

SUB-SECTION D

GENERAL ANNEXURE H

Functional Guarantee Test Procedure

TABLE OF CONTENTS

FUNCTIONAL GUARANTEE TEST	3
1 INTRODUCTION	3
Section I	4
O&M TARGET GENERATION TEST	4
1 PRE OTGT	4
2 GENERAL REQUIREMENTS	5
3 OTGT TEST REQUIREMENTS	5
4 GENERAL PROCEDURE FOR THE OTGT	5
5 OTGT Pass/Fail Criterion:	10
6 LIQUIDATED DAMAGES FOR SHORTFALL IN GENERATION DURING OTGT	10
7 ILLUSTRATION	12
Section II	15
BESS SYSTEM RATING VERIFICATION	15
1 Energy Content Test	15
2 Round-trip Efficiency	17
3 Step Response Test: Step Response Time and Ramp Rate	18
4 Auxiliary Power Consumption Test	21
5 Liquidated Damages due to shortfall of Round-Trip Efficiency during PG Test: -	22

FUNCTIONAL GUARANTEE TEST

1 INTRODUCTION

To ensure proper functionality of the plant facilities against Operational Acceptance Milestone, and to ensure proper Operation & Maintenance (O&M) during O&M Period, there shall be a Functional Guarantee (FG) Test. The FG Test shall be conducted at Site by the Contractor, in the presence of the Employer/Owner's Engineer, as described in this document. The FG Test shall be conducted after successful commissioning of the Plant, and as mutually agreed between the Owner and the Contractor.

During the FG Test, the Contractor shall be responsible for the operation and maintenance of the Plant Facilities so as to ensure that the Plant is running in the most optimum manner and generating in line with the designed parameters. The final target generation applicable for the O&M Period shall be determined upon successful completion of the O&M Target Generation Test.

The Functional Guarantee for the Plant Facilities shall comprise of following two tests:

1.1 O&M TARGET GENERATION TEST (OTGT)

Verification of the Actual Generation of the Solar PV Plant against the Expected/Target Generation, carried out over a continuous period of ninety (90) days at Site. This test establishes the OTG Test Factor (OTF), which is used both to determine successful Operational Acceptance of the Plant and to benchmark the Target Generation for subsequent years of the O&M Period. Liquidated Damages, where applicable, shall be levied for any shortfall in generation identified during this test, in accordance with the procedure and formulae detailed in Section I.

1.2 BESS SYSTEM RATING VERIFICATION TEST

BESS System Rating Verification shall include the following tests:

- (i) Energy Content Test
- (ii) Round-Trip Efficiency (RTE)
- (iii) Step Response Time
- (iv) Ramp Rate
- (v) Auxiliary Power Consumption

The Energy Content Test and Round-Trip Efficiency (RTE) Demonstration shall meet the acceptance criteria specified in the Scope of Work (SoW) of this Tender Document. The remaining tests shall be performed for compliance towards completing the FG Test for BESS. In the event that the demonstrated Energy Content does not comply with the SoW requirements, the Contractor shall, at no additional cost to the Employer, deploy additional BESS capacity toward meeting the Plant's operational acceptance criteria. Liquidated Damages, where applicable, shall be levied for any shortfall in the guaranteed Round-Trip Efficiency, in accordance with the procedure and formulae detailed in Section II.

Section I

O&M TARGET GENERATION TEST

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 **Ninety (90) Days**. 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 **Ninety (90) Days** 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 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.

1 PRE OTGT

- 1.1 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.
- 1.2 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.

2 GENERAL REQUIREMENTS

- 2.1 The O&M target generation test shall commence within 60 days of the commissioning of plant facilities.
- 2.2 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.
- 2.3 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.
- 2.4 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.
- 2.5 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 and the global horizontal solar irradiation.
- 2.6 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.

