAA). The requirements stated in this Appendix H apply to all Solar Plants, not operating as part of a Continuous Storage Facility (CSF), that will be or are dispatched by ISO and/or represented in the ISO Energy Management System (EMS). Included also are requirements for data that will be integrated into the ISO EMS in order to facilitate operator system awareness. |
|  | Note that this Appendix H discusses Solar Plant data reporting and operating requirements. To the extent that there are other operating, transmission service and market requirements applicable to Solar Plants, the Solar Plant Operator must refer to and comply with the applicable ISO New England Operating Documents. |
|  | The following examples were written primarily for solar Generator Assets that produce energy using photovoltaic (PV) panels and inverters. If the solar Generator Asset uses alternative technologies for converting solar insolation to electrical energy delivered to the Point of Interconnection (POI), data requirements may be modified at the discretion of ISO. |

# Definitions

|  |  |
| --- | --- |
|  | The following are the definitions for terms used in this Appendix H: |
|  | ***Curtailment or Curtailed*** – Solar Plant Operator action (whether manual, scheduled, or automatic), resulting from an ISO Dispatch Instruction, that limits the amount of power produced by the Solar Plant to below the maximum amount of power that could be produced by the normally operating available equipment given the current weather conditions at the Solar Plant. |
|  | ***Met Gathering Station*** – a permanent purpose-built and/or sited station dedicated to the collection of Meteorological Data. |
|  | ***Meteorological Data*** – the real-time data (e.g., Global Horizontal Insolation, Direct Normal Insolation, wind speeds and directions) collected at a specific Solar Plant’s location. |
|  | ***Plant Max Reactive Lagging Capability*** – the maximum reactive capability in the lagging direction (i.e., VAr management that increases local voltage levels) that the Solar Plant can supply at the interconnection point given the existing voltage, in a continuous manner within one minute and maintain for at least one hour. |
|  | ***Plant Max Reactive Leading Capability*** – the maximum reactive capability in the leading direction (i.e., VAr management that decreases local voltage levels) that the Solar Plant can supply at the interconnection point given the existing voltage, in a continuous manner within one minute and maintain for at least one hour. |
|  | ***Plant Wind Directions*** – the instantaneous wind direction measured by wind measuring equipment (e.g., wind vane). |
|  | ***Plant Wind Speeds*** – the instantaneous wind speeds measured by wind measuring equipment (e.g. anemometry). |
|  | ***Real-Time High Operating Limit*** – is defined in the ISO New England Inc. Transmission, Markets, and Services Tariff Section I - General Terms and Conditions (Section I). |
|  | ***Solar High Limit (SHL)*** – is defined in the ISO New England Inc. Transmission, Markets, and Services Tariff Section I-General Terms and Conditions (Section I) See Section 5.1.2 of this Appendix H and Attachment B hereto for more details regarding SHL. |
|  | ***Solar Plant*** – for the purpose of this Appendix H, a Solar Plant is a collection of one or more solar-collecting/electricity-generating equipment and the additional equipment required to interconnect these collectors/converters into the electrical power system, consistent with the definition of a Generator Asset in Section I. |
|  | ***Solar Plant Future Availability (SPFA)*** – is defined in the ISO New England Inc. Transmission, Markets, and Services Tariff Section I - General Terms and Conditions (Section I). |
|  | ***Solar Plant Operator*** – for the purposes of this Appendix H, is the Lead Market Participant (Lead MP), or its designee, who operates a Solar Plant and/or reports the data to ISO as required in this Appendix H, as applicable. |

# Standard Operational Practice and Requirements

## Solar Plant Data

|  |  |
| --- | --- |
|  | Unless other modeling and data arrangements are agreed to by ISO, Solar Plant data (whether static or telemetered) that is submitted by a Solar Plant Operator in accordance with this Appendix H shall be consistent with the definition of Solar Plant. |

