SHAMS DUBAI

CHECKLIST
TESTING AND INSPECTION WITH INTERCONNECTION TO THE GRID

VERSION 1.0 AUGUST 2015

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1 SCOPE

This document presents the layout to be used for the results of Testing and Inspection with Interconnection.

Testing and Inspection activity consists of checks and measurements of selected characteristics.

At completion of the test a Test report has to be prepared. The template for the results is contained within this document.

Participants shall take note of inspection checks and measurements for their own record. The Applicant/ Contractor's Test Engineer shall prepare the Draft Test Report that will be distributed to the participants for their comments and approval.

The testing instruments shall be provided by the Applicant / Contractor and have valid calibration certificates in order to ensure that valid on-site testing can be performed.

1.1 PV PLANT AND INSPECTION DATA

Name of the PV Plant	Nominal Power (kW)			Location of the Plant	
Type of installation	Rooftop	Flat rooftop	Ground	Pole	BIPV
Date of the inspection					
……					

Name of Test Engineer (1)	Affiliation	Licence / Register ID
	Consultant	

TESTING AND INSPECTION WITH INTERCONNECTION RESULT	**PASSED**
	REJECTED

Participant	Affiliation	Role
	Consultant	Designer
	Consultant	Test engineer
	Contractor	Installer
	DEWA	Inspector

1 Tests are to be carried out by a licensed engineer

2 TESTING EQUIPMENT

Test equipment						
Type of measurement		Manufacturer	Model	SN	Calibration Certificate	Date of last calibration
1	**DC power**					
	Wattmeter					
	DC clamp meter					
2	**AC power**					
	Wattmeter					
	AC clamp meter					
3	**Test of Interface Protection**					
4	**Performance Test**					
5	**Additional instruments**					

3 DOCUMENTS

3.1 Reference documents and standards

[1] DEWA Standards for Distributed Renewable Resources Generators Connected to the Distribution Network

[2] DEWA Connection Guidelines for Distributed Renewable Resources Generators Connected to the Distribution Network

[3] DEWA Inspection and Testing Guidelines for Distributed Renewable Resources Generators Connected to the Distribution Network

3.2 PV plant design documents (Technical dossier)

A list of documents provided by the Applicant to DEWA will be filled as in the proposed template here below.

Data-sheets and catalogues

[1]	
[2]	
[3]	
....	

Technical Reports

[1]	
[2]	
[3]	
....	

Drawings

[1]	
[2]	
[3]	
....	

4 TESTING WITH INTERCONNECTION TO NETWORK – PERFORMANCE TESTS

4.1 Functionalities of the RRGU/RRGP

These checks and controls can be carried out after the Inspection has been performed, the meter installed and the plant energized with connection to the distribution network.

4.1.1 Connection to grid and start-up of RRGU/RRGP

The test starts by connecting and energizing the equipment of the RRGU / RRGP. Each unit of the solar PV generator will receive power from the grid allowing auxiliary services to supply switchboards and AC equipment.

The Test Engineer will specify the tests carried out to verify the electrical installations and the respective outcomes in a table like in the template reported hereinafter (one row for each test).

<table>
<tr><th colspan="8">Connection to grid and start-up of RRGU/RRGP</th></tr>
<tr><th colspan="2">Equipment / Switchboard</th><th>Doc. ref.</th><th colspan="4">Result</th><th>Ref. to Note</th></tr>
<tr><td colspan="8">The test starts by connecting and energizing the equipment of the RRGU / RRGP. Each unit of the solar PV generator will receive power from the grid, allowing auxiliary services to supply switchboards and switchgears up to string combiner boxes.</td></tr>
<tr><td colspan="2"></td><td></td><td>OK</td><td>☐</td><td>NO ☐ N/A</td><td>☐</td><td></td></tr>
<tr><td rowspan="3">Note:</td><td>1. …..</td><td colspan="6" rowspan="3"></td></tr>
<tr><td>2……</td></tr>
<tr><td>3……</td></tr>
</table>

4.1.2 Parallel with the grid

After the plant is connected to the grid and then energized, the checks mentioned below have to be executed.
Rows may be added to the proposed table if deemed necessary to specify other tests carried out by the Test Engineer.

Parallel with the grid									
		Doc. ref.	Result						Ref. to Note
1	The grid connection equipment and related protections are set in accordance with the parameters defined in the Standards		OK	☐	NO	☐	N/A	☐	
2	The PV power generation and transformation equipment is correctly working and no failures or error messages have been detected		OK	☐	NO	☐	N/A	☐	
Note:	1.								
	2.....								
	3.....								