3 OTGT TEST REQUIREMENTS

- 3.1 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.
- 3.2 Pyranometer Cleanness: The pyranometers shall be verified before the test commences and then visually inspected at regular intervals for cleanliness during the tests.
- 3.3 The Pyranometers and any other sensors used for the purpose of the PG Test shall have valid calibration certificates.
- 3.4 Bidder shall follow the benchmark O&M practices during the OTGT.
- 3.5 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)

4 GENERAL PROCEDURE FOR THE OTGT

- 4.1 **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 (Ninety) 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 (220kV) (kWh) (Source: Plant End ABT Meter at POI, Temporal Resolution: 15 minute)
- Energy exported into grid (33kV) (kWh) (Source: TVM meters at 33 kV Solar Feeder at CMCS Pooling Switchgear, 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 ($^{\circ}\text{C}$) (Source: SCADA, Temporal Resolution: 1 minute) (Average Reading of all the Temperature Sensors supplied under the scope of work will be considered)

4.2 MEASUREMENT OF DAILY GENERATION

- Solar Plant generation measured both at plant end ABT meter and TVM meters of 33 kV Solar Feeders at CMCS Pooling Switchgear (**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.

4.3 RADIATION CORRECTION FACTOR (RCF):

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.

- 4.3.1 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-

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

Note:

- (a) 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 $\pm 10\%$ 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.
- (b) RCF shall be rounded off to 3 decimal places
- 4.3.2 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.
- 4.3.3 All the plant Pyranometers shall be under CCTV coverage.

4.4 COMPUTATION OF UPDATED TARGET GENERATION (G_T):

The **Reference Solar Target Generation ($G_{TS_{ref}}$)** (P90 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)** exclusive of BESS. The formula for calculation of Updated Target Generation (G_T) is mentioned below:

$$G_T = (RCF \times G_{TS_{ref}})$$

- $E_{BESS,ref}$: Energy discharge by BESS as per detailed engineering
- RTE_{ref} : Round Trip efficiency of BESS as per detailed engineering

4.5 ESTIMATION OF ACTUAL GENERATION (G_a):

4.5.1 Metering point for Solar PV Plant shall be as per the Scope of Works of this Tender Document

4.5.2 The Actual Generation (G_a) at the TVM meter at the 33 kV Solar Feeder in the CMCS Pooling Switchgear (Refer SA – B - Indicative Single Line Diagram (SLD)) shall be noted at regular intervals which shall be calculated for OTGT period as follows

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

Where,

- $\sum E_{export}$: Net Energy export recorded at the TVM meter at the 33 kV Solar Feeder in the CMCS Pooling Switchgear (Refer SA – B - Indicative Single Line Diagram (SLD)) (Exclusive of BESS discharge)
- E_{aux} : Net Energy Import recorded (due to auxiliary consumption of Solar Plant)

4.6 ESTIMATION OF DEEMED GENERATION ON ACCOUNT OF CURTAILMENT (G_{deemed})

4.6.1 The Deemed Generation (G_{deemed}) shall be estimated for any curtailment event occurring during the OTGT period where the Solar Power Plant's generation is curtailed due to grid constraints arising from increased wind power injection at a different feeder connected to the same 33 kV CMCS Pooling Switchgear.

4.6.2 The G_{deemed} shall be calculated based on the Energy Gap Filling Method as follows:

$$G_{deemed} = G_{avg} - G_{actual_curtailed}$$

Where,

- G_{avg} : Average energy generation of the Solar Power Plant during the time interval/period of the curtailment event, computed over the past 10 days of un-curtailed operation preceding the curtailment event
- $G_{actual_curtailed}$: Actual energy recorded in the TVM meters at the 33 kV Solar Feeders in the CMCS Pooling Switchgear during the curtailment period

4.6.3 Conditions for applicability of Deemed Generation

- (i) Only those days where no curtailment event occurred shall be considered for computing G_{avg} . Any day with a curtailment event in the preceding 10-day window shall be excluded and replaced by the next available un-curtailed day going further back.
- (ii) The curtailment event shall be duly evidenced by SCADA logs, ABT meter data, and written curtailment instruction from SLDC/DISCOM/Pooling Station operator.
- (iii) The curtailment shall be solely attributable to grid-side constraints at the 33 kV CMCS Pooling

Switchgear and not due to any fault, outage, or underperformance of the Solar Power Plant.

- (iv) The quantum of G_{deemed} so computed shall be mutually verified and certified by the Owner and the Contractor/Testing Authority prior to its inclusion in Adjusted Actual Generation (G_{a_adj}).