## Reclosing and Restarts

|  |  |
| --- | --- |
|  | A Solar Plant shall be designed and operated (including the performance of re-closings and re-starts) by the Solar Plant Operator in accordance with ISO New England Operating Documents, which apply to all resources within the ISO-NE BAA. |
|  | If the Solar Plant main breaker is opened (i.e., the plant is manually or automatically disconnected from the rest of the New England Transmission System) the Solar Plant Operator must receive permission from ISO and the respective LCC prior to reclosing (i.e., reconnect to the New England Transmission System). An automatic restart of the Solar Plant is **not** permitted following a fault to the Distribution System or Transmission System that is severe enough to disconnect the Solar Plant [e.g., a Low Voltage Ride Through (LVRT) event that is **not** “ridden through”] or following any Solar Plant-wide out-of-service event. |

## Ramp Rate Limitations

|  |  |
| --- | --- |
|  | Due to the very fast ramping capabilities of Solar Plants, there is potential for the equipment with which they are interconnected, to become significantly loaded or unloaded. This condition may lead to operational and reliability concerns, therefore ramp rate limits have been determined as described below. As operational experience is gained, ISO shall reevaluate these limits on either a Solar Plant-by-Solar Plant basis, or as applied to all Solar Plants in New England, as warranted. Where alternative ramp rates are determined to be acceptable on a Solar Plant-specific basis (e.g., for the provision of ancillary and/or essential reliability services), those plant-specific limits shall be provided to the Lead MP by ISO. |
|  | * For Solar Plants totaling 200 MW or less in nameplate, under all conditions except for emergencies and decreasing solar conditions, a default maximum ramp rate of 20 MW/min averaged over five minutes is **not** to be exceeded unless otherwise requested by ISO. |
|  | * For Solar Plants totaling greater than 200 MW in nameplate, under all conditions except for emergencies and decreasing solar conditions, a default maximum ramp rate of 10% of nameplate per minute (in MW/min) averaged over 5 (five) minutes is **not** to be exceeded unless otherwise requested by ISO; see example below. |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Plant nameplate 110 MW. Limit: no more than 20 MW per minute when averaged over five (5) minutes** | | | | | | | |
| **Minute1** | **Minute2** | **Minute3** | **Minute4** | **Minute5** | **Average rate** | **Exceeds Ramp Rate** | **Corr. Action** |
| 100 MW/ min | 0 MW/ min | 0 MW/ min | 0 MW/ min | 0 MW/ min | 20 MW/ min | No | None |
| 100 MW/ min | 10 MW/ min | 0 MW/ min | 0 MW/ min | 0 MW/ min | 22 MW/ min | Yes | Limit ramp in either first or second minute |

# Static Plant Data Requirements

|  |  |
| --- | --- |
|  | The static plant data requirements that describe the physical layout of the Solar Plant and any associated meteorological equipment as well as data relevant to the design and operation of the Solar Plant are listed below. This data must be maintained and submitted by the Solar Plant Operator to ISO using the Solar Plant-Static Data Information Form. The Solar Plant-Static Data Information Form is an editable Excel workbook file and must be requested from ISO, completed, and returned as an Excel workbook file to the ISO at [RenewableResourceInt@iso-ne.com](mailto:RenewableResourceInt@iso-ne.com?subject=Solar%20Plant%20Static%20Data%20Form%20Request). A sample Solar Plant-Static Data Information Form is available to in Attachment A of this Appendix H. Instructions are included, on the form, on how to complete and submit the required information. Consistent with ISO New England Inc. Transmission, Markets, and Services Tariff Section II - Open Access Transmission Tariff (OATT) Schedules 22 and 23, and OP-14, the Solar Plant Operator shall verify that the static plant data for each Solar Plant is kept current and changes are communicated to ISO if any data point changes in a material fashion. |
|  | Static plant data requirements: |
|  | 1. Solar Plant: |
|  | * 1. Latitude, Longitude, and elevation above sea level (in meters to one decimal place) of polygon corners determining spatial location of the solar project using WGS84 DD-MM-SS.SS using GPS WAAS, or comparable, methodology |
|  | * 1. Solar module type(s) and model number(s) |
|  | * 1. Panel tilt angle(s) – if fixed-axis, or indication of tracking along this axis |
|  | * 1. Panel azimuth angle(s) – if fixed-axis, or indication of tracking along this axis |
|  | * 1. Total MW DC Nameplate Capacity   2. Total MW AC Nameplate Capacity |
|  | * 1. Inverter module type(s) and model number(s) |
|  | * 1. Inverter-by-inverter breakdown of relative DC nameplate feed |
|  | * 1. Location and types of weather measurement devices (e.g., pyranometer type & manufacturer) and manufacturer’s data specification sheets |
|  | * 1. High and Low temperature cutoff threshold(s) |
|  | * 1. High Wind Speed cutout threshold(s) and behaviors |
|  | * 1. Descriptions of any permitting or administrative restrictions for the Solar Plant or any portion of the Solar Plant such as requirements to reduce or to cease power production during certain hours or during certain events or weather conditions. |
|  | * 1. For model training purposes, the ISO or its designee may require that any available historical information regarding plant power output, plant meteorological conditions, and conditions that may have caused power output to be below theoretical maximum power output given the experienced insolation, which are required by the solar power forecaster, be provided. |

