Annexure – B

Performance Guarantee Measurement Test Procedure

Contents

1. INTRODUCTION

This document lays down the procedures and requirements for conducting Performance Guarantee tests including scope of the tests, procedures for the tests, Reporting Formats and process for determining test results in accordance with the Tender Specifications, Applicable standards and best practices.

Performance Guarantee (PG) test period would be continuous measurement of 30 consecutive days. The procedure of PG testing is described further in Section 5.

The report shall contain all the measured energy and Met data values, calculations, results and conclusions.

2. PERFORMANCE RATIO

The Efficiency or performance ratio (PR) of the PV Plant is calculated as follows (according to IEC 61724 Ed.2)

Performance Ratio:

$$PR = \frac{Y_A}{Y_R} * [1 - \alpha * (T_{average} - T_{cell})]$$

$Y_A = E_{ac} / P_{Nom}$

$Y_R = IR_{Site} / IR_{STC}$

Where,

Y_A = Final PV system yield (representing the number of hours that the system would need to operate at its rated output power P_{Nom} to contribute the same energy to the grid as was monitored.

Y_R = Reference yield (representing the number of hours during which the solar radiation would need to be at STC irradiance levels in order to contribute the same incident energy as was monitored).

E_{ac} = AC energy injected into the grid during a clearly specified amount of time (kWh).

P_{Nom} = Installed nominal peak power of modules (Nameplate rating at STC) (kWp);

IR_{Site} = Irradiation on the module plane of array during a clearly specified amount of time (measured with a pyranometer installed on the plane of array, POA) (kWh/sq. m)

IR_{STC} = Irradiance at STC (kW/ sq. m); 1000W/m^2

$T_{average}$ = Average cell/ module temperature (°C) over a period of time

T_{cell} = STC cell/ module temperature (°C); 25°C

α = temperature coefficient of power (negative sign) corresponds to the installed module (%/°C) (as per PV Module Datasheet)

3. GENERAL REQUIREMENT

- The PG test of power supply facility shall be carried out for a period of 30 consecutive days.
- These tests shall be binding on both the parties to the contract to determine compliance of the equipment with the guaranteed performance parameters.
- The test will consist of guaranteeing the correct operation of plant individually over 30 days, by the way of the performance ratio based on the reading of the energy produced and delivered to the grid and the average incident solar radiation.
- PR is calculated as per the formula given in Clause no. 2 and recorded as per the format provided at Annexure 1.
- All the end of each day, the filled-in format shall be signed by both the parties and each party will keep one copy for record. **The same will continue for 30 consecutive days and at the end of PG test period, the average of all the days will be calculated.**
- During this PG test, equipment failure/interruption of any kind will be considered and that day or part thereof will not be part of PG test period. The test will be continued once the complete system will be rectified and working properly. The test will extend exactly as number of breakdown days.

4. Pre-PG *TEST*

The EPC Contractor shall perform the PG start-up tests incorporating both visual inspection and functional testing. Such testing shall be conducted under the SECI's supervision. The test results shall be recorded as part of a signed-off commissioning record.

Preliminary Test Check:

The preliminary checks includes all the warranty certificates for the major equipment, pre – commissioning test reports, field quality checklists verified through the FQP documents of all equipment and works along with the calibration reports of all the instruments and sensors, wherever applicable.

Visual /Mechanical Test

Visual checks shall be done on all the components that form part of the plant including the grid connection equipment in compliance with the field quality plans. The following critical elements as a minimum shall be subjected to visual inspection:

- Module mounting structure and foundations.

- PV module and DC installation.
- Inverters.
- Transformers.
- Switchgear.
- Lightning protection systems.
- Earthing protection systems.
- Electrical protection systems, junction boxes and cabling.
- Grid connection compliance protection and disconnection systems.
- Monitoring systems (including meteorological sensors).

Electrical Tests

Subsequent to mechanical completion and visual testing of the plants, following functional electrical tests shall be performed. These tests also referred as start-ups tests shall be the first step for PG guarantee of the plant. These tests shall essentially include:

- Open circuit voltage (V_{OC}) test.

