Performance Test Methodology

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1. Introduction

Part of Infratec's Testing and Commissioning scope in the EPCC for Waiotahe Solar Farm (and the remaining Lodestone sites) is to conduct a performance test. The performance test methodology is set out in EPCC contract schedule 15 Part 2 and the referenced parts of IEC 61724-1:2021 and IEC 61724-2:2016.

There have been documented lessons learnt from the performance test procedure that was followed at the Kaitaia site. The performance test methodology outlined in this document is largely based on what was followed at Kaitaia and Edgecumbe. Where applicable, we have included suggested changes to the methodology based on the lessons learned feedback received from both Kaitaia and Edgecumbe.

Waiotahe is configured differently to both Kaitaia and Edgecumbe as it has PV Arrays oriented to two different azimuths but still only has a single revenue meter that measures the energy output from the whole PV plant. The methodology adopted in the previous projects will be modified to account for this.

2. Methodology

The performance test method specified in the EPCC contract is based on the performance testing methodology in IEC 61724.

It should be noted that there are two separate PVSyst models for Waiotahe to account for the two different arrays, which have different azimuths. Each of the two PV arrays has its own weather station to measure and capture relevant weather data.
To determine the performance ratio target, the outputs of the as-built PVSyst models will be used with an input of filtered measured irradiance and temperature captured during the performance test. The output from each PVSyst model will be summed together to calculate the expected combined output from the entire PV plant. This will then be compared against the actual measured energy from the site revenue meter.

The high-level methodology is specified in EPCC contract schedule 15 Part 2 (included in Appendices) and the IEC 61724-1 and IEC 61724-2 standards.

Test data will be recorded from Lodestone's Ovation EDS historian. Data will be recorded at 3 second intervals during the performance test (as per the Class A sampling interval specified in IEC 61724).

Filtering of data is explained in detail in section 2.6 below.

The performance test will start after commissioning of the solar plant is complete and all plant is functioning correctly. Plant outages and equipment failures that occur during the performance test will be managed as per the EPCC contract.

2.1 Purpose

The purpose of the performance test is to ensure the constructed (as built) system satisfies an indicated minimum Performance Ratio (as defined in IEC 61724-1) within the agreed test boundaries.
A secondary purpose is to determine if there is any performance shortfall due to Infratec's workmanship for Infratec's scope in the EPCC.

2.2 Pre-Test Checks

Prior to commencing with the data capturing for the actual performance test, the following checks will be performed:

- Check that all the points that need to be monitored / recorded have been set up in SCADA i.e. that they are available to be trended
- Check that all the required points are reading sensible values
- Check and confirm calibration of all sensors and the site revenue meter
- Compare readings between similar sensors installed at different locations (see note below)
    - Compare readings between Global Horizontal Irradiance (GHI) sensors on the 2 separate weather stations
    - Compare readings between ambient temperature sensors on the 2 separate weather stations
    - Compare wind speed readings between the 2 separate weather stations
- Confirm that all inverter modules are running in each inverter

    - Check the "number of modules running" parameter for each inverter
- Visually check cleanliness of the irradiance sensors (via pictures)

Note: Since Waiotahe has two PV array groups with different azimuths, a direct comparison between the Plane of Array (POA) Irradiance sensors will not be useful as each has its own tracking angle.

2.3 Test Boundary Inclusions

The test boundaries for Waiotahe are outlined below:

- Total duration of the performance test – 14 continuous days minimum
- Minimum number of 15-minute average data points required is 20

Notes:

1. ***If required, the duration of the performance test may need to be extended to achieve the required minimum number of usable 15-minute average data points.***
2. ***Should the minimum number of usable 15-minute average data points be reached before the 14 continuous days lapses, the performance ratio can be calculated at this point. If the calculated performance ratio meets or exceeds the contractual requirement and it is accepted by the Principal, then the test can be stopped. While the performance ratio is being calculated, data collection must continue.***

- The performance test is for the whole solar farm including all balance of system (BOS) components such as combiner boxes, cables and connectors. The test is bounded by the revenue meter of the solar farm on the 33 kV side.
- Inverter performance to be unconstrained.
- Soiling during the test period to be included.
    - Irradiance sensors and PV modules will not be cleaned before or during the performance test but will be checked for unacceptable uncleanliness.
    - The soiling on both panels and irradiance sensors has been assumed to be the same, therefore soiling loss will be set to 0% on the PVSyst Model for the performance test.
    - If irradiance sensors are cleaned in future and it is necessary to do a subsequent performance test, soiling losses will be assessed to determine the appropriate soiling loss percentage.
- The same version of PVSyst used to produce the as-built model, should be used to determine the final Performance Ratio (PR).