# Real-Time Data Collection and Transfer

|  |  |
| --- | --- |
|  | This section presents the real-time operational and meteorological data requirements for Solar Plant Operators. In accordance with Table 6.1 to this Appendix H, data required under this Section must be electronically and automatically transmitted by the Solar Plant Operator to ISO as detailed in OP-18 section V - Internal New England Metering And Telemetering For Dispatch, Market, And Reliability Purposes. In addition, if any recommended (i.e. not required) data is provided by the Solar Plant Operator, it must also follow the same OP-18 requirements. Solar power forecasting accuracy is highly dependent on the availability of the real-time meteorological, power production, and status data for tuning the forecaster models. As such, this required information must be provided with a high degree of accuracy and reliability. |

## Required Data Collection Points

### Meteorological Data

|  |  |
| --- | --- |
|  | Ambient air temperature, ambient air pressure, ambient air relative humidity, solar irradiance, wind speed, and wind direction must be measured, at a minimum, at one location within the Solar Plant (preferably as near to the capacity-weighted centroid of the Solar Plant as possible) whose height above ground may be in the range of 2 m to 10 m and the measurement height above must be stated to within 10 cm. |
|  | Solar irradiance, wind speed and wind direction measuring equipment (e.g. pyranometry and anemometry) should be mounted in, on, or near the Solar Plant with reasonable attempt to minimize the effects of obstruction. Wind direction should be calibrated for True North equal to 0 degrees and reported between 0 degrees and 359.9 degrees |

### Solar High Limit

|  |  |
| --- | --- |
|  | The Solar High Limit of a Solar Plant should be calculated as follows:   1. When a Solar Plant is not being Curtailed, its Solar High Limit shall be calculated equal to the net generation. 2. When a Solar Plant is being Curtailed, its Solar High Limit shall be calculated equal to the Solar Plant’s possible power production given current sun/weather conditions and equipment status if the curtailment were not in place. This will be greater than the net generation. 3. Solar High Limit must be greater than or equal to 0 4. Solar High Limit must be less than or equal to Real Time High Operating Limit   (See Attachment B to this Appendix H for additional guidance and examples). |

### Real-Time High Operating Limit

|  |  |
| --- | --- |
|  | A Solar Plant Real-Time High Operating Limit (RTHOL) is the maximum power production (MW) the Solar Plant would be capable of in real-time, given ideal sun conditions and **no** Curtailment. (See Attachment B to this Appendix H for additional guidance and examples).  RTHOL should not be impacted by less than ideal sun conditions (e.g. cloudiness), or time of day (e.g. before the sun has risen, or after the sun has set), except if the Solar Plant is disconnected based upon a day/night cycle. If the Solar Plant is disconnected solely because of day/night cycle, the RTHOL should be set to zero but an outage is not required pursuant to OP-5.  When snow, ice, or other materials are fully or partially covering the PV panels, the RTHOL should be reduced to reflect the generation capability given those conditions. If panels are unable to produce energy given the conditions, it should be reported equivalent to a full or partial outage as applicable. |