4.1.3 Start-up tests on inverters

Tests performed separately on each inverter and progressively throughout the whole RRGU/RRGP, to assess whether the inverters are working properly and are set in accordance with the parameters defined in the Standard [1].

Start-up tests on inverters										
		Doc. ref.	Result						Ref. to Note
1	Cable connections		OK	☐	NO	☐	N/A	☐	
2	Voltage/current input/output values from inverter instruments		OK	☐	NO	☐	N/A	☐	
3	Start-up and shut-down tests		OK	☐	NO	☐	N/A	☐	
Note:	1. …..								
	2……								
	3……								

4.1.4 Alarms and messages

Alarms and warning messages can help ensure reliable and safe operation of any plant. PV plant equipment may send alarms and warning messages to remote users. According to the plant size, such messages shall be managed by the Installer or by the Owner or by the entity appointed for the "Operation and Maintenance" service. In any case, it is important to check the correct operation of alarms and messages through simulated tests of intervention.

Alarms and messages										
Describe each check performed										
		Doc. ref.	Result						Ref. to Note
1	Check alarm "high temperature" in Transformer windings or oil		OK	☐	NO	☐	N/A	☐	
2	Check alarm "high temperature" in Transformer room		OK	☐	NO	☐	N/A	☐	
3	Check alarm high temperature in INVERTER room		OK	☐	NO	☐	N/A	☐	
4	Check messages going through the monitoring system (or SMS or email)		OK	☐	NO	☐	N/A	☐	
Note:	1. …..								
	2……								
	3……								

4.1.5 Verification of connection of energy meters

Installation and verification of the energy meter is the responsibility of DEWA. It is recommended that during the Final Inspection, the participants collect the information and that the data is summarized below.

Verification of connection of energy meters									
		Doc. ref.	Result						Ref. to Note
1	Detect nameplate data of all voltage and current transducers (if any)		OK	☐	NO	☐	N/A	☐	
2	Check connection of meters to voltage/ current transducers, and transformation ratio settings		OK	☐	NO	☐	N/A	☐	
3	Check compliance of meter calibration certificates		OK	☐	NO	☐	N/A	☐	
Note:	1. …..								
	2……								
	3……								

4.1.6 Measurements

This part of the tests is devoted to checking that the measuring equipment is in accordance with the technical specifications and that the degree of accuracy of the measurements performed with this equipment will be sufficient.

Measurements									
Describe each check performed									
		Doc. ref.	Result						Ref. to Note
1	Equipment, room, and external temperature		OK	☐	NO	☐	N/A	☐	
2	Inverter operational parameters		OK	☐	NO	☐	N/A	☐	
3	Auxiliary services power supply		OK	☐	NO	☐	N/A	☐	
Note:	1. …..								
	2…….								
	3…….								

4.1.7 RRGU/RRGP Monitoring system

In accordance with the size of the DRRG (in particular for plants with $P_{MC} \geq 100$ kW), a monitoring system is to be installed to facilitate the management as well as the O&M of the PV plant and to allow DEWA a possible remote monitoring.

The following checks are required to verify the correct behaviour of the system.

RRGU/RRGP Monitoring system The test shall verify the accordance of the monitoring system to the design, the operation of such system, and the reliability of the measurements. The following checks shall be performed.									
		Doc. ref.	Result						Ref. to Note
1	Verify the certification of the meteorological sensors: ☐ solar radiation ☐ PV module temperature ☐ pyranometer ☐ wind ☐ external air temperature		OK	☐	NO	☐	N/A	☐	
2	Verify the solar radiation sensors by comparing their readings with those of a reference sensor. This test shall concern especially PV plants of Maximum Capacity larger than or equal to 100 kW, for which a performance test is required (see below). The verification of the solar sensors shall ensure that the sensors and instruments of the PV plants are reliable and ensure the PV plant performance can be evaluated any time in the frame of the operation of the PV plant.		OK	☐	NO	☐	N/A	☐	
3	Verify the remote monitoring functions available from the monitoring equipment and system.		OK	☐	NO	☐	N/A	☐	
Note:	1. …..								
	2……								
	3……								

4.1.8 Operation of electrical systems in each substation

The proper behaviour of the electrical systems in each substation, both for power and auxiliary systems shall be verified. The checks shall be performed by verifying the correct operation of the systems through their instruments, particularly to assess the absence of warning or error messages.