2.4 Test Boundary Exclusions

The test boundaries for Waiotahe will exclude the following:

- Inverters constraining
    - Periods when any inverter's apparent power output is greater than 99.8%; considering the number of power modules available within each inverter.
    - Periods when there are inverter communications faults
- If any of the inverters are curtailed, these periods will be excluded.
- Missing or bad data periods for irradiance / temperature and AC output power / energy will be excluded.
- Periods where the wind speed exceeds the threshold and the interval configured in the tracker control units (TCU) for wind stow, will be excluded.

- Any periods where there is AC curtailment due to the network or not being fully dispatched will be excluded.
  Any 15-minute datapoints that have a recorded POA irradiance less than 450 W/m² will be excluded.
- If either Plane of Array (POA) irradiance sensor is faulty, data from these periods may be excluded, subject to a reasonability check.

Note:
Waiotahe has two array groups (North array and South array) with different azimuths and each array has its own tracking angle and separate weather station. Due to the two arrays having different tracking angles, the POA sensors fitted to each array can't be used to correlate each other. Therefore, each array must use the POA readings from its specific POA sensor and we can't take the average of the two sensors as was done previously at Kaitaia and Edgecumbe.

- If both Global Horizontal Irradiance (GHI) sensors are faulty, then these periods will be excluded.
- If both ambient temperature sensors are faulty, then these periods will be excluded.

Note:
The GHI, ambient temperature and wind sensors readings on the two weather stations are not related to tracking angle and therefore will still be used to verify correlation between similar sensors on the two weather stations. Similarly, for data collection we will take the average reading of these sensors during data collection.

2.5 Data Collection

The data collection process is outlined below:

- Data for all points used for performance testing to be sampled on a three (3) second interval, as per class A requirements outlined in Table 1 of IEC 61724-1.
- In-plane irradiance for each of the two arrays will be the POA sensor reading from each individual array. Due to the arrays having different tracking angles, we can't take the average value between the two POA sensors.
  - If either POA sensor measurement is faulty these periods may be excluded subject to a reasonability check
- Global Horizontal irradiance for PVSyst will be the average of the two global horizontal irradiance sensors.
  - If either sensor measurement is faulty the other sensor value will be used
  - If both sensors are faulty these periods will be excluded.
- Ambient temperature used for PVSyst will be the average of the two sensors.
  - If either sensor measurement is faulty the other sensor value is used
  - If both sensors are faulty these periods have been excluded.
- PVSyst requires Global Horizontal Irradiance as the irradiance input when creating a custom meteorological file for a tracking system. So GHI will be used in the performance test rather than Plane of Array irradiance specified in the EPCC contract. POA irradiance readings are, however, still used in the actual bifacial performance ratio calculation and will have some impact on the final calculation.
- Periodic checks will be done on the recorded data at the following intervals:
  - After day 3
  - After day 7
  - After day 10
  - After day 14

The main purpose of these periodic checks is to:

a) Evaluate if an extension of the test period may be required i.e. if an insufficient number of usable 15-minute average data points have been captured.
b) Ensure that the measurements are working correctly i.e. checking for broken or malfunctioning sensors

2.6 Data Filtering Methodology

The Data filtering methodology is outlined below.

Note: Steps 1 through 3 below will be done for each of the two arrays separately, as each array has its own PVSyst model.