4.7 COMPUTATION OF OTG TEST FACTOR (OTF):

The **Adjusted Actual Generation** (G_{a_adj}), obtained by adding the **Deemed Generation** (G_{deemed}) corresponding to periods of grid curtailment to the **Actual Generation** (G_a) shall be compared with **Updated Target Generation** (G_T) for the OTG test period to determine the **OTG Test Factor (OTF)**.

The **OTG Test Factor (OTF)** shall be calculated as follows:

$$OTF = \frac{\text{Adjusted Generation } (G_{a_adj})}{\text{Updated Target Generation } (G_T)}$$

Where,

- G_{a_adj} : Adjusted Actual Generation, calculated by adding the Deemed Generation (G_{deemed}) corresponding to periods of grid curtailment to the Actual Generation (G_a) measured at the 33 kV Solar Feeders in the CMCS Pooling Switchgear.

The Adjusted Actual Generation shall be calculated as:

$$G_{a_adj} = G_a + G_{deemed}$$

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.

5 OTGT Pass/Fail Criterion:

5.1.1 For **successful O&M Target Generation Test**, $OTF \geq 1$, i.e., Adjusted Actual Generation (G_{a_adj}) at the 33 kV Solar Feeders in the CMCS Pooling Switchgear 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.

5.1.2 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).

5.1.3 In case the Bidder fails to demonstrate the required performance ($OTF \geq 1$), the BoS Contractor shall be allowed one additional opportunity to demonstrate compliance. Prior to the re-test, the BoS Contractor shall carry out root cause analysis and implement necessary corrective measures, including modification or addition of PV modules, replacement or augmentation of Balance of Plant equipment, and/or changes in O&M practices, as required to achieve the target generation.

5.1.4 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)

5.1.5 In case the contractor fails to demonstrate the Successful OTGT even after the second chance, the Contractor shall be liable for Liquidated Damages for shortfall in generation over the Plant life as per relevant clause of this document.

6 LIQUIDATED DAMAGES FOR SHORTFALL IN GENERATION DURING OTGT

6.1 **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. 4.5 per unit (kWh) and discount rate of 6.93 % shall be levied.

6.2 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 Updated 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.

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

7 ILLUSTRATION

Sample OTF Calculation and calculations of shortfall/excess in energy generation during O&M **Target Generation Test for 70 MW Solar Power Plant with 50 MWh BESS** is given below-

7.1 **OTGT Period** – 12th March, 2026 to 9th June, 2026 (90 Days)

7.1.1 Sample Target Generation for 70 MW 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)	213	205	200	157	775.00 kWh/m ²
Reference Target Generation for 70MW Plant as per approved PVSyst Report during detailed Engineering (GTref) (b) (*)	12,800.00	12,300.00	12,000.00	11,600.00	48,700.00 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 (GHlref) (e)=(a)x(c)/(d)	137.42	205.00	200.00	47.10	589.52 kWh/m ²
Reference Target Generation for OTG Test Period (GTref) (f)=(c)x(b)/(d)	8,258.06	12,300.00	12,000.00	3,480.00	36,038.06 MWh
Measured GHI at Site (GHIm) (g)	135.0	205.0	210.0	50.0	600.0 kWh/m ²

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)= $\sum(e)$	589.52 kWh/m ²
Cumulative Reference Target Generation for OTGT Period (B)= $\sum(f)$	36,038.06 MWh
Cumulative Measured GHI at Site (C) = $\sum(g)$	600.00 kWh/m ²
Radiation Correction Factor (RCF) for OTGT Period (D)=(C)/(A)	1.018
Updated Target Generation (GT) for OTGT period (E)=(B)x(D)	36,686.75 MWh

Case (1) OTF $\geq$ 1:

If Actual Generation at site during OTGT Period (G_a) = 36,600.00 MWh; and

Deemed Generation corresponding to the time intervals of grid curtailment (G_{deemed}) = 300.00 MWh

(Note: Deemed Generation shall be computed in accordance with the relevant provisions of this Tender Document for the OTGT period)

Adjusted Actual Generation (G_{a_adj}) = $G_a + G_{deemed}$ = 36,900.00 MWh

Then O&M Test factor (OTF)=(G_{a_adj})/(G_T) = 1.006

Here, $OTF \geq 1$; O&M Target Generation test is successfully completed.