The Test Engineer will specify the tests carried out to verify the electrical installations and the respective outcomes in a table like in the template reported hereinafter (one row for each test).

Operation of electrical systems in each substation								
Describe each check performed								
Type of verification /Equipment verified		Doc. ref.	Result					Ref. to Note
			OK	☐	NO	☐	N/A ☐	
Note:	1. …..							
	2……							
	3……							

4.2 Verification of the Technical Dossier

The availability of the as-built designs and documents as well as the documentation of the equipment (e.g. technical specification, installation guide, user's manuals, certifications, etc.) is important for the operation of the PV plant, particularly for the technicians involved in the O&M activity.

Check with reference to delivered documents listed in 3.2.

	Verification of the technical dossier			
	Description	Doc. available	Doc. ref.	Comments
1	Layout of PV modules			
2	Layout of inverters			
3	Single Line diagram			
4	Wiring layouts			
5	Structural drawings			
6	Certificates of PV modules, Inverters and other equipment			
7	Electrical installation Test Certificate			
8	Reports			
9	Test of Interface protection			
10	Additional documents ….			
Note:	1. …..			
	2……			
	3……			

4.3 Performance Tests

4.3.1 Energy Performance Tests

Test requirements and details

Description of the test

The objective of this test is to prove that the plant is able to produce energy continuously by measuring its Performance Ratio on a given period of time.

Definitions:

- E_{AC} = AC active energy [kWh] at the output of inverter measured in the given period (accuracy ±2%)
- P_{nom} = Nominal power of PV generator [kW] (total nominal power of installed modules) @ STC
- Δt_s = Sampling interval [min]
- G = Solar Irradiance [$\frac{W}{m^2}$] sensor coplanar to the surface of the modules (accuracy equal or better than ±5%)
- ϑ_{PV} = PV module temperature [°C]
- Υ = Power temperature coefficient of the module [%/°C] (this coefficient is usually negative)

The tests can be carried out after successful commissioning and shall last a rolling 10 Days duration accounting for the with the following criteria:

- at least five (5) days with irradiance (G) measured on the plane of the array greater than 600 W/m² for 3 contiguous hours
- for at least five (5) days, the daily total irradiation on the plane of the array exceeds 4.0 kWh/m² (these days may be the same as those indicated in the previous point).
- In the event that the five days are not reached with the required irradiation levels, the measurement period will be extended until the irradiation criteria are achieved.
- Availability of the PV Plant and the grid shall be 100%. In the event of unavailability, the testing period will be extended accordingly by the relevant number of days.
- The sampling interval Δt_s is constant and not larger than 15 min.

Performance ratio without temperature correction (PR)

$$PR = \frac{E_{ac}}{P_{nom} * \Delta t_s \sum_j G_j} * 60 * 10^3$$

Performance ratio with temperature correction (PR_ϑ)

The temperature correction is useful for comparison among measurements of PR made in different periods. The STC temperature ϑ_{REF} = 25 °C is assumed in the formula.

$$PR_\vartheta = \frac{E_{ac}}{P_{nom} * \Delta t_s * \sum_j (G_j * [1 + (\vartheta_{pvj} - \vartheta_{REF}) * \Upsilon / 100])} * 60 * 10^3$$

The Performance Test is carried out for the whole plant, involving the following measurements:

a) Read active energy as measured by the production meter.

b) Measurements of the solar irradiance from a reference solar cell or pyranometer connected to a data logger in order to store them in the performance test time span.

c) Measurements of the PV module temperature by means of a temperature sensor located on the back surface. Values to be sent to the data logger

Energy Performance tests – Inverter						
Start date (dd/mm/yyyy): . . . / . . . /			Stop date (dd/mm/yyyy): . . . / . . . /			
DC			AC			Note
P_{nom}		kW	PR		-	
ϑ_{REF}		°C	PR_{ϑ}		-	
Υ		%/°C			-	
Δt_s		°C				
Note:	1. …..					
	2……					
	3……					

The active energy which may be produced by the modules, according to the actual operating conditions, as calculated by applying the formula in the box on the previous page, is compared with the measured active energy (by the meter), in order to calculate the Performance Ratio.

4.3.2 Power Performance Tests

The Results for the Power Performance test may be taken directly from the Energy Performance Test as regard an instantaneous set of measurements.

In the checklist of the Power Performance Test additional information must be given because in this case it is possible to report the instantaneous values of the electrical and environmental measurements.

