PROCEDURE
FOR THE TESTING AND COMMISSIONING OF GRID-CONNECTED PHOTOVOLTAIC SYSTEMS IN MALAYSIA

Part 4 – SYSTEMS GREATER THAN 425 kWp

SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY (SEDA)
MALAYSIA

2014

TABLE OF CONTENTS

1. PRE-COMMISSIONING CHECKLIST AND TEST

Prior to commissioning, the service provider of the GCPV systems must perform the pre-commissioning checks.

This activity shall be conducted by the competent persons as stated at the end of the checklist, whilst adhering to the relevant laws and regulations.

A copy of the completed pre-commissioning checklist and test results must be submitted to SEDA and Distribution Licensee (DL) for application of Testing and Commissioning.

During the pre-commissioning checks, the GCPV systems shall not be engaged to the grid.

The pre-commissioning checks consist the following (**mandatory minimum**):

1. Information about Project
2. Checklist for General Inspection
3. Checklist for PV Module Mounting Structure & Civil foundation
4. Checklist for DC Junction Box or String Monitoring Box
5. Checklist for Earthing & Lightning Arrestor
6. Checklist for PV Module
7. Checklist for Inverter
8. Checklist for AC Distribution Box
9. Checklist of Cable identification and cable routing inspection
10. Checklist for weather monitoring station and monitoring system
11. Cable insulation test
12. String fuse continuity and string open circuit voltage test
13. String DC short circuit current test
14. Isolation device functional test

1.1 INFORMATION ABOUT PROJECT

Table 1.1 Information about project	
Project details	
FIT application number	
Project description	
Site GPS coordinates (Latitude, Longitude)	
Site address	
Date of inspection (dd_mmm_yyyy)	

Customer details	
Name	
Full postal address	
Mobile phone number/Ground phone number	
Email address	

Installation details	
Date of completion of installation	
Date of planned connection to grid	
Import meter reading (kWh) at pre-comm session	
Export meter reading (kWh) at pre-comm session	
Remarks	

1.2 CHECKLIST FOR GENERAL INSPECTION

Table 1.2 Checklist for General Inspection			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each sub-array connected to one inverter	Inverter ID:	Sub-array ID:

A. General	i.	All necessary safety equipment are available at the site	☐
	ii.	Array frame correctly fixed and stable	☐
	iii.	All cable entries are weather proof	☐
	iv.	PV module location, perimeter, gate, control room & switch yard, plant internal road location as per approved layout drawing	☐
	v.	Components comply with standards and are selected as per design & not damaged	☐
	vi.	Equipment accessible for inspection, operation & maintenance	☐
	vii.	Equipment & accessories are connected as per approved drawing	☐
	viii.	Protective measures for special locations have been addressed (if applicable)	☐
	ix.	Equipment & protective measures are appropriate to external influenc	☐
	x.	System installed to prevent mutual detrimental influence	☐
	xi.	All cables are identified and connected as per approved drawing	☐
	xii.	All cables are selected for current carrying capacity and voltage drop as per approved design	☐
	xiii.	Conductors routed are in safe zone or protected against mechanical damage	☐
	xiv.	All tagging are appropriate.	☐
	xv.	All signages are appropriate.	☐
	xvi.	All relevant documents are available.	☐
	xvii.	Emergency procedure displayed at site	☐
	xviii.	PV system schematic displayed at site	☐

B. DC Side	i.	Adequate physical separation of AC, DC & communication cables	☐
	ii.	All DC components are sized for rated operation at maximum DC system voltage	☐
	iii.	All DC cables are meant for solar PV applications and as per design document	☐
	iv.	PV string fuse or DC breaker are available in the combiner boxes	☐
C. Protection against over voltage & Electric Shock	i.	Live parts are insulated and protected by barrier/enclosure, placed out of reach	☐
	ii.	Surge protection devices are available	☐
	iii.	External lightning protection system is available	☐
	iv.	PV frame grounding correctly integrated with existing installation	☐
D. AC Side	i.	Inverter protection setting as per local regulation (labelling & identification mark)	☐
	ii.	Protection setting by installers displayed at site (maximum current, range of voltage and frequency)	☐
Comments:			