OTF= 1.006 (rounded off to 3 decimal places) **shall be accepted for O&M Period Generation Guarantee.**

Case (2) $OTF < 1$:

If Actual Adjusted Generation at site during OTGT Period (G_{a_adj}) = 35,800.00 MWh; (including deemed generation)

Then O&M Test factor (OTF) = (G_{a_adj}) / (E) = 0.976

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) - (G_{a_adj}) = 886.75 MWh

Shortfall in Generation for Entire Year (i.e., 365 in case of non-leap year) (I) = (H) $\times$ 365 / 90 = 3,596.26 MWh

Ceiling Tariff (J) = 4.5 Rs/kWh

Estimated Revenue Loss in a year due to Shortfall in generation (K) = (I) $\times$ (J) = ₹ 161.83 Lakhs

NPV of the estimated shortfall in cash flow resulting over the period of 25 years (at 6.93% discount rate)

(L) = ₹ 1,897.87 Lakhs

Let us assume - Payment against Successful completion of Milestone against Operational Acceptance (M) is ₹ 1,400.00 Lakhs

LD applicable as per Clause 7 = ₹ 1,400.00 Lakhs

OTF= 0.976 (rounded off to 3 decimal places) **shall be accepted for O&M Period Generation Guarantee.**

Case (3) $OTF < 1$:

If Actual Adjusted Generation at site during OTGT Period (G_{a_adj}) = 36,500.00 MWh; (including deemed generation)

Then O&M Test factor (OTF) = (G_{a_adj}) / (E) = 0.995

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) - (G_{a_adj}) = 186.75 MWh

Shortfall in Generation for Entire Year (i.e., 365 in case of non-leap year) (I) = (H) $\times$ 365 / 90 = 757.37 MWh

Ceiling Tariff (J) = 4.5 Rs/kWh

Estimated Revenue Loss in a year due to Shortfall in generation (K) = (I) $\times$ (J) = ₹ 34.08 Lakhs

NPV of the estimated shortfall in cash flow resulting over the period of 25 years (at 6.93% discount rate)

(L) = ₹ 399.69 Lakhs

Let us assume - Payment against Successful completion of Milestone against Operational Acceptance (M) is ₹ 1,400.00 Lakhs.

LD applicable as per Clause 7 = ₹ 399.69 Lakhs

OTF= 0.995 (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/m ²)	POA Irradiance (W/m ²)	GHI (kWh/m ²)	Humidity (%)	Wind Direction (°)	Generation (kWh) (Source: 33kV TVM)	Generation (kWh) (Source: 220kV ABT)

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/m ²)	POA Irradiance (W/m ²)	GHI (kWh/m ²)	Humidity (%)	Wind Direction (°)	Generation (kWh) (Source: TVM)	Generation (kWh) (Source: 220kV ABT)	Remarks

Section II

BESS SYSTEM RATING VERIFICATION

1 Energy Content Test

Energy Content Test shall be performed in accordance with the following steps:

- The BESS shall be charged to its full available energy level at rated input power in accordance with the system specifications and operating instructions.
- The BESS shall be discharged at the rated power of the system in accordance with the system specifications and operating instructions. The system shall be discharged to the minimum available energy level associated with the system specification and operation instructions (including the needed rest times between input and output power operation).
- The constant output power, output time and energy consumption of the auxiliary subsystem shall be measured and recorded during output. The actual energy capacity is calculated as follows:

Case I: If the auxiliary subsystem is fed internally, actual energy capacity is calculated by following equation.

$$E_o = \sum_{i=1}^n P_{O_i} \times \Delta t \quad (1)$$

where,

E_o is the calculated total output energy at the POC (kWh);

P_{O_i} is the active output power at time i , measured at the POC (kW);

Δt is the sampling time of the measurement (h);

n is the discharge time (h).

