SUB-SECTION D

GENERAL ANNEXURE J

Functional Guarantee Test Procedure

TABLE OF CONTENTS (to be updated)

O&M TARGET GENERATION TEST

1 INTRODUCTION

To ensure proper functionality of the plant against operational acceptance milestone, and to ensure proper O&M during O&M Period, there shall be an O&M Target Generation Test for **THREE** months. The test shall be conducted at Site by the Contractor in presence of the Employer as described in this document. This test shall be binding on all the parties of the Contract. Any consecutive **three months** period after the successful commissioning of the plant, as mutually agreed by Owner and Contractor, shall be considered for conducting the O&M Target Generation Test (OTGT).

During O&M Target Generation Test, contractor shall be responsible for operation and maintenance of the plant so that the plant is running in the most optimum operation and generating in line with the designed parameters. The target generation for O&M shall be determined after the completion of O&M Target Generation test.

The Functional Guarantee shall comprise of following:

(i) Visual/mechanical/Electrical checks

(ii) O&M Target Generation Test (OTGT)- Verification of Actual Generation against the Expected generation

The OTGT is intended to:

(i) Facilitate operational acceptance of the plant

(ii) Establish the target generation for the O&M period

This document lays down the procedures and requirements for conducting O&M Target Generation test including scope of the test, procedures for the test, reporting formats and process for determining test results in accordance with the Tender Specifications, applicable standards and industry best practices.

2 PRE OTGT

2.1 The EPC Contractor shall perform start-up tests after completion of Commissioning and Test Procedure as per General Annexure – I: Plant Documentation, Commissioning and Test Procedure and recording of punch points**.**

2.2 O&M Target Generation Test shall commence immediately after all issues arising from the functional/ start-up test have been rectified.

Note:

(a) All measurement(s) shall be carried out taking proper safety precaution.

(b) Also, it shall 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 accuracy class of the instrumentation shall be as per the relevant clause of SS-B: TS-Electrical.

(e) Pyranometers used for measurement of GHI shall be calibrated.

(f) The above test procedure shall be conducted in presence of site in-charge.

3 GENERAL REQUIREMENTS

3.1 The O&M target generation test shall commence within 60 days of the commissioning of plant facilities.

3.2 The OTGT shall be carried out for a period of 90 days at site by the contractor in presence of the employer/ employer's representative/ owner's engineer.

3.3 The dates of commencement of the OTGT shall be communicated to BOS Contractor and agreed upon by both parties i.e. Owner and EPC contractor. Any consecutive 90 days period (excluding interruptions that last entire day on account of grid outage or as per hindrance record maintained at site or weather conditions) for the purpose of conducting OTGT shall be mutually discussed and agreed between Owner and BOS contractor.

3.4 These tests shall be binding on both the parties to the contract for plant's operational acceptance as well as to determine O&M target generation.

3.5 The test shall consist of guaranteeing the target generation of the plant facilities, which is determined during the detailed engineering phase as per relevant clause, and based on the reading of the energy produced and delivered to the grid (ABT meter) and the global horizontal solar irradiation**.**

3.6 Any special equipment, instrumentation, tools, tackles, and manpower required for successful conduct of OTGT shall be arranged and provided by the Contractor at no additional cost to the Employer.

4 OTGT TEST REQUIREMENTS

4.1 Before the commencement of OTGT, the plant shall have completed pre-OTG tests as per **Clause 2** above and SCADA system and WMS shall be fully commissioned and functional.

4.2 Pyranometer Cleanness: The pyranometers shall be verified before the test commences and then visually inspected at regular intervals for cleanliness during the tests.

4.3 The Pyranometers and any other sensors used for the purpose of the PG Test shall have valid calibration

certificates.

4.4 Bidder shall follow the benchmark O&M practices during the OTGT.

4.5 Average Reading of all the Pyranometers supplied shall be considered for Measurement of Global Horizontal Solar Irradiation for the site. (Erratic / erroneous data from any of the pyranometers may be excluded for the purpose of GHI measurement at site)

5 GENERAL PROCEDURE FOR THE OTGT

5.1 **Data Collection:** The EPC Contractor shall provide the raw data as per **Annexure-1 (Format for Raw Data Submission)** to Owner. PV Power Plant test related parameters are collected in one-minute and 15 intervals for the 90 (Thirty) days reference period. The data shall consist of the following at a minimum:

- Irradiance at Horizontal Plane (GHI); (Source: SCADA, Temporal Resolution: 1 minute) (Average Reading of all the Pyranometers supplied under the scope of work will be considered)
- Other Met Data received from installed WMS; (Source: SCADA, Temporal Resolution: 1 minute)
- Energy generated at Plant (kWh) (Source: Plant TVM Meter from SCADA, Temporal Resolution: 1 minute)
- Energy exported into grid (kWh) (Source: Plant End ABT Meter, Temporal Resolution: 15 minute)
- Auxiliary Energy imported from grid (kWh) (Source: Plant End ABT Meter or separate meter for Auxiliary consumption, Temporal Resolution: 15 minute)
- PV Module Temperature recorded from the temperature Sensors (°C) (Source: SCADA, Temporal Resolution: 1 minute) (Average Reading of all the Temperature Sensors supplied under the scope of work will be considered)

5.2 **MEASUREMENT OF DAILY GENERATION**

- Plant generation measured at plant end ABT meter (**15-min time-block wise)**
- The same shall be recorded on daily basis from **0:00 am to 11:59 pm** as per the format provided at **Annexure-2: Sample for Daily Generation Report**
- This exercise shall be carried out & recorded for a period of 90 consecutive days for calculation of **OTF**.
- The filled-in format (Daily Generation Report) shall be signed by both the parties (EPC Contractor and Owner) and each party will keep one copy for record.

5.3 **RADIATION CORRECTION FACTOR (RCF):**

5.3.1 Adjustment due to Grid Outage: The measured global horizontal irradiance (kW/m^2) for the period of grid outage shall be excluded to estimate the cumulative measured global horizontal irradiation (GHI_m) (kWh/m^2) for the period of Target Generation Test. Under such situation, the radiation corresponding to the warm-up time of inverter as per data sheet shall also be adjusted to arrive at the cumulative global insolation for the OTGT period.

Note: The Contractor shall submit grid outage certification from competent authority of STU/CTU/DISCOM.

5.3.2 The Measured GHI (GHI_m) shall be calculated from the recorded irradiance values from the Pyranometer installed in horizontal plane at the site location (average in case of multiple pyranometers). This measured GHI (GHI_m) data shall be compared with the Reference GHI (GHI_{ref}) (mentioned in **SA-B: Project Specific Technical Details** of Tender Document) to estimate the **Radiation Correction Factor (RCF)** which is calculated as follows-

$$RCF = \frac{Measured\ \ GHI\ (GHI_m)}{Reference\ GHI\ (GHI_{ref})}$$

Note:

1. If the O&M Target Generation Test is performed over 90 days across four consecutive months, the Reference Target Generation should be determined on a pro-rata basis, based on the number of days in each month. The radiation data from the Plant Pyranometer shall be used for computation, except in case of any discrepancy (i.e. more than ± 10% variation from the Reference Irradiation, GHI_{ref}), in which case the radiation data from SolarGIS database for the said period will be used for computation.
2. RCF shall be rounded off to 3 decimal places

5.3.3 In case GHI data is not available from any of the Plant Pyranometers, the same shall be substituted by average of GHI measured for the same period in the past three (3) days or the test shall be extended for affected no. of days (**up to 15 days**) as decided by Owner.

5.3.4 All the plant Pyranometers shall be under CCTV coverage.

5.4 COMPUTATION OF UPDATED TARGET GENERATION (GT):

The **Reference Target Generation (G_{T_ref})** (P75 value) which is estimated during Detailed Engineering Phase as per **SA-B: Project Specific Technical Details** of Tender Document shall be radiation corrected to compute the **Updated Target Generation (G_T).** The formula for calculation of Updated Target Generation (G_T) is mentioned below:

$$G_T = RCF \times G_{T\_ref}$$

5.5 ESTIMATION OF ACTUAL GENERATION (Ga):

The Actual Generation (G_a) at the Plant End ABT meter shall be noted at regular intervals which shall be calculated for OTGT period as follows –

$$G_a = E_{export} - E_{aux}$$

Where,

- E_{export}: Energy export recorded in the Plant End ABT meter
- E_{aux}: Energy Import recorded (due to auxiliary consumption)

5.6 COMPUTATION OF OTG TEST FACTOR (OTF):

This Actual Energy exported (G_a) at the Plant End ABT meter shall be compared with Updated Target Generation (G_T) of the test period to calculated the **OTG Test Factor (OTF)**. The **OTF** of the plant facility shall be calculated for the OTGT period as per following formula:

$$OTF = \frac{Actual\ Generation\ (G_a)}{Updated\ Target\ Generation\ (G_T)}$$

Note: OTF value calculated in above shall be used for calculation of Target Generation During O&M Period **(G_{Tn})** (where n is the year of operation of the plant i.e., n- 1, 2,3, 4, etc.) as per relevant clause of **SS-F: O&M Agreement** of the tender document upon successful completion of OTGT test.