1.3 CHECKLIST FOR PV MODULE MOUNTING STRUCTURE & CIVIL FOUNDATION

Table 1.3 Checklist for PV Module Mounting Structure & Civil Foundation

Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each sub-array connected to one inverter	Inverter ID:	Sub-array ID:

i.	Mounting structure and jointing materials as per approved drawing	☐
ii.	Foundation dimensions as per approved drawing	☐
iii.	Switch yard civil foundation as per approved drawing	☐
iv.	The material for structure has corrosion proof coating (check for availability of factory test certificate)	☐
v.	Structures are correctly fixed at specific tilt and orientation as per design document	☐
vi.	No crack found in the foundation and/or mounting structure	☐
vii.	Structures are designed based on the maximum wind load of the location (check for availability of structure engineer certificate)	☐
viii.	No rust (for steel) or discoloration (for aluminium) found in the structure materials (e.g. frame, clamp, bolt and nuts, etc.)	☐
ix.	Water drainage is available	☐

Comments:

1.4 CHECKCHECKLISTLIST FOR DC JUNCTION BOX OR STRING MONITORING BOX

Table 1.4 Checklist for DC Junction Box or String Monitoring Box			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each sub-array connected to one inverter	Inverter ID:	Sub-array ID:

i.	DC Junction/String Monitoring Box connection diagram is available at the inside of the cover	☐
ii.	Wiring is as per approved schematic	☐
iii.	String fuses or DC circuit breakers are available	☐
iv.	Metal casings are earthed as per design document	☐
v.	All boxes are properly fixed at appropriate locations as per design document	☐
vi.	Surge protections devices are available inside the box as per design document	☐
vii.	Box and related component & insulation rating based on maximum DC voltage	☐
viii.	Boxes for outdoor use should be suitably rated based on Malaysia climate	☐

Comments:

1.5 CHECKLIST FOR EARTHING & LIGHTNING ARRESTOR

Table 1.5 Checklist for earthing & lightning arrestor			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each earthing pit and each lightning arrestor	Earth pit ID:	Lightning arrestor ID:

i.	Earthing location as per approved drawing	☐
ii.	Earthing conductor properly connected to metal parts of all structures	☐
iii.	All array frames (for framed modules) and structures are earthed and bonded properly	☐
iv.	Earthing & lightning arrestor are installed as per design document	☐

Comments:

1.6 CHECKLIST FOR PV MODULE INSPECTION

Table 1.6 Checklist for PV module			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each sub-array structure	Structure ID:	Sub-array ID:

i.	PV modules are fixed on the structure as per design drawing	☐
ii.	PV modules are properly levelled on the structure	☐
iii.	PV modules conform to relevant IEC standards as per design document	☐
iv.	Inter-module connectors are properly crimped & securely connected	☐
v.	PV modules are connected with correct polarity	☐
vi.	Non-metallic isolator is present between each PV module frame & structure (if they are made from different metals)	☐
vii.	Installation of PV modules are done as per manufacturer's guidelines	☐

Comments:

1.7 CHECKLIST FOR INVERTER INSPECTION

Table 1.7 Checklist for inverter			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each inverter	Inverter ID:	