### Solar Plant Future Availability

|  |  |
| --- | --- |
|  | Solar Plant Future Availability is equivalent to the future hour’s expected RTHOL and should therefore be calculated using the same methodology as RTHOL but with the expected equipment status for the hour being calculated.  In contrast to all other Real-Time data which is provided to the ISO via telemetry, Solar Plant Future Availability is provided to the ISO using the ISO-NE Wind and Solar Integration web services. In the future, once a solar power forecast can be developed, this web service could also be used to gather solar plant power forecasts provided by the ISO-NE solar power forecaster. Information on using the web service platform, including data specification and sample files are available in the following Zip file: <https://www.iso-ne.com/static-assets/documents/2016/08/wind_integration_data_exchange_specification_and_sample_files_AssetID_change.zip> |

## Recommended Data Collection Points and Practices

|  |  |
| --- | --- |
|  | In order to ensure that data of a high quality will be incorporated into the centralized forecasting system, ISO requests that Solar Plant Operators follow the practices for meteorological data collection for each Solar Plant as outlined below: |
|  | 1. Collect and provide to ISO, Meteorological Data from at least one met station that is strategically placed or utilized so that it will be impacted to a minimal extent by plant operations. |
|  | 1. The Met Gathering Station equipment should be located at well‐exposed sites. It is recommended that each solar panel in the Solar Plant should be within 5 km of a Met Gathering Station. |
|  | 1. In order to avoid outage of data, it is recommended that additional “backup” data collection sites are selected in addition to the required data specified in Section 5.2.1. |
|  | 1. The method(s) of measuring solar irradiance (e.g. Global Horizontal Irradiance, Direct Normal Irradiance, etc.) should be identified to the ISO during the data collection points setup so they can be utilized properly within forecasting systems. |
|  | 1. Utilize the Do-Not-Exceed (DNE) Dispatch Limit provided by the ISO over the RTU, along with the Solar Plant’s possible power production capability when determining if the Solar Plant is operating in a Curtailed mode for purposes of calculating Solar High Limit. |
|  | 1. If the Solar Plant DNE limit is lower than the possible power production, this would be considered a Curtailment. 2. If the Solar Plant DNE limit is not lower than the possible power production, this would not be considered a Curtailment. |