Test requirements and details
Description of the test The aim of the test is to assess the actual PV plant power. Definitions: • P_{DC} = DC power [kW] of the PV generator (accuracy ±2%) as measured at the inverter DC input • P_{AC} = AC active power [kW] at the output of inverter (accuracy ±2%) • P_{nom} = Nominal power of PV generator [kW] (total nominal power of installed modules) @ STC • N_m = Number of PV modules • A_m = Area of each PV module [m2] • G = Solar Irradiance [$\frac{W}{m^2}$] sensor coplanar to the surface of the modules (accuracy equal or better than ±5%) • ϑ_{PV} = PV module temperature [°C] • ϑ_{Air} = Air temperature [°C] • Υ = Power temperature coefficient of the module [%/°C] (this coefficient is usually negative) Tests are valid if Solar Irradiance G > 600 [$\frac{W}{m^2}$] . Performance ratio on power without temperature correction (PR_p) $PR_p = \frac{P_{AC}}{G} * \frac{1000}{P_{nom}}$ $\eta INV = \frac{P_{AC}}{P_{DC}}$ Performance ratio on power with temperature correction ($PR_{p\vartheta}$) The temperature correction is useful for comparison among measurements made in different periods. The STC reference temperature ϑREF = 25 °C is assumed in the formula. $PR_p = \frac{P_{AC}}{G} * \frac{1000}{P_{nom}*[1+(\vartheta_{PV}-\vartheta_{REF})*\Upsilon/100]}$ $\eta INV = \frac{P_{AC}}{P_{DC}}$ Array efficiency (sunlight to electricity conversion efficiency of the PV array) (η_A) $\eta A = \frac{P_{DC}}{G * N_m * A_m} * 1000$

In principle the test is performed for each inverter and related strings of PV modules (array), and is based on the following measurements.

a) Measure power input to inverter by DC wattmeter (including voltage and current).

b) Measure power output from inverter by AC wattmeter (single or three-phase electrical quantities) connected to inverter busbar.

c) DC and AC measurements must be synchronized. Measurements shall be carried simultaneously or in fast sequence, for each subsection (inverter) of RRGU.

d) Measurements of the solar Irradiance from a reference solar cell or pyranometer.

e) Measurements of the PV module temperature by means of a temperature sensor located on the back surface

