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

PART 1 - SYSTEMS LESS THAN OR EQUAL TO 12 kWp (USE OF DC POWER OPTIMISER)

SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY (SEDA) MALAYSIA

2016

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