6 OTGT Pass/Fail Criterion:

6.1.1 For **successful O&M Target Generation Test, $OTF \geq 1$,** i.e., Actual Generation (G_a) at the Plant End ABT meter shall be greater than or equal to Updated Target Generation (G_T) for 90 days* of OTGT period.

Note: * 90 days excluding any interruption due to rainy/cloudy day or allowable interruptions as per this document.

6.1.2 During the OTGT, equipment failure/interruption of any kind, except for SCADA communication failures, will not be accountable. In case of such breakdown, the test may be resumed once the complete system is rectified and working properly (max 15 days beyond 90 days for any reason identified in this document).

6.1.3 If bidder is not able to demonstrate the same (OTF>=1), BoS Contractor shall be given **one more** chance to demonstrate the test, after carrying out necessary modifications/ replacement/O&M practices and after carrying out root cause analysis for the shortfall. In case the contractor fails to demonstrate the Successful OTGT even after the second chance, further action shall be taken as per the provisions of contract. (i.e, Liquidated Damages shall be applicable to contractor as per relevant clause of this document.)

6.1.4 The test shall be repeated for 90 days in case of any outage of following equipment (as applicable) for more than 7 days:

(i) Power Transformer/Inverter Duty Transformer
(ii) Power Conditioning Unit
(iii) HT Switchgear Panel
(iv) SCADA and data logger combined
(v) All the Horizontal Pyranometers
(vi) Other WMS sensors (if required)

6.2 **IN CASE OF SHORTFALL DURING TARGET GENERATION TEST (I.E., OTF<1):**

6.2.1 In case, the shortfall during OTGT is due to the Non-performance of the PV Modules, contractor shall be responsible for bringing the issue to the notice of the Employer at the earliest with necessary evidence should be provided to the Employer, clearly showing that the shortfall in generation during OTGT is due to PV Modules and not attributable to the Systems supplied by the contractor, erection issues and/or O&M practices followed by contractor during OTGT,

6.2.2 In case the Contractor fails to demonstrate that shortfall is due to non-performance of the PV Modules, supply, testing and commissioning of additional plant capacity (approved by the Employer), including PV Modules and Balance of Plant to meet the target generation shall be in the scope of the Contractor. Alternatively, the Contractor shall be liable for Liquidated Damages for shortfall in generation over the Plant life as per relevant clause of this document.

7 LIQUIDATED DAMAGES FOR SHORTFALL IN GENERATION DURING OTGT

7.1 **FOR SHORTFALL IN OTGT (OTF<1)**: Liquidated damages (LD) of amount equal to the NPV of the estimated shortfall in cash flow resulting over the period of 25 years due to shortfall in actual generation against target generation, calculated at a tariff of Rs. 2.57 per unit (kWh) and discount rate of 6.8% shall be levied.

7.2 In case the above LD amount is more than the amount against 'Operational Acceptance Milestone' in line with the defined payment terms, then the total plant will be accepted on "as-is basis" & no payments will be made to the contractor pertaining to 'Operational Acceptance Milestone'. OTF value calculated during OTGT shall be accepted for calculation of Target Generation during O&M period (G_{Tn}) as per relevant clause of SS-F: O&M Agreement of the tender document. However, any other earlier pending/running payments as may be applicable, will be paid to the contractor as usual.

7.3 Cumulative value of the liquidated damages shall be limited to 'operation acceptance' milestone in line with the defined payment terms.

8 ILLUSTRATION

Sample OTF Calculation and calculations of shortfall/excess in energy generation during O&M **Target Generation** Test for **200MW plant** with is given below-

8.1 **OTGT Period** – 12th March, 2025 to 9th June, 2025 (90 Days)

8.1.1 Sample Target Generation for 200MW plant for the site for different months are mentioned in the table below:

Month	March	April	May	June	Total
Reference GHI of the month as per tender clause) (a)	206.7	214.2	225.2	164.9	811.00 kWh/m2
Reference Target Generation for 200MW Plant as per approved PVSyst Report during detailed Engineering (GTref) (b) (*)	46,410.00	44,440.00	44,660.00	33,260.00	1,68,770.00 MWh
No of test days in a Month (c)	20	30	31	9	90.00
No of Days in a Month (d)	31	30	31	30	
Reference GHI for OTG Test Period (GHIref) (e)=(c)x(a)/(d)	133.4	214.2	225.2	49.5	622.2 kWh/m2
Reference Target Generation for OTG Test Period (GTref) (f)=(c)x(b)/(d)	29,941.94	44,440.00	44,660.00	9,978.00	1,29,019.94 MWh
Measured GHI at Site (GHIm) (g)	130.0	220.0	230.0	50.0	630.0 kWh/m2

Note: *Generation assumed above for illustration purpose only and shall be finalized during Detailed Engineering (as per approved DBR).