i.	Inverter is installed as per manufacturer's guideline	☐
ii.	Sufficient ventilation is available around the inverter (as per manufacturer's guideline)	☐
iii.	Inverter conforms to relevant IEC standards (or equivalent) as per design document	☐
iv.	Inverter unit is properly fastened to floor/wall surfaces	☐
v.	Inverter is properly earthed	☐
vi.	Inverter incoming/outgoing cables are properly tagged	☐
vii.	Inverter incoming/outgoing cables are properly connected as per drawing	☐
viii.	The connections for phase sequence L1, L2 & L3 are in proper order (for three phase inverters)	☐
ix.	The connections for L and N are in proper order (for single phase inverters)	☐
x.	Inverter for outdoor use shall be suitable rated based on Malaysia climate.	☐
xi.	Gap maintained between power cables and signal cables routing as per design document	☐
xii.	The auxiliary power cables are connected properly	☐
xiii.	All cable terminations are done properly	☐
xiv.	Proper labelling of all the cables and components are done	☐
xv.	Inverter factory settings are as per local utility guidelines	☐

Comments:

1.8 CHECKLIST FOR AC DISTRIBUTION BOX

Table 1.8 Checklist for AC Distribution Box (ACDB)			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each ACDB	ACDB ID:	

i.	ACDB is properly mounted as per design document	☐
ii.	Sufficient free space available around each ACDB	☐
iii.	ACDB is properly earthed as per design document (if applicable)	☐
iv.	The connections for phase sequence L1, L2 & L3 are in proper order (for three phase inverters)	☐
v.	The connections for L and N are in proper order (for single phase inverters)	☐
vi.	Incoming/outgoing cables are properly connected as per approved schematic diagram	☐
vii.	All cable terminations are done properly	☐
viii.	Proper tagging of all cables and components are done	☐
ix.	All cable glands are properly secured & tightened	☐
x.	Boxes for outdoor use shall be suitably rated based on Malaysia climate	☐

Comments:

1.9 CHECKLIST OF CABLE IDENTIFICATION AND CABLE ROUTING INSPECTION

Table 1.9 Checklist for cable identification & route inspection

Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.	Date of inspection: (dd_mmm_yyyy)
i.	All cable routed areas are properly marked on the ground	☐
ii.	All power cable route & locations are as per drawing	☐
iii.	All cables are properly tagged	☐
iv.	All DC cables are meant for solar PV applications and as per design document	☐
v.	Cable caution tape is used for all underground cables as per design document	☐
vi.	All trunking and conduits are installed as per design document	☐

Comments:

1.10 CHECKLIST FOR WEATHER MONITORING STATION AND PV MONITORING SYSTEM

Table 1.10 Checklist for weather monitoring station and PV monitoring system		
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.	Date of inspection: (dd_mmm_yyyy)

An automated monitoring system is required and a closed circuit television (CCTV) system is recommended

i.	Local & remote communication & data logging system is available as per design document	☐
ii.	The communication software test report as per design document	☐
iii.	Identification marks on communication cable are available and as per design document	☐
iv.	Communication system architecture diagram is displayed near the computer in the control room	☐
v.	Gap maintained between power cables and signal cables routing	☐
vi.	All parameters are properly configured in the computer as per requirement	☐
vii.	Internet connection is available at the control room	☐
viii.	Remote monitoring via internet or other means is available	☐
ix.	Monitored data for Weather Monitoring Station (WMS) must comprise at least:	
	- Solar irradiance on the horizontal	☐
	- Solar irradiance on the plane of array (for static and tracking systems)	☐
	- Ambient temperature	☐
	- Wind speed	☐
x.	Monitored data for system monitoring must comprise at least:	
	- Module temperature	☐
	- Inverter temperature	☐
	- DC electrical parameters such as voltages and currents for each string	☐
	- AC electrcial parameters such as voltages and current from each inverter	☐
xi.	All weather monitoring system and PV monitoring system shall be synchronised and sampled at **FIVE-minute** intervas	☐
xii.	All CCTV images are sampled continuously (if required)	☐
xiii.	All sensors are accompanied with test certificates and relevant documents	☐

Comments:

1.11 CABLE INSULATION TEST

Table 1.11 Cable insulation test					
Cable ID					Date of inspection: (dd_mmm_yyyy)
Description			References (Please state)		
Test point			All new cables		
Use appropriate tools to measure and record					
Testing is performed on new cable installations to determine if the insulation has been damaged.			Instructions: **SWITCH OFF / DISCONNECT** the following: - PV AC Main Switch (Isolator) - All AC switches - All DC switches - All DC fuses Isolate all cables except for inter-module connection and earthing cables.		
No.	Cable from (originating)	Cable to (terminating)	Insulation resistance value	Pass	Fail
				(Please tick ✓ in the box)	
1					
2					
3					
Comments:					

1.12 STRING FUSE CONTINUITY AND STRING OPEN CIRCUIT VOLTAGE TEST

Table 1.12 String fuse and String Open Circuit Voltage test							
String cable ID						Date of inspection: (dd_mmm_yyyy)	
Description			References (Please state)				
Test point			Each Array Junction Box/String Monitoring Box				
Use appropriate tools to measure and record							
Test the continuity of each string fuse (Please tick ✓)					OK: ☐	Not OK: ☐	
Determine the following: 1. Measured Open Circuit Voltage (Voc_mea) of each string. 2. Expected Open Circuit Voltage (Voc_exp) of each string. 3. % Difference between measured and expected Voc. **ACCEPT** if • % difference of Voc (between measured Voc and expected Voc) with respect to expected Voc is within ±5% • Voc measured of each string is less than the maximum input voltage of the inverter • Polarity of all DC cables (string and array) is correct					Solar irradiance should be at least **350 Wm^{-2}** when performing this test. Instructions: **SWITCH OFF / DISCONNECT** the following: - PV AC Main Switch (isolator) - All AC switches - All DC switches - All DC fuses		
String No.	Voc of string at STC (V)	Voc measured (V)	Voc expected (V)	Measured module temp (^{0}C)	Measured Irradiance (Wm^{-2})	% difference of Voc	Accept (A) or Reject (R)
1							
2							
3							
4							
5							
…							
…							
Comments:							

1.13 STRING DC SHORT CIRCUIT CURRENT TEST

Table 1.13 String DC Short circuit current test

String Cable ID		Date of inspection: (dd_mmm_yyyy)
Description	References (Please state)	
Test point	All DC Junction Boxes	
Inverter No		

Use appropriate tools to measure and record

Using appropriate method, determine the following:

1. Measured short circuit current (Isc_mea) of each string
2. Expected short circuit current (Isc_exp) of each string
3. % Difference between measured and expected Isc.

ACCEPT if

- % difference of Isc (between measured Isc_mea and expected Isc_exp) with respect to Isc_exp is within $\pm 5\%$

AJB: Array Junction Box
SMB: String Monitoring Box

Solar irradiance should be at least **350 Wm^{-2}** when performing this test.

Instructions:
SWITCH OFF / DISCONNECT the following:
- PV AC Main Switch (isolator)
- All AC switches
- All DC switches
- All DC fuses

No.	AJB/SMB ID No.	No. of strings per AJB/SMB	String no.	Solar irradiance (Wm^{-2})	Measured module temp (^0C)	Measured Isc of string (A)	Expected Isc string (A)	% difference of Isc	Accept (A) or Reject (R)

Comments:

1.14 ISOLATION DEVICE FUNCTIONAL TEST

Table 1.14 Isolation device test				
Description		Date of inspection: (dd_mmm_yyyy)		
Test point	All isolators, switches and fuses			
Use appropriate tools to measure and record				
Please tick ✓ in the appropriate box	Solar irradiance should be at least **350 Wm^{-2}** when performing this test. Instructions: **SWITCH OFF / DISCONNECT** the following: - PV AC Main Switch (isolator) - All AC switches - All DC switches - All DC fuses			