Case II: If the auxiliary subsystem is fed from other feeder, actual energy capacity is calculated by following equation.

$$E_o = \sum_{i=1}^n P_{O_i} \times \Delta t - E_{aux_o} \quad (2)$$

where,

E_o is the calculated total output energy at POC (kWh);

P_{O_i} is the active output power at time i , measured at the POC (kW);

Δt is the sampling time of the measurement (h);

E_{aux_o} is the energy consumption of the auxiliary subsystem measured at the auxiliary POC during the output operation (kWh);

n is the discharge time (h)

This test shall be conducted 3 times for 100% Rated Power, 1 time each for 75%, 50%, 25% of rated power. Data shall be collected from the Plant SCADA, and the following data shall be tabulated in Table 1 for each case.

Table 1: Actual Energy Content

Case 1: Auxiliary subsystem is fed internally				Power: ____ % of Rated Value = ____ MW				
Parameter	Observed during Charging			Observed during Discharging				
	Power P _I	Energy E _I	Duration T _I	Power P _O	Energy E _O	Duration T _O		
Unit	kW	kWh	h	kW	kWh	h		
	(a)	(b)	(c)	(d)	(e)	(f)		
Actual Energy Content (kWh)		$E_o = \sum_{i=1}^n P_{O_i} \times \Delta t$						
Case 2: Auxiliary subsystem is fed from other feeder				Power: ____ % of Rated Value = ____ MW				
Parameter	Observed during Charging				Observed during Discharging			
	Power P _I	Energy E _I	Duration T _I	Aux Con. E _{aux_I}	Power P _O	Energy E _O	Duration T _O	Aux Con. E _{aux_O}
Unit	kW	kWh	h	kWh	kW	kWh	h	kWh
	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)
Actual Energy Content (kWh)		$E_o = \sum_{i=1}^n P_{O_i} \times \Delta t - E_{aux_o}$						

Acceptance criteria

Dispatchable energy at the Point of Interconnection shall be at least equal to the dispatchable capacity for the first year specified by the Owner at Point of Interconnection

2 Round-trip Efficiency

The EES system shall be tested for its roundtrip efficiency following the test procedures a) to c) presented in the above clause for Energy Content Test. This test shall be performed under the rated input active power and rated output active power.

The roundtrip efficiency η_{rt} shall be determined in accordance with Formulae (3) and (4) for at least 3 cycles for 100% of Rated Power) based on the data secured from the tests conducted in accordance with the provisions in Clause 1 of Section II, taking into account possible auxiliaries power consumption from auxiliary POC during idle/rest times.

Case I:

$$\eta_{rt} = \frac{E_{out}}{E_{in}} \quad \dots\dots\dots(3)$$

Where,

E_{out} is the Total Energy Discharged from BESS as recorded in the Energy Meter(s) at the POC.

E_{in} is the Total Charging Energy into the BESS as recorded in the Energy Meter(s) at the POC.

Case II:

$$\eta_{rt} = \frac{E_{out} - E_{aux,o}}{E_{in} + E_{aux,i}} \quad \dots\dots\dots(4)$$

The roundtrip efficiency shall be reported as shown in Table 2. In case more than 1 cycle is performed, round trip efficiency shall be reported based on average values:

Table 2: Round Trip Efficiency

	Energy E_{in}	Energy E_{out}	Aux Cons. $E_{aux,i}$	Aux Cons. $E_{aux,o}$	Roundtrip Efficiency
	kWh	kWh	kWh	kWh	%
	(p)	(q)	(r)	(s)	(t)
Test 1					

Test 2					
...					
Test N					
Average					

Acceptance criteria

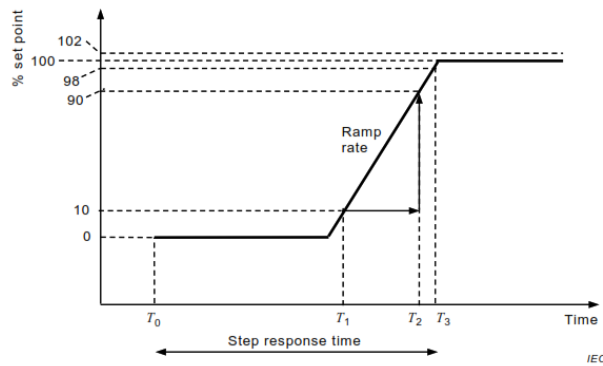
Round-trip efficiency of the BESS shall be more than or equal to, including auxiliary Consumption at 100% rated power shall be as per the Scope of Works at Interconnection Point