Cumulative Reference Solar Insolation for OTGT Period, i.e. 90 days (A)=∑(e)	622.22 kWh/m2
Cumulative Reference Target Generation for OTGT Period (B)=∑(f)	1,29,019.94 MWh
Cumulative Measured GHI at Site (C) =∑(g)	630.00 kWh/m2
Radiation Correction Factor (RCF) for OTGT Period (D)=(C)/(A)	1.012
Updated Target Generation (GT) for OTGT period (E)=(B)x(D)	130568.17 MWh

Case (1) OTF>=1:

If Actual Generation at site during OTGT Period (Ga) = 1,31,000.00 MWh;

Then O&M Test factor (OTF)=(Ga)/(E) = 1.003

Here, OTF>=1; O&M Target Generation test is successfully completed.

OTF= 1.003 (rounded off to 3 decimal places) **shall be accepted for O&M Period Generation Guarantee.**

Case (2) OTF<1:

If Actual Generation at site during OTGT Period (Ga') = 1,25,000.00 MWh;

Then O&M Test factor (OTF)=(Ga')/(E) = 0.957

Here, OTF<1; Therefore, Liquidated Damage may be applicable as below-

Liquidated Damage Calculations-

Shortfall in Generation during OTGT Period (i.e., 90 days) (H)=(E)-(Ga') = 5,568.17 MWh

Shortfall in Generation for Entire Year (i.e., 365 in case of non-leap year) (I)=(H)x365/90 = 22,582.04 MWh

Ceiling Tariff (J) = 2.57 Rs/kWh

Estimated Revenue Loss in a year due to Shortfall in generation (K)=(I)x(J) = ₹ 580.36 Lakhs

NPV of the estimated shortfall in cash flow resulting over the period of 25 years (at 6.8% of discount rate) (L) = ₹ 6,886.88 Lakhs

Let us assume - Payment against Successful completion of Milestone against Operational Acceptance (M) is ₹ 2,400.00 Lakhs

LD applicable as per Clause 7 = ₹ 2,400.00 Lakhs

OTF= 0.957 (rounded off to 3 decimal places) **shall be accepted for O&M Period Generation Guarantee.**

Case (3) OTF<1:

If Actual Generation at site during OTGT Period (Ga') = 1,30,000.00 MWh;

Then O&M Test factor (OTF)=(Ga')/(E) = 0.996

Here, OTF<1; Therefore, Liquidated Damage may be applicable as below-

Liquidated Damage Calculations-

Shortfall in Generation during OTGT Period (i.e., 90 days) (H)=(E)-(Ga') = 568.17 MWh

Shortfall in Generation for Entire Year (i.e., 365 in case of non-leap year) (I)=(H)x365/90 = 2,304.26 MWh

Ceiling Tariff (J) = 2.57 Rs/kWh

Estimated Revenue Loss in a year due to Shortfall in generation (K)=(I)x(J) = ₹ 59.22 Lakhs

NPV of the estimated shortfall in cash flow resulting over the period of 25 years (at 6.8% of discount rate) (L) = ₹ 702.73 Lakhs

Let us assume - Payment against Successful completion of Milestone against Operational Acceptance (M) is **₹ 2,400.00 Lakhs.**

LD applicable as per Clause 7 = ₹ 702.73 Lakhs

OTF= 0.996 (rounded off to 3 decimal places) **shall be accepted for O&M Period Generation Guarantee.**

Annexure -1 (Format for Raw Data Submission)

Temporal Resolution: 1 Minute

Date & Time dd/mm/yyyy hh:mm:ss format	Wind Speed (m/s)	Module Temp. (°C)	Ambient Temp. (°C)	Horizontal Irradiance (W/m²)	POA Irradiance (W/m²)	GHI (kWh/m²)	Humidity (%)	Wind Direction (°)	Generation (kWh) (Source: TVM)

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

Date & Time Dd/mm/yyyy hh:mm:ss format	Wind Speed (m/s)	Module Temp. (° C)	Ambient Temp. (° C)	Horizontal Irradiance (W/m²)	POA Irradiance (W/m²)	GHI (kWh/m²)	Humidity (%)	Wind Direction(°)	Generation (kWh) (Source: TVM)	Remarks