No.	Description	Accept	Reject	Note
1	Confirm voltage is NOT present at array cable terminal at AJB before all fuses are engaged			
2	Confirm voltage is present at array cable terminal at AJB after all fuses are engaged			
3	Confirm voltage is NOT present at the outgoing terminal of PV DC Main Switch when the switch is in OFF position			
4	Confirm voltage is present at the outgoing terminal of PV DC Main Switch when the switch is in ON position			
5	Confirm voltage is NOT present at the outgoing terminal of AC Switch when the switch is in OFF position			
6	Confirm voltage is present at the outgoing terminal of AC Switch when the switch is in ON position			
7	Confirm voltage is NOT present at the outgoing terminal of PV AC Main Switch when the switch is in OFF position			
8	Confirm voltage is present at the outgoing terminal of PV AC Main Switch when the switch is in ON position			

Comments:

Signature		
Date		
Name		
Designation	Chargeman/Wireman with SEDA PV certification	SEDA Malaysia GCPV System Design certificate holder

2. TESTING AND COMMISSIONING CHECKLIST

This activity shall be conducted by competent persons as stated at the end of the checklist whilst adhering to the provisions of all relevant laws and regulations.

After completion of the pre-commissioning checklist and tests, the service provider **must perform commissioning tests** to ensure all inter-connections of the components are satisfactory.

The commissioning test comprises the following:

1. Information about PV module
2. Information about PV array
3. Information about inverter
4. Inverter functional test
5. Acceptance test

Conditions:

1. All tests **must be done in sequence**.
2. If a test fails, the next test **shall not be performed**.
3. **Failure of any test nullifies** the entire Testing and Commissioning.
4. The Weather Monitoring Station and PV Monitoring System shall be provided, installed and maintained by the FIAH for the entire duration of the Deed in Approval.

2.1 INFORMATION ABOUT PV MODULE

Table 2.1 Information about PV module				
Description		Visual Inspection If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
No.	Item	Details		Check (✓)
1	Module make & model			
2	Power at maximum power point (Pmp_stc)		Wp	
3	Open Circuit Voltage (Voc_stc)		V	
4	Short Circuit Current (Isc_stc)		A	
5	Fill factor at STC		-	
6	Module efficiency at STC		%	
7	Temperature coefficient for Pmp (at STC)		% per deg C	
8	Temperature coefficient for Voc (at STC)		% per deg C	
9	Temperature coefficient for Isc (at STC)		% per deg C	
10	Maximum system voltage		V	
11	Maximum reverse current		A	
Comments:				

2.2 INFORMATION ABOUT PV ARRAY

Table 2.2 Information about PV array			
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each connection to one inverter	Inverter ID:	Sub-array ID:

No.	Item	Details		Check (✓)
1	No. of modules per string		pcs	
2	Total no. of strings		pcs	
3	Total array power at STC		Wp	
4	PV array inclination		deg	
5	PV array orientation (azimuth angle from South)		deg	
6	No. of strings per Array Junction Box/String Monitoring Box		pcs	
7	No. of Array Junction Box/String Monitoring Box		pcs	

Comments:

2.3 INFORMATION ABOUT INVERTER

Table 2.3 Information about inverter				
Description	If the job has been done satisfactorily, please tick ✓ in the box. If not applicable, write 'NA' in the box.			Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each connection to one inverter	Inverter ID		

No.	Item	Details		Check (✓)
1	Inverter model			
2	Nominal AC power rating		W	
3	Maximum AC power rating		W	
4	Maximum DC voltage		V	
5	DC voltage range		V	
6	MPPT voltage range		V	
7	No. of MPPT trackers		unit	

Comments:

2.4 INVERTER FUNCTIONAL TEST

Table 2.4 Inverter functional test					
Format No			Date of inspection: (dd_mmm_yyyy)		
Description		References			
Test point		All Inverters			
Use appropriate tools to measure and record					
		Please tick ✓ in the appropriate box Solar irradiance should be at least **350 Wm^{-2}** when performing this test. Instructions: **SWITCH ON** the system and ensure that the inverter is operating. **CAUTION**: Before switching on the inverter, make sure Voc measured at the inverter input terminal must be LESS THAN the maximum allowable input DC voltage of the inverter.			
No.	**Description**	**Value**	**Accept**	**Reject**	**Reasons**
1	Check whether the measured DC voltage falls within the allowable MPPT voltage range of the inverter				
2	Check whether the measured grid voltage and frequency are within the acceptable limit				
Comments:					