3 Step Response Test: Step Response Time and Ramp Rate

Step response time: Duration of the time interval between the instant T0, when the set point is received at the EES system, which is in stand-by mode, or when the grid parameter changes in a way to trigger the system response, and the instant T3 when the active power at the POC reaches within 2 % of the set point

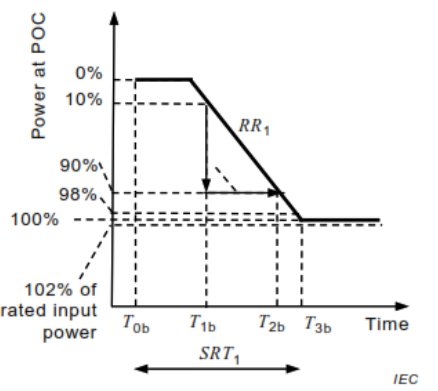
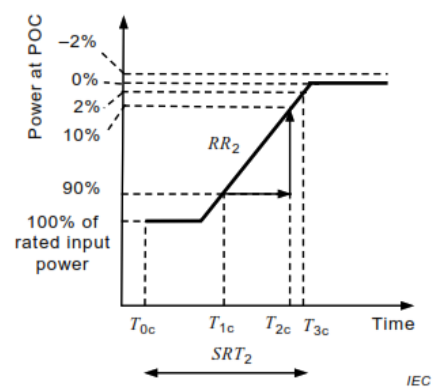
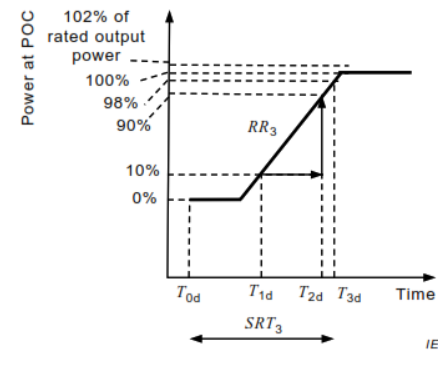
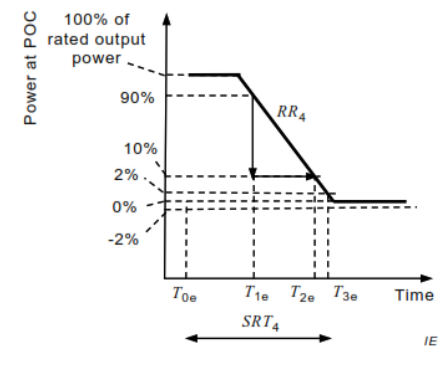
Ramp Rate: Average rate of active power variation per unit of time between T2 and T1 as shown in Figure given below. T1 is the time when the active power at the POC becomes higher than 2 % of the set point value. T2 is the time when the active power at the POC becomes higher than 98 % of the set point value.

$$RR (W/s) = \frac{P(T_2) - P(T_1)}{T_2 - T_1}$$



- The EES system shall be charged or discharged to a 50 % state of available energy.
- The set point (power, kW) shall be zero. The set point value shall be retained until the output comes to within (0 ± 2) % of rated input power.
- The set point shall be changed to rated input power. The set point value shall be retained until the active power at the POC reaches within 2 % of the range of rated input power. Step response time and ramp rate for step c) shall be recorded as SRT1 and RR1 respectively.
- The set point shall be changed to zero. The set point value shall be retained until the active power at the POC reaches within (0 ± 2) % of rated input power. Step response time and ramp rate of step d) shall be recorded as SRT2 and RR2 respectively.
- The EES system shall be charged or discharged to a 50 % state of available energy or specified capacity value agreed between the system supplier and user.
- The set point shall be changed to rated output power. The set point value shall be retained until the active power at POC reaches within 2 % of the range of rated output power. Step response time and ramp rate for step f) shall be recorded as SRT3 and RR3 respectively.
- The set point shall be zero. The set point value shall be retained until the active power at the POC reaches within (0 ± 2) % of rated input power. Step response time and ramp rate for step g) shall be recorded as SRT4 and RR4 respectively.