This test verifies that strings are properly connected (module and string polarity) and that all modules are producing the expected voltage according to the module data sheet. To measure Voc, the following procedure shall be used;

- DC string combiner box is opened; fuses leading to the sub main junction box are removed.
- The voltage is measured with a calibrated, industry accepted instrument from the negative bus bar to the string positive lead.
  Performance Guarantee Test for shall commence immediately after all issues arising from the functional/ start-up test have been rectified.

DC Side Voltage Drop: Maximum voltage-drop at full power from the PV modules to inverter should be less than 1.5% (including diode voltage drop). The detailed measurements and calculations shall be provided by the EPC Contractor.

Note:

a) All measurement(s) procedure should be carried out taking proper safety precaution.
b) Also it should be ensured that to avoid any loose connection at the terminal points for which measurement procedure is conducted.
c) Ensure proper functioning (e.g. Multimeters shall be calibrated) of all measuring instruments before conducting above measurement procedure.
d) The above test procedure shall be conducted in presence of site in-charge.

5. PG TEST *PROCEDURE*

The date of commencement of the PG Test Procedure shall be communicated in advance and agreed upon by both parties i.e. SECI and EPC Contractor. Any consecutive 30 Days period (excluding interruptions that last entire day on account of grid outage or as per hindrance record maintained at site only) for the purpose of conducting performance guarantee test shall be mutually discussed and agreed between SECI and EPC Contractor. It shall comprise of the following procedures:

Pre-test Procedure

1. Before the commencement of PG test, the plant shall have achieved visual/mechanical/Electrical completion and DC Voltage Drop functional requirements as per Clause 4 above and SCADA system and WMS shall be fully commissioned and functional.
2. Trial Run: The PG Test for Plant Facilities shall commence with a trial run for 7 consecutive days. The EPC Contractor shall provide the data in requisite formats (specified elsewhere in the document) to SECI. SECI shall vet the data for any discrepancies and systemic errors and revert within 3 working days. If and once the 7 day trial run is passed, the 30 day PR test will commence after communication from SECI in this regard. If the trial run fails, the trial run will start again after rectification and restoration of the system. The practice for trial run can follow for 3 times before the PR to continue. In case the contractor fails to achieve even trial run, the further action shall be taken as per the provisions of contract.
3. Pyranometer Tilt Angle & Cleanness: The pyranometers & Tilt Angle shall be verified before the test commences and **then visually inspected at regular intervals for cleanliness during the tests**.
4. All the calibration certificates for each measuring instruments which shall be used for PG test shall be checked and ensure that these certificates are up to date.

Following the completion of the pre-test procedures, Performance Guarantee Test of plant shall commence in accordance with the procedures, conditions and requirements provided in the next section.

General Procedure for the PG Test

The PG Test Procedure shall include the following components:

Data Collection:

PV Power Plant test related parameters are collected in one-minute and 15 intervals for the 30 (Thirty) days (consecutive) reference period. The data shall consist of the following at a minimum:

- Irradiance at Collector's (i.e. PV Module) POA; (Source: SCADA, Temporal Resolution: 1 minute)
- Other Met Data received from installed WMS ; (Source: SCADA, Temporal Resolution: 1 minute)
- Energy generated at Plant (kWh) (Source: Plant MFM Meter from SCADA, Temporal Resolution: 1 minute)
- Energy injected into grid (kWh) (Source: Plant ABT Meter at GSS/injection point, Temporal Resolution: 15 minute)
- PV Module Temperature recorded from the temperature Sensors (^{o}C) (Source: SCADA, Temporal Resolution: 1 minute)

Data Filtering:

The data shall be filtered so that the data set is free of nuisance data points and bad data that exhibit a high degree of error (such as errors caused by faulty instrumentation. The EPC Contractor shall document data which is to be eliminated along with reasons. The following criteria shall be excluded from the dataset used for this test:

- **Nuisance or bad data** – Nuisance data points or bad data that clearly exhibit a high degree of error including required meteorological measurement equipment that is identified as being out of calibration or requiring adjustment. A 15 minute time-block shall be *explicitly* flagged through a flag parameter on account of this factor after recording reasons thereof (**Note**: no filtration shall be done at site level). The same shall be corroborated/veriified by SECI.
- **Time blocks** with insufficient (less than equal to 10) 1-minute records.
- **Grid Interruptions** – Time periods (in 15 minute time blocks) of the grid interruptions at the utility substation, recorded manually jointly by EPC Contractor and SECI representatives shall be eliminated. Grid outage period, if any, shall be verified from SCADA.
- **Any Force majeure** condition
- **Radiation Criteria** – Radiation on Plane of Array (POA) less than 200 W/m2
- **Shutdown** explicitly demanded by the Owner/DISCOM/STU.
- As per the **hindrance record maintained at site.**

6. DETERMINATION OF PG TEST

Daily PR shall be calculated as the average of valid (i.e. time blocks not filtered as per 5.2.2) 15 minute time blocks for the 30 day duration. If the EPC Contractor is not able to demonstrate PG test during these this period they will be given one more chance to demonstrate the PG test after

incorporation of suitable corrective measures. In that case the steps for PG test shall be repeated again as above.

The test shall be repeated for 30 days in case of any outage of following equipment for more than 1 day.

- Power Transformer
- Power Conditioning Unit
- SCADA and data logger combined
- Tilted pyranometer
- Other WMS sensors.

7. RAW DATA FORMATS AND REPORTS

The EPC Contractor shall submit to SECI raw data from the Plant SCADA on a daily basis in the following format, at a minimum.

Temporal Resolution: 1 Minute:

Date & Time **Dd/mm/yyyy hh:mm:ss format**	**Wind Speed (m/s)**	**Module Temp. (° C)**	**Ambient Temp. (° C)**	**POA Radiation (K-Wh/m²)**	**POA Irradiance (W/m²)**	**Horizontal Irradiance (W/m²)**	**Humidity (%)**	**Wind Direction (°)**	**Generation(KW-h) (Source: MFM)**

Temporal Resolution: 15 Minute (Every 15th Min record from the 1 Min Data at 7.1):

Date & Time **Dd/mm/yyyy hh:mm:ss format**	**Wind Speed (m/s)**	**Module Temp. (° C)**	**Ambient Temp. (° C)**	**POA Radiation (K-Wh/m²)**	**POA Irradiance (W/m²)**	**Horizontal Irradiance (W/m²)**	**Humidity (%)**	**Wind Direction(°)**	**Generation (KW-h) (Source : MFM)**	**Generation (KW-h) (Source : ABT Meter)**	**Explicit Removal Flag* (0 or1)**	**Remarks**

***** Explicit Removal Flag: 0 indicates time block considered; 1 indicates time block not considered.

PR Test Report shall be generated from the Raw Data (Sample Report provided at Annexure 1 after data filtering as per criteria laid out in 5.2.2. The Report shall be contain the signature of both representatives (SECI/Employer & EPC Contractor).

Annexure 1

Reports

1. Project Overview

S. No.	Parameter		Details	
1	Solar PV plant Co ordinates		Latitude Longitude	
2	Plant AC capacity			
3	Plant DC Capacity			
4	PV Module Fixing Configuration			
5	PV Module Tilt Angle			
6	PV module Pitch Details			
7	Solar PV Module Ratings			
8	No of PV Module in Series per String			
9	Total no of Strings			
10	No of SMB			
11	String Monitoring Box Config			
12	Solar Inverter Technology			
13	Solar Inverter Ratings			
14	EPC Contractor			