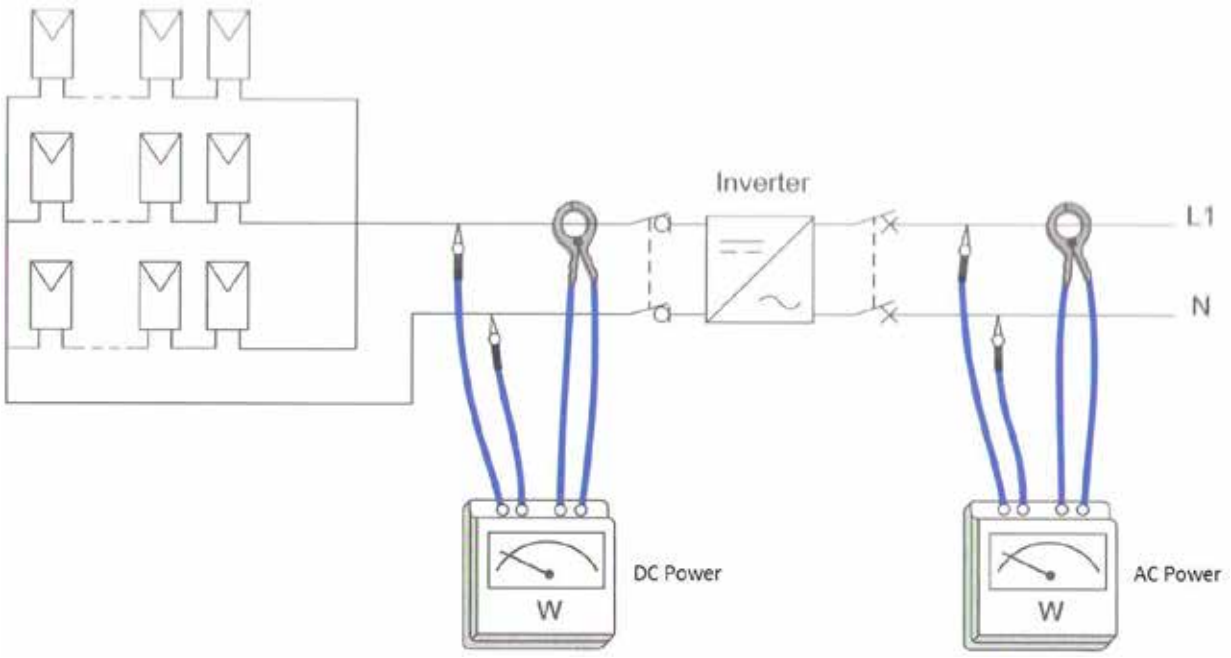

Figure 1 – Measurement of DC and AC power on a PV plant

Power Performance tests – Inverter						
Date (dd/mm/yyyy): . . . / . . . /			Hour (hh:mm): . . . / . . .			
DC			AC			Note
P_{nom}		kW	PR_p		-	
ϑ_{REF}		°C	$PR_{p\vartheta}$		-	
Υ		%/°C	η_{INV}		-	
N_m		-	η_A		-	
A_m		m^2	Pac		kW	
Vdc		V	Vac1		V	
Idc		A	Iac1		A	
Pdc		kW	Vac2		V	
Solar Irradiance		W/m^2	Iac2		A	
ϑ_{PV}		°C	Vac3		V	
ϑ_{Air}		°C	Iac3		A	
Note:	1.					
	2.....					
	3.....					

4.3.3 Harmonic Measurements

Assessment of harmonic measurements and analysis of the results.

Harmonic voltage measurements											
		Doc. ref.	Result								Ref. to Note
1	Measurement interval from …….. to ……..		OK	☐	NO	☐					1
2	Measurement step = 10 minutes		OK	☐	NO	☐					
3	N = number of 10-minute intervals in which the supply voltage is within normal operating range										
4	N1 = number of 10-minute intervals in which voltage harmonics level exceeds individual harmonic limit and the supply voltage is within normal operating range (for the harmonic voltage limits refer to Table 7 of [1] below annexed)										
5	N2 = number of 10-minute intervals in which the THD value for one or more of the phase voltages exceeds the harmonic voltage limits and the supply voltage is within normal operating range (for the harmonic voltage limits refer to Table 7 of [1] below annexed)										
6	N1/N ≤ 5% for each individual harmonics and N2/N ≤ 5% for THD during observation period		OK	☐	NO	☐					
7	Instrumentation used: Smart meter		OK	☐	NO	☐					
8	Instrumentation used: Specific instrumentation		OK	☐	NO	☐					
Note:	1……At least one week										

Harmonic voltage measurements - Background												
		Doc. ref.	Result									Ref. to Note
1	Measurement interval from …….. to ……..		OK	☐	NO	☐						1
2	Measurement step = 10 minutes		OK	☐	NO	☐						
3	N = number of 10-minute intervals in which the supply voltage is within normal operating range											
4	N1 = number of 10-minute intervals in which voltage harmonics level exceeds individual harmonic limit and the supply voltage is within normal operating range (for the harmonic voltage limits refer to Table 7 of [1] below annexed)											
5	N2 = number of 10-minute intervals in which the THD value for one or more of the phase voltages exceeds the harmonic voltage limits and the supply voltage is within normal operating range (for the harmonic voltage limits refer to Table 7 of [1] below annexed)											
6	N1/N ≤ 5% for each individual harmonics and N2/N ≤ 5% for THD during observation period		OK	☐	NO	☐						2
7	Instrumentation used: Specific instrumentation		OK	☐	NO	☐						

Odd harmonics		Even harmonics	
Order h [-]	Harmonic voltage [%].	Order h [-]	Harmonic voltage [%].
3		2	
5		4	
7		6	
…		…	
49		50	
Note:	1. At least one week 2. In case the two conditions are not fulfilled, the background harmonics are already above the limits		

Table 7 of [1]: Indicative planning levels for Harmonic Voltages (in % of fundamental voltage) in MV, HV and EHV systems (source IEC/TR 61000-3-6)

Odd harmonics						Even harmonics		
Not multiples of 3			Multiples of 3					
Order h	Harmonic voltage %		Order h	Harmonic voltage %		Order h	Harmonic voltage %	
5	5.0	2.0	3	4.0	2.0	2	1.8	1.4
7	4.0	2.0	9	1.2	1.0	4	1.0	0.8
11	3.0	1.5	15	0.3	0.3	6	0.5	0.4
13	2.5	1.5	21	0.2	0.2	8	0.5	0.4
17≤ h ≤49	1.9×17/ h-0.2	1.2×17/h	21 ≤ h ≤ 45	0.2	0.2	10 ≤ h ≤ 50	0.25×10/ h+0.22	0.19×10/ h+0.16