	Representative Figure	Measured Parameters	SRT _n	RR _n
--	-----------------------	---------------------	------------------	-----------------

(c)		<table><tr><td>SoC (%)</td><td></td></tr><tr><td>Setpoint (kW)</td><td></td></tr><tr><td>T0b (sec)</td><td></td></tr><tr><td>T1b (sec)</td><td></td></tr><tr><td>T2b (sec)</td><td></td></tr><tr><td>T3b (sec)</td><td></td></tr></table>	SoC (%)		Setpoint (kW)		T0b (sec)		T1b (sec)		T2b (sec)		T3b (sec)		SRT1 =	$RR_1 = \frac{P(T_{2b}) - P(T_{1b})}{T_{2b} - T_{1b}}$
SoC (%)																
Setpoint (kW)																
T0b (sec)																
T1b (sec)																
T2b (sec)																
T3b (sec)																
(c)		<table><tr><td>SoC (%)</td><td></td></tr><tr><td>Setpoint (kW)</td><td></td></tr><tr><td>T0c (sec)</td><td></td></tr><tr><td>T1c (sec)</td><td></td></tr><tr><td>T2c (sec)</td><td></td></tr><tr><td>T3c (sec)</td><td></td></tr></table>	SoC (%)		Setpoint (kW)		T0c (sec)		T1c (sec)		T2c (sec)		T3c (sec)		SRT2 =	$RR_2 = \frac{P(T_{2c}) - P(T_{1c})}{T_{2c} - T_{1c}}$
SoC (%)																
Setpoint (kW)																
T0c (sec)																
T1c (sec)																
T2c (sec)																
T3c (sec)																
(d)		<table><tr><td>SoC (%)</td><td></td></tr><tr><td>Setpoint (kW)</td><td></td></tr><tr><td>T0d (sec)</td><td></td></tr><tr><td>T1d (sec)</td><td></td></tr><tr><td>T2d (sec)</td><td></td></tr><tr><td>T3d (sec)</td><td></td></tr></table>	SoC (%)		Setpoint (kW)		T0d (sec)		T1d (sec)		T2d (sec)		T3d (sec)		SRT3 =	$RR_3 = \frac{P(T_{2d}) - P(T_{1d})}{T_{2d} - T_{1d}}$
SoC (%)																
Setpoint (kW)																
T0d (sec)																
T1d (sec)																
T2d (sec)																
T3d (sec)																
(e)		<table><tr><td>SoC (%)</td><td></td></tr><tr><td>Setpoint (kW)</td><td></td></tr><tr><td>T0e (sec)</td><td></td></tr><tr><td>T1e (sec)</td><td></td></tr><tr><td>T2e (sec)</td><td></td></tr><tr><td>T3e (sec)</td><td></td></tr></table>	SoC (%)		Setpoint (kW)		T0e (sec)		T1e (sec)		T2e (sec)		T3e (sec)		SRT4 =	$RR_4 = \frac{P(T_{2e}) - P(T_{1e})}{T_2 - T_1}$
SoC (%)																
Setpoint (kW)																
T0e (sec)																
T1e (sec)																
T2e (sec)																
T3e (sec)																

	Step Response Time (SRT)	s	
	Ramp Rate (RR)	kW/s	

Acceptance criteria

Step Response time and Ramp Rate shall be at least the values committed to by the Supplier.

4 Auxiliary Power Consumption Test

Auxiliary Power Consumption shall be measured for Case 1 and 2 delineated in Section I, as per the following:

1. In case the auxiliary subsystem is fed from the POC, auxiliary power consumption shall be measured at the point of supply of the auxiliary subsystem.
2. In case the auxiliary subsystem is fed from the auxiliary POC, the auxiliary power consumption shall be measured as input power at the auxiliary POC.

Before measurement, the EES system shall be charged or discharged to a 50 % state of available energy capacity or specified energy capacity value agreed between the system supplier and user. Auxiliary Consumption shall be recorded at Rated Input Active Power, Rated Output Active Power, Rated Injected Reactive Power, Rated Absorbed Reactive Power, and Standby State.

The tolerance on Input and Output power must be within 2% of the Rated Power.