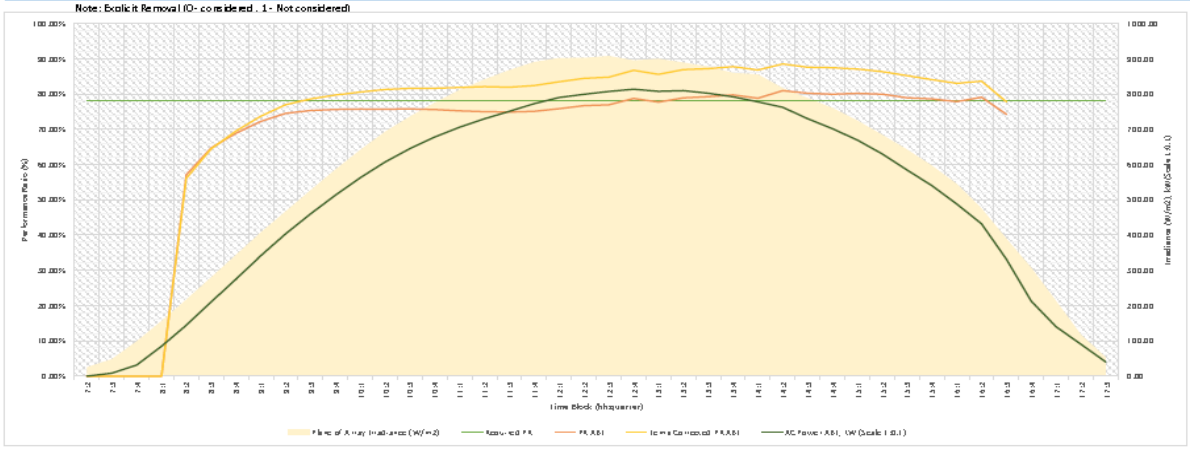
2. Sample Report

PR Guarantee Test Report

Day	20-Nov-2016	Criteria	>200	Average POA Irradiance in a time block in W/m2
No. of Timeblocks considered	36 /42	Tot Gen	53694 kWh	Source: ABT Meter at GSS
Plant PR for the day ABT	80.66%	Average PR (temp corrected) of 15 min time blocks where POA irradiance is greater than 200W/m2 and not explicitly removed		
	(Guaranteed PR: 78%)			