2.5 ACCEPTANCE TEST

	Table 2.5 System acceptance test		
Inverter ID		References (please state)	Date of inspection: (dd_mmm_yyyy)
	Determine the following: 1. Measured AC output power of inverter, Pac_mea 2. Expected AC output power of inverter, Pac_exp 3. Please declare the following: • Tolerance due to module mismatch : _____ • Soiling index : _____ • Ageing factor : _____ • Cable loss : _____ • Maximum inverter efficiency : _____ • Shading factor : _____ 4. Acceptance Ratio (AR) : _____ Note: AR is the ratio of Pac_mea to Pac_exp **ACCEPT** if • AR is greater than or equal to 0.9		Solar irradiance should be at least **350 Wm^{-2}** when performing this test. Instructions: **SWITCH ON** the system and ensure that the inverter is operating.

Inv No.	Irradiance (Wm^{-2})	Measured module temp (^0C)	Temperature de-rating factor	Pac expected (W)	Pac measured (W)	AR	Accept (A) or Reject (R)
1							
2							
3							
…							
…							
	If AR is not acceptable, please troubleshoot the system, rectify the fault and repeat the test until all parties are satisfied.						
Comments:							

Signature			
Name			
Date			
Designation	Chargeman / Wireman with SEDA PV certification	SEDA Malaysia GCPV System Design certificate holder	SEDA Representative

3. RELIABILITY RUN TEST

This activity shall be conducted by the competent persons as stated at the end of the checklist whilst adhering to the provisions of all relevant laws and regulations.

Upon the successful completion of the testing and commissioning section, Performance Ratio (PR) is needed to be carried out.

The reliability of the system is tested by using the Performance Ratio Test. During this test, the following real time parameters must be sampled at a maximum of **five-minute** intervals for **AT LEAST SEVEN consecutive days**:

1. Solar irradiance
2. Ambient temperature
3. Module temperature
4. DC voltage of each central inverter or group of string inverters
5. DC current of each central inverter or group of string inverters
6. AC voltage from each central inverter or group of string inverters
7. AC current from each central inverter or group of string inverters

All data shall be submitted to SEDA/SEDA Representative in csv format immediately after the test.

3.1 PERFORMANCE RATIO TEST

Table 3.1 Performance Ratio (PR) Test		
Test point	At Monitoring Station / Grid Injection Point	Date of inspection: (dd_mmm_yyyy)
Test duration		

Predicted annual PR at design stage:

Using the logged data for seven complete consecutive days during the reliability test period, determine the following parameters for the entire system:

1. Energy Yield, Y_f
2. Specific Yield, SY
3. Performance Ratio, PR

$$PR = \frac{Y_f}{\eta_{mod} \times A_{PV} \times H}$$

η_{mod} = is efficiency of module (decimal)
A_{PV} = is area of array (m^2)
H = solar irradiation (kWh/m^2)

ACCEPT if

- PR is greater than or equal to 0.8

Note: Inverter failure **shall NOT occur more than three (3) times** within the reliability test period (excluding forced outages). If this happens, this test should be repeated. Please provide evidence in the form of chart (Voltage vs Time) for the 7 days Reliability Run (RR).

Day no.	Energy Yield (kWh)	Specific Yield ($kWh\ kWp^{-1}$)	Performance Ratio	Accept (A) or Reject (R)	Remarks
1					
2					
3					
4					
5					
6					
7					
One Week Value					
Comments:					

Signature			
Name			
Date			
Designation	Chargeman / Wireman with SEDA PV certification	SEDA Malaysia GCPV System Design certificate holder	SEDA Representative

End of Document