Table 4: Auxiliary Power Consumption Measurement

Point of Measurement of Auxiliary Power Consumption (Select Applicable Case)	Point of supply of the Auxiliary subsystem	
	Auxiliary PoC	
Operation at Rated Input Active Power		
SoC at start of measurement	%	
Measured Input Active Power	kW	
Measured Auxiliary Power Consumption	kW	
Operation at Rated Output Active Power		
SoC at start of measurement	%	
Measured Output Active Power	kW	

Measured Auxiliary Power Consumption	kW	
Operation at Injected Reactive Power (if the system has a rated value of reactive power)		
SoC at start of measurement	%	
Measured Output Reactive Power	kVAr	
Measured Auxiliary Power Consumption	kW	
Operation at Absorbed Reactive Power (if the system has a rated value of reactive power)		
SoC at start of measurement	%	
Measured Input Reactive Power	kVAr	
Measured Auxiliary Power Consumption	kW	
Stand-by state (i.e. PCS Active power = 0 W, Reactive Power = 0 VAr)		
SoC at start of measurement	%	
Measured Output Active and Reactive Power	kW, kVAr	
Measured Auxiliary Power Consumption	kW	

The Energy Content Test and Round-Trip Efficiency (RTE) Demonstration shall also constitute the Functional Guarantee (FG) Test and shall meet the acceptance criteria specified in the Scope of Work (SoW) of this Tender Document. In the event that the demonstrated Energy Content does not comply with the SoW requirements, the Contractor shall, at no additional cost to the Employer, deploy additional BESS capacity toward meeting the Plant's operational acceptance criteria.

The measured auxiliary consumption data shall be recorded for information.

5 Liquidated Damages due to shortfall of Round-Trip Efficiency during PG Test: -

5.1 PERFORMANCE GUARANTEE REQUIREMENT

The Contractor shall demonstrate compliance with the guaranteed Round Trip Efficiency (RTE) of the Battery Energy Storage System (BESS) during the Performance Guarantee Test conducted at the time of commencement of commercial operations, in accordance with the procedure and testing methodology specified in this Contract.

5.2 NON-COMPLIANCE AND LIQUIDATED DAMAGES

In the event the Contractor fails to demonstrate the guaranteed Round Trip Efficiency during the Performance Guarantee Test, the Contractor shall be liable to pay Liquidated Damages (LD), not amounting to a penalty, to compensate the Owner for the Net Present Value (NPV) of the estimated annualized losses arising from the reduced efficiency of the BESS. Further,

the new measured value of Round-trip efficiency shall be benchmarked for the O&M Agreement.

5.3 CALCULATION OF LIQUIDATED DAMAGES

The LD amount shall be calculated as follows:

$$LD = \sum_{i=1}^n \frac{\Delta E \times R}{(1 + r)^i}$$

Where:

$$\Delta E \text{ is } \left(\frac{E_i + E_{i+1}}{2} \right) \times 365 \times A \times \left(\frac{1}{\eta_{\text{actual}}} - \frac{1}{\eta_{\text{guaranteed}}} \right)$$

E_i and E_{i+1} are the minimum dispatchable energy for year *i* and *i+1* as specified elsewhere in the document (refer Scope of Works)

A is the guaranteed availability as specified elsewhere in the document (refer Scope of Works)

η_{guaranteed} is the guaranteed minimum round trip efficiency as specified elsewhere in the document (refer Scope of Works)

η_{actual} is the round trip efficiency demonstrated during the Performance Guarantee Test

R is the reference rate of Rs 4.5 per kWh (INR/kWh)

r is the annual discount rate, i.e. 6.93%

N is the number of years over which the performance is evaluated as specified elsewhere in the document (refer Scope of Works)

5.4 REVERSAL OF LD

In the event that the Contractor is able to demonstrate compliance with the minimum guaranteed Round Trip Efficiency (η_{min}) under the Service Level Agreement (SLA) during any two (2) distinct billing periods within the SLA monitoring window (post-commissioning), the LD amount levied under Clause 5.3 shall be subject to reversal. The reversal shall be calculated by deducting the energy arbitrage losses for the intervening period (between initial test failure and the second compliant billing period). Upon such compliance, the Round Trip Efficiency shall thereafter be deemed to be benchmarked to the guaranteed efficiency (η_{min}) for all further purposes of the Contract.