NOTE: The corresponding planning level for the total harmonic distortion is THD = 6.5%

Harmonic current measurements								
		Doc. ref.	Result				Ref. to Note	
1	Measurement interval from …….. to ……..		OK	☐	NO	☐	1	
2	Measurement step = 10 minutes		OK	☐	NO	☐		

Order h [-]	Harmonic current [%] in the range 0-25% of rated power	Harmonic current [%] in the range 25-50% of rated power	Harmonic current [%] in the range 50-75% of rated power	Harmonic current [%] in the range 75-100% of rated power	Harmonic current reference [%][2]
2					
3					
4					
…					
50					
Note:	1. At least one week 2. Harmonics current spectrum declared by RRGP/RRGUs manufacturers				

4.4 Post-connection inspections

4.4.1 Power Performance Tests

If required. To be carried out as in the Chapter Performance Tests

4.4.2 Check the behaviour of energy meters

Check of correct behaviour of energy meters											
		Doc. ref.	Result						Ref. to Note
1	Voltage drop measurements		OK	☐	NO	☐	N/A	☐	
2	Active power instrumental reading		OK	☐	NO	☐	N/A	☐	
3	Check of correctness of protection settings		OK	☐	NO	☐	N/A	☐	
			OK	☐	NO	☐	N/A	☐	
			OK	☐	NO	☐	N/A	☐	
Note:	1.....								
	2.....								
	3.....								

Verify the proper behaviour of the meters, by means of the following checks in the internal registries of the meter											
		Doc. ref.	Result						Ref. to Note
1	Reading of the RMS input currents (OBIS codes 31.7.0, 51.7.0, 71.7.0)		OK	☐	NO	☐	N/A	☐	
2	Reading of the RMS input voltages on the three-phases to verify the balance of the three (OBIS codes 32.7.0, 52.7.0, 72.7.0)		OK	☐	NO	☐	N/A	☐	
3	Reading of the instantaneous active power absorbed (OBIS code 1.5.0) and comparison with power read by other instruments		OK	☐	NO	☐	N/A	☐	
4	Reading of the instantaneous active power produced (OBIS code 2.5.0) and comparison with power read by other instruments		OK	☐	NO	☐	N/A	☐	
			OK	☐	NO	☐	N/A	☐	
Note:	1.....								
	2.....								
	3.....								

Checks and verification of meter connection, certifications and remote reading											
		Doc. ref.	Result						Ref. to Note
1	Check of the certificate of calibration as released by a recognized calibration laboratory		OK	☐	NO	☐	N/A	☐	
2	Check of the integrity of the sealed parts		OK	☐	NO	☐	N/A	☐	
3	Check of the correct value of the K ratio (VT ratio * CT ratio) as set in the meter in comparison with the actual and rated values of the VT and CT ratios.		OK	☐	NO	☐	N/A	☐	
4	Check of the correct connections between CTs, VTs and meter		OK	☐	NO	☐	N/A	☐	
5	Tests of remote reading (from DEWA system)		OK	☐	NO	☐	N/A	☐	
			OK	☐	NO	☐	N/A	☐	
Note:	1.....								
	2.....								
	3.....								

Supervise the performance tests "on Power" as repeated by the Applicant on explicit request of DEWA, if considered necessary; and Obtain the reading of the meters in order to begin to consider the exports and net metering										
		Doc. ref.	Result						Ref. to Note
1	Reading and recording of the active energy absorbed (OBIS code 1.8.0) from the time of activation of the meter		OK	☐	NO	☐	N/A	☐	
2	Reading and recording of the active energy produced (OBIS code 2.8.0) from the time of activation of the meter		OK	☐	NO	☐	N/A	☐	
3	Reading and recording of the reactive energy absorbed (OBIS code 3.8.0) from the time of activation of the meter		OK	☐	NO	☐	N/A	☐	
4	Reading and recording of the reactive energy produced (OBIS code 4.8.0) from the time of activation of the meter		OK	☐	NO	☐	N/A	☐	
			OK	☐	NO	☐	N/A	☐	
Note:	1.....								
	2.....								
	3.....								

4.5 Final notes and Observations

In this table all the notes and the observation made at different stages of inspection and testing activities are noted.

Notes and Observations
[1]
[2]
[3]