# Real-Time Data Table

## Table 6.1 Real-Time Data

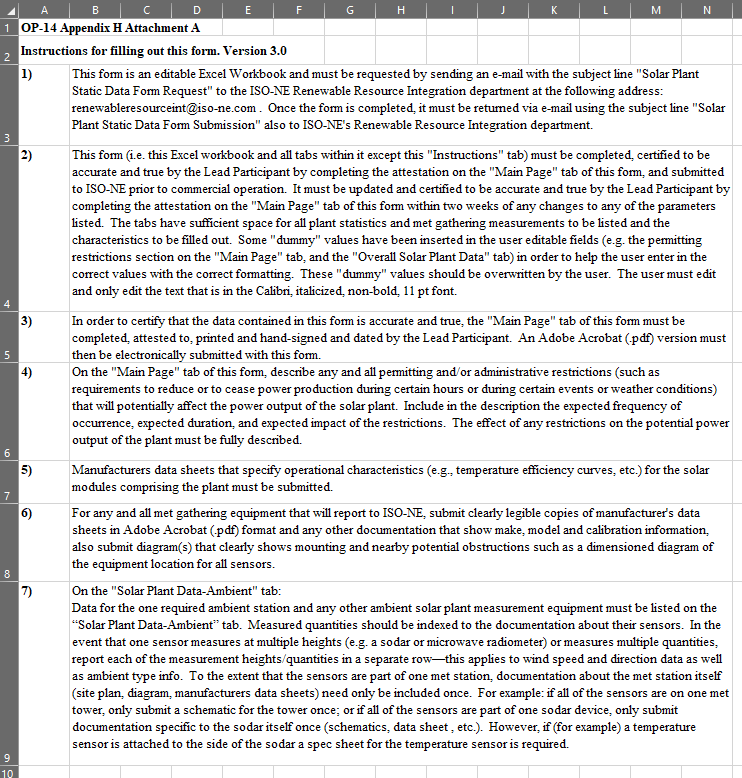
| **Parameter** | **Required/ Recommended** | **Location** | **Height** | **Units** | **Instantaneous/ Average** | **Minimum Resolution/ Accuracy** | **Minimum Update Frequency** | **Requirement Reference(s)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Future Availability Data (Web Services)*** | | | | | | | |  |
| Solar Plant Future Availability   1. Hourly values for the next 48 hours 2. Hourly values for the next 49 to 168 hours | Required | Plant-wide total | N/A | MW | N/A | 0.01 MW | 1. Every hour at the top of the hour 2. By 1000 hours each day | Market Rule 1 Section 1.11.5(c)(iii) |
| ***Instantaneous Real-Time Data (SCADA)*** | | | | | | | |  |
| Real Time High Operating Limit (RTHOL) | Required | Plant-wide total | N/A | MW | Instantaneous | 0.01 MW with accuracy of +/- 1% | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(ii)  OP-14 App. H Section 5.1.3 |
| Solar High Limit (SHL) | Required | Plant-wide total | M/A | MW | Instantaneous | 0.01 MW with accuracy of +/- 1% | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(ii)  OP-14 App. H Section 5.1.2 |
| Plant Power Generation | Required | Plant-wide total | N/A | MW | Instantaneous | As required by OP-18 | As required by OP-18 | OP-18 Section V.C  OP-18 App.F |
| Plant Reactive Power Production | Required | Plant-wide total | N/A | MVAr | Instantaneous | As required by OP-18 | As required by OP-18 | OP-18 Section V.C  OP-18 App.F |
| Voltage | Required | Plant | N/A | kV | Instantaneous | As required by OP-18 | As required by OP-18 | OP-18 Section V.C  OP-18 App.F |
| Plant Main Breaker Status | Required | Plant | N/A | binary | Instantaneous | N/A | As required by OP-18 | OP-18 Section V.C  OP-18 App .F |
| Plant Voltage Regulation Mode | Required | Plant | N/A | binary | Instantaneous | N/A | As required by OP-18 | OP-18 Section V.C  OP-18 App.F |
| Plant Max Reactive Lagging Capability | Recommended | Plant-wide total | N/A | MVAr | Instantaneous | 0.01 MVAr with accuracy of +/- 1% | Every 4s or every 10s | OP-14 App H Section 2 |
| Plant Max Reactive Leading Capability | Recommended | Plant-wide total | N/A | MVAr | Instantaneous | 0.01 MVAr with accuracy of +/- 1% | Every 4s or every 10s | OP-14 App H Section 2 |
| ***Average Real-Time Solar plant ambient information / Meteorological Station (***data typically sampled at 1Hz) (***SCADA***) | | | | | | | |  |
| Ambient air temperature | Required | One location within Solar Plant | Between 2 and 10 meters | Degrees Centigrade (oC) | Average over 5 minute interval | to 0.1oC with accuracy+/- 1.25oC | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Standard deviation of ambient air temperature | Required | One location within Solar Plant | Between 2 and 10 meters | Degrees Centigrade (oC) | Average over 5 minute interval | Same as above | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Ambient air pressure | Required | One location within Solar Plant | Between 2 and 10 meters | Kilopascals (kPa) | Average over 5 minute interval | to 0.1 kPa with accuracy to +/- 1.5kPa | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Standard deviation of ambient air pressure | Required | One location within Solar Plant | Between 2 and 10 meters | Kilopascals (kPa) | Average over 5 minute interval | Same as above | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Ambient air relative humidity | Required | One location within Solar Plant | Between 2 and 10 meters | (Percent) | Average over 5 minute interval | to 1% with accuracy to +/- 3% | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Standard deviation of ambient air relative humidity | Required | One location within Solar Plant | Between 2 and 10 meters | (Percent) | Average over 5 minute interval | Same as above | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Solar irradiance | Required | One location within Solar Plant | Between 2 and 10 meters | W/m2 | Average over 5 minute interval | To 1 W/m2 | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Wind speed | Required | One location within Solar Plant | Between 2 and 10 meters | m/s (scalar) | Average over 5 minute interval | to 0.1 m/s  accuracy of +/- 0.5 m/s | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Standard Deviation of Wind speed | Recommended | One location within Solar Plant | Between 2 and 10 meters | m/s (scalar) | Average over 5 minute interval | Same as above | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |
| Wind direction | Required | One location within Solar Plant | Between 2 and 10 meters | Degrees from True North (vector) | Average over 5 minute interval | to 1 degree with accuracy to  +/- 5 degrees | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14App. H Section 5.1.1 |
| Standard Deviation of Wind direction | Recommended | One location within Solar Plant | Between 2 and 10 meters | Degrees from True North (vector) | Average over 5 minute interval | Same as above | Every 5 minutes | Market Rule 1 Section 1.11.5(c)(i)  OP-14 App. H Section 5.1.1 |