1. Filtering at the 3 second level will be done for:
    - Point of Connection Limitation – both 30.0 MW and 35.12 MVA. Periods where real power or apparent power was greater than 99.8% of point of connection ratings will be excluded.
    - Inverters Constraining
        - Inverter are considered constrained if their apparent power output was greater than 99.8% of the maximum power rating considering how many power modules are available for operation (as reported by the inverter). Each power module is rated at 1.0975 MVA (4.39 MVA / 4 modules).
    - High wind speed resulting in wind stow
        - Periods of wind stow can be detected by checking the wind sensors readings against the tracker controller settings. If both wind speed readings are over 40 km/hr for two consecutive 3 second readings (i.e. 6 seconds in total), then wind stowing will be assumed until the wind speed measured by both sensors drops below 38 km/hr for 300 seconds.

   Output: An excel spreadsheet with all 3-second data points recorded including a column identifying which points will be excluded and the reason(s) for exclusion.

2. Following sampling and filtering of the 3 second data, the next step is averaging to 1-minute data
    - Data will be averaged into minutes from the remaining (filtered) 3 second periods.
    - One-minute periods will be excluded if there are less than 5 valid data points in that 1-minute period.

   Output: An excel spreadsheet listing all filtered (usable) 3-second data points. The spreadsheet will identify which additional 3-second data points will be excluded due to there not being a minimum of 5 x 3-second data points within any given minute.

3. Filtering and averaging to 15-minute data:
    - Only periods with 15 x 1 minute data points remaining after 3 second filtering will be used.
    - Irradiance to be filtered as per Table 1 in IEC 61724-2:2016
    - Target Reference Conditions (TRC) to be defined and any 15-minute periods that did not fall within the acceptable irradiance range (<0.5xTRC or >1.2xTRC) will be excluded.
        - TRC will be selected to be 700 W/m², as was done for Kaitaia and Edgecumbe. This value is selected as at the STC value of 1000 W/m², the solar farm is typically constrained due to the high DC to AC ratio.

- This TRC value means that average GHI below 350 W/m² and above 840 W/m² will be excluded from the performance test.

***Note:* Despite the lower GHI value being 350 W/m², any Plane of Array irradiance readings below 450 W/m² will also be excluded, as per the recommended minimum irradiance suggested by Kilo.**

- Temperature will be filtered as per Table 1 in IEC 61724-2:2016, and 15-minute periods to be excluded if they do not meet the filtering criteria.

Power will be filtered as per Table 1 in IEC 61724-2:2016, and 15-minute periods to be excluded if they do not meet the filtering criteria.

4. All remaining 15-minute periods of averaged value data after filtering will be used for the performance test. Each valid 15-minute period will be simulated as an hour period in PVsyst.

Output: An excel spreadsheet with all the averaged 1-minute data points. The spreadsheet will include a column identifying which 1-minute data points will be excluded along with the reasons for exclusion, which could include one or more of the following (reasons to be concatenated where more than one applies):

- "Lack of 15 x 1-minute points"
- "Irradiance Out of Range"
- "Irradiance Dead Value"
- "Irradiance Stability"
- "Temperature Out of Range"
- "Temperature Dead Value"
- "Temperature Stability"
- "Power PoC Out of Range"
- "Power PoC Dead Value"
- "Power PoC Stability"

The final output will be an excel spreadsheet with all remaining (usable) 15-minute data points, which is what will be used as the input to PVSyst.

2.7 Performance Ratio Calculation

- The Design Performance Ratio will be calculated using the bifacial performance ratio calculation specified in IEC 61724-1
- The calculation will be performed by taking the sum of energy in the as-built PVSyst output files simulation (i.e. summing the energy from the two different PVSyst simulations) and dividing the total sum of energy by the amount of unconstrained DC energy that would be produced in the same timeframe (at STC) and correcting with the front and rear irradiance measured on the panels. Noting that this will have to take into account the North and South arrays having different front and potentially rear irradiances.
- The Actual Performance Ratio will be calculated using energy measurements from the site revenue meter and using the same calculation methodology as Design Performance Ratio.
- The Bifacial Performance Factor will be calculated from the Actual Performance Ratio and applying the view factor assumed in PVSyst to correct the actual rear irradiance.