Time Block (hh:Qtr)	Wind Speed (m/s)	Module Temp. (°C)	Ambient Temp. (°C)	POA Radiation (kWh/m2)	Plane of Array Irradiance (W/m2)	GHI (W/m²)	Humidity (%)	Wind Direction (°)	Generation ABT GSS (KWh)	AC Power ABT, kW (Scale 1:0.1)	PR ABT	Temp Corrected PR ABT	Explicit Removal
7:2	1.62	13.91	15.10	2.17	25.25	27.00	45.92	88.10	0.00	0.00	0.00%	0.00%	0
7:3	1.41	14.47	15.25	12.34	47.92	50.47	45.53	38.35	21.00	8.40	14.73%	14.10%	0
7:4	0.57	15.84	15.73	25.08	98.48	92.93	44.41	0.00	79.00	31.60	27.27%	26.24%	0
8:1	0.26	17.73	16.01	39.51	156.11	143.67	44.55	0.00	212.00	84.80	46.45%	45.07%	0
8:2	0.66	20.64	17.01	54.73	216.78	193.67	42.19	0.00	361.00	144.40	57.10%	56.08%	0
8:3	0.43	24.09	17.94	70.40	279.62	245.80	40.17	0.00	526.00	210.40	64.69%	64.45%	0
8:4	0.71	27.22	18.85	86.46	343.62	291.80	38.39	0.00	688.00	275.20	68.90%	69.52%	0
9:1	0.71	29.93	19.74	102.34	407.36	348.47	36.74	0.00	854.00	341.60	72.25%	73.71%	0
9:2	0.71	32.98	20.73	117.25	466.99	398.00	35.17	0.00	1009.00	403.60	74.51%	76.95%	0
9:3	0.80	35.60	21.52	132.29	527.14	445.27	33.94	0.00	1151.00	460.40	75.33%	78.61%	0
9:4	0.74	38.17	22.31	146.86	585.56	486.27	32.98	0.00	1283.00	513.20	75.64%	79.72%	0
10:1	0.87	40.55	23.23	160.77	641.34	516.87	31.86	0.00	1406.00	562.40	75.72%	80.54%	0
10:2	0.93	42.99	24.08	173.62	692.91	540.33	31.13	0.00	1518.00	607.20	75.70%	81.28%	0
10:3	0.99	43.78	24.78	184.38	736.02	559.67	30.67	0.00	1613.00	645.20	75.74%	81.57%	0
10:4	1.18	44.44	25.53	194.12	775.43	576.53	29.87	12.76	1695.00	678.00	75.60%	81.63%	0
11:1	1.05	46.52	26.17	203.12	811.43	593.60	28.97	0.00	1765.00	706.00	75.23%	81.87%	0
11:2	0.89	48.11	26.74	210.57	841.02	609.07	28.28	0.00	1824.00	729.60	75.00%	82.10%	0
11:3	1.51	47.95	27.61	217.05	867.66	624.60	26.97	0.00	1877.00	750.80	74.87%	81.92%	0
11:4	2.03	48.74	28.04	222.77	890.54	642.47	25.69	76.95	1932.00	772.80	75.09%	82.40%	0
12:1	1.61	49.61	28.91	225.54	902.04	656.13	24.24	0.00	1975.00	790.00	75.82%	83.47%	0
12:2	2.03	49.58	29.45	225.55	902.30	664.40	22.97	129.40	1998.00	799.20	76.69%	84.42%	0
12:3	2.34	49.79	29.73	227.09	907.75	672.60	21.62	131.02	2018.00	807.20	76.94%	84.75%	0
12:4	2.48	49.66	29.92	223.65	895.29	671.87	20.71	96.20	2034.00	813.60	78.74%	86.70%	0
13:1	2.10	49.70	30.20	224.96	899.51	670.93	18.75	0.00	2019.00	807.60	77.71%	85.57%	0
13:2	2.32	49.80	30.31	222.11	889.25	665.80	18.11	22.42	2024.00	809.60	78.90%	86.92%	0
13:3	2.59	49.39	30.42	219.07	877.23	649.13	17.75	219.19	2005.00	802.00	79.24%	87.17%	0
13:4	2.22	49.55	30.70	215.00	859.72	630.67	17.39	0.00	1980.00	792.00	79.73%	87.76%	0
14:1	1.87	49.88	30.98	213.62	855.38	620.80	16.27	0.00	1944.00	777.60	78.79%	86.83%	0
14:2	2.27	47.80	31.28	203.86	816.52	584.27	16.13	19.15	1906.00	762.40	80.95%	88.51%	0
14:3	2.30	47.34	30.99	196.95	788.89	548.20	16.46	38.30	1825.00	730.00	80.23%	87.58%	0
14:4	2.05	47.88	31.01	189.95	760.16	520.20	16.53	7.33	1754.00	701.60	79.95%	87.45%	0
15:1	1.75	45.99	31.44	180.73	724.65	484.80	15.75	0.00	1674.00	669.60	80.19%	87.10%	0
15:2	2.30	44.51	31.33	170.69	684.26	442.27	15.51	95.39	1576.00	630.40	79.94%	86.34%	0
15:3	2.10	44.35	31.19	160.33	642.47	402.40	15.57	28.93	1462.00	584.80	78.95%	85.21%	0
15:4	2.33	41.86	31.19	148.67	596.65	358.47	15.41	45.73	1350.00	540.00	78.62%	84.06%	0
16:1	1.91	41.25	31.19	135.70	544.70	311.80	15.33	90.91	1220.00	488.00	77.84%	83.02%	0
16:2	2.37	38.99	31.12	118.23	475.45	255.73	14.96	5.47	1080.00	432.00	79.09%	83.62%	0
16:3	2.57	36.66	30.95	96.68	389.67	195.27	15.01	86.82	829.00	331.60	74.24%	77.79%	0
16:4	1.60	34.83	30.62	70.86	306.83	143.86	15.44	76.91	531.00	212.40	64.88%	67.50%	0
17:1	1.56	32.61	30.19	52.45	212.88	92.47	15.59	63.97	350.00	140.00	57.78%	59.58%	0
17:2	1.75	29.57	29.68	26.61	117.56	48.14	15.94	103.66	226.00	90.40	73.53%	74.91%	0
17:3	0.84	27.22	28.80	4.19	52.66	21.40	16.82	0.00	100.00	40.00	206.71%	208.59%	0

Note: Explicit Removal (0- considered , 1- Not considered)



Remarks: [to be recorded, if any]