# Revision History

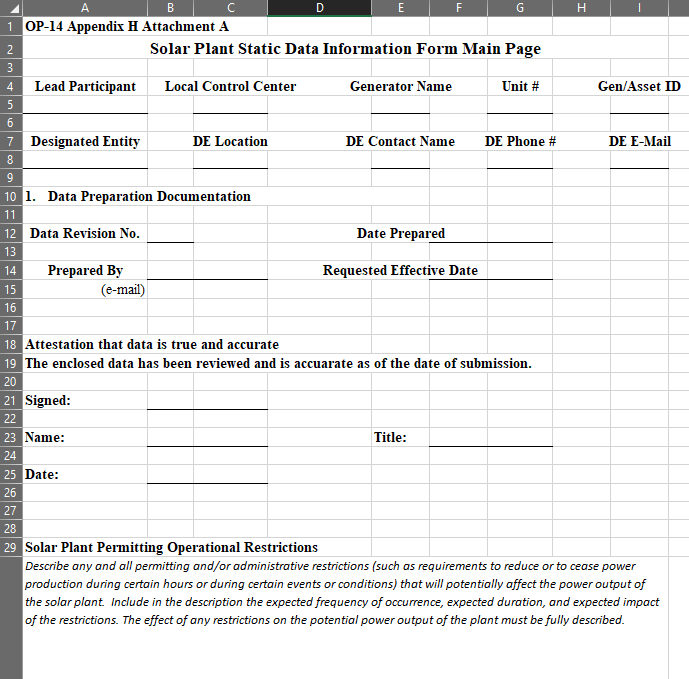
| **Rev No.** | **Date** | **Reason** |
| --- | --- | --- |
| Rev 0 | 07/20/21 | Initial version |
| Rev 1 | 07/18/23 | Biennial review performed by procedure owner;  5.1.3 Real-Time High Operating Limit: Added Solar Plant day/night cycle disconnection clarification;  Table 6.1 Real-Time Data: Added clarifications to headers, removed at point of interconnection from Voltage Parameter, and updated references in Minimum Resolution/Accuracy, Minimum Update Frequency, and Requirement Reference(s) columns. |
| Rev 2 | Draft | Periodic review performed by procedure owner;  Include language making Curtailment an explicit function of DNE -- exactly as in OP14-F |
|  |  |  |

## Attachment A - Solar Plant-Static Data Information Form Exemplar

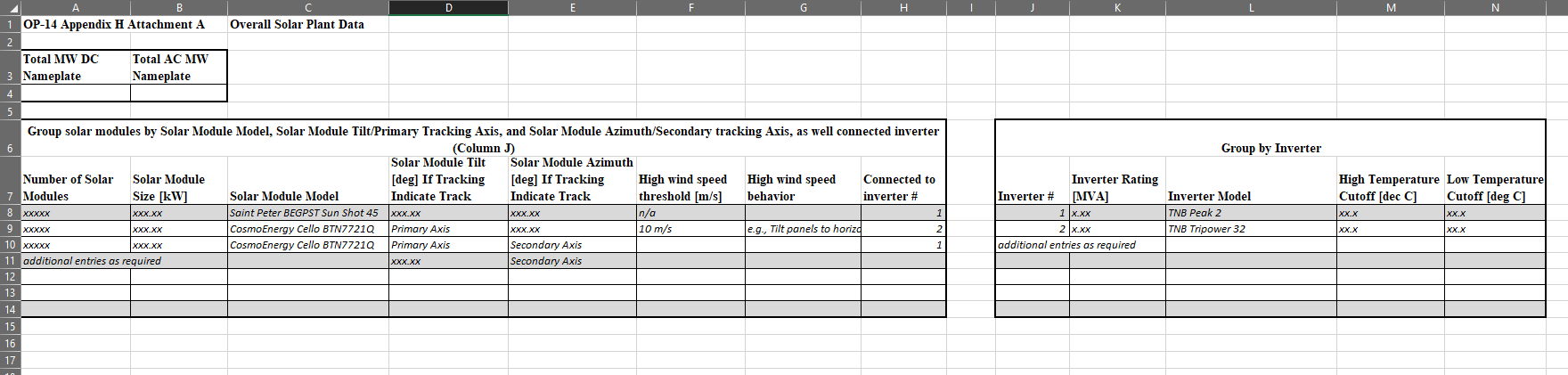
***Sample only*** – For a functioning version of this Excel workbook file contact the   
ISO at [RenewableResourceInt@iso-ne.com](mailto:RenewableResourceInt@iso-ne.com?subject=Solar%20Plant%20Static%20Data%20Form%20Request).

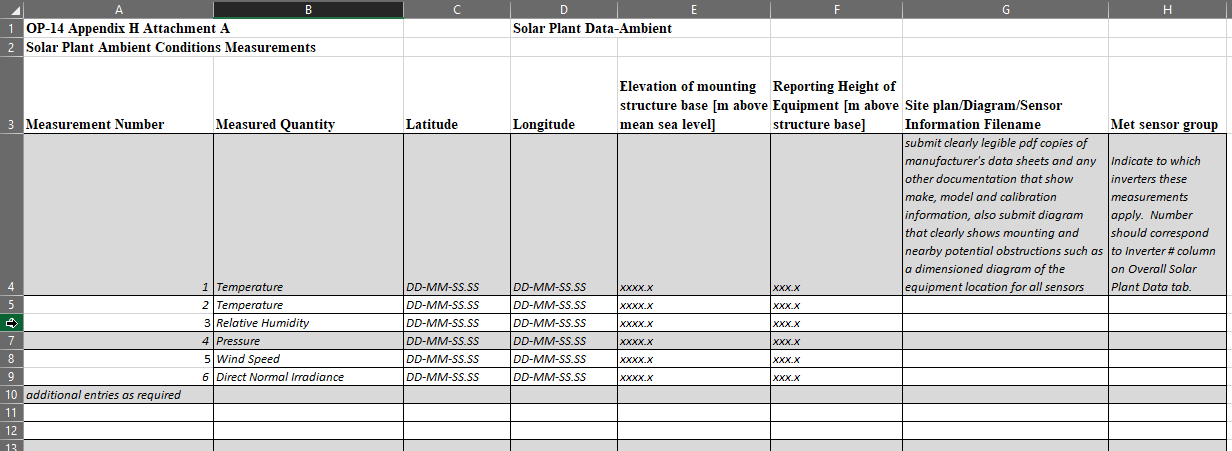


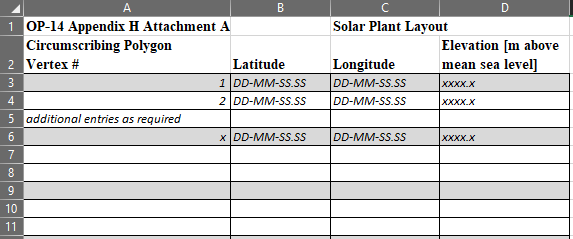
**Attachment A - Solar Plant-Static Data Information Form (cont.)**



**Attachment A - Solar Plant-Static Data Information Form (cont.)**







## Attachment B – RTHOL and SHL Calculation Examples

The following examples are presented to illustrate how RTHOL and SHL would be calculated under various conditions.

Solar irradiance values in the following examples are assumed to be constant. Variability of solar conditions will likely introduce some error into the calculation of SHL; this is expected. Losses between the Solar Plant and the Point of Interconnection (POI) are not taken into account in these simplified examples, but should be in the SHL calculation such that the SHL reports the net power injection at the POI rather than the gross production.

The following Solar Plant is used within all subsequent examples:

A Solar Plant has three strings of solar panels each connected to dedicated inverters as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **String #** | **Solar Panel Type** | **Solar Panel Capacity [MW DC]** | **Inverter Rating [MW AC]** | **Inverter Efficiency [%]** |
| 1 | A | 5 | 3 | 95 |
| 2 | B | 4 | 3 | 95 |
| 3 | C | 3 | 2 | 97 |

Each solar panel type can produce power according the amount of solar irradiance as follows:

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Solar Panel Type | Solar irradiance [W/m2] | | | | | | | | | | |
| **0** | **100** | **200** | **300** | **400** | **500** | **600** | **700** | **800** | **900** | **1,000** |
| A | 0 | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| B | 0 | 9% | 18% | 27% | 36% | 45% | 54% | 63% | 72% | 81% | 90% |
| C | 0 | 12% | 24% | 36% | 48% | 60% | 72% | 84% | 96% | 100% | 100% |

Example 1:

Solar irradiance is measured to be 500 W/m2 by the pyranometer in the Solar Plant. All three strings are fully available.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Individual String Details** | | | | | | | |
| String # | Available | DC Panel Capacity | Power % based on irradiance | DC Potential MW | Inverter Efficiency | AC Potential MW | Inverter Capability MW |
| 1 | Yes | 5 | 50% | 2.5 | 95% | 2.375 | 3 |
| 2 | Yes | 4 | 45% | 1.8 | 95% | 1.71 | 3 |
| 3 | Yes | 3 | 60% | 1.8 | 97% | 1.746 | 2 |
| Total |  | 12 |  | 6.1 |  | 5.831 | 8 |

|  |  |
| --- | --- |
| **Solar Plant Totals** | |
| DNE Limit | 8.0 MW |
| Net Generation: | 6.0 MW |
| RTHOL: | 8.0 MW |
| SHL: | 6.0 MW |

Explanation:

Based on the solar irradiance, the % of DC Panel Capability can be determined. With that value determined, it can be used to calculate the DC Potential MW. Applying the Inverter Efficiency, the AC Potential MW values are calculated. Note, that there could be some error in the calculation of AC Potential MW (e.g., in this example, the AC Potential MW does not equal the actual Net Generation – this is intentional in the example and is to illustrate correct calculation of SHL). For all three strings, it can be seen that AC output is not limited by Inverter Capability. The RTHOL is the maximum output that could be achieved given available equipment. In this case that is 8 MW (limited by the Inverter Capability). The Solar High Limit is 6.0 MW because the Solar Plant is not Curtailed (i.e., the DNE is not limiting the total possible power production) and therefore SHL equals Net Generation. If the Solar Plant receives a DNE limit of 4 MW, the SHL would be 5.831 MW, based upon the AC Potential MW of each string, adjusted for losses.

Example 2:

Solar irradiance is measured to be 800 W/m2 by the pyranometer in the Solar Plant. String 3 is unavailable due to maintenance on the inverter.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Individual String Details** | | | | | | | |
| String # | Available | DC Panel Capacity | Power % based on irradiance | DC Potential MW | Inverter Efficiency | AC Potential MW | Inverter Capability MW |
| 1 | Yes | 5 | 80% | 4 | 95% | 3.8 | 3 |
| 2 | Yes | 4 | 72% | 2.88 | 95% | 2.736 | 3 |
| 3 | No | 0\* | 0\*% | 0\* | 0\*% | 0\* | 0\* |
| Total |  | 9 |  | 6.88 |  | 6.536 | 6 |

*\*Set to 0 due to being unavailable*

|  |  |
| --- | --- |
| **Solar Plant Totals** | |
| DNE Limit | 4.5 MW |
| Net Generation: | 4.5 MW |
| RTHOL: | 6.0 MW |
| SHL: | 5.736 MW |

Explanation:

With String 3 unavailable, its capability is excluded from all calculations. Values for String 1 and 2 are determined in a similar manner as in Example 1, however, in this example it can be seen that String 1’s AC potential MW capability exceeds the inverter rating. The RTHOL would be 6 MW (limited by inverter capability). Because the DNE limit is 4.5 MW (i.e., below what the Solar Plant would otherwise be capable of producing), the Solar Plant is Curtailed (i.e., its Net Generation is limited to 4.5 MW) and the SHL is therefore 5.736 MW (3 MW from String 1, limited by the inverter; plus 2.736 MW from String 2, limited by the AC Potential MW)

## Attachment C – Solar Plant Power Generation Chart

A diagram of solar energy

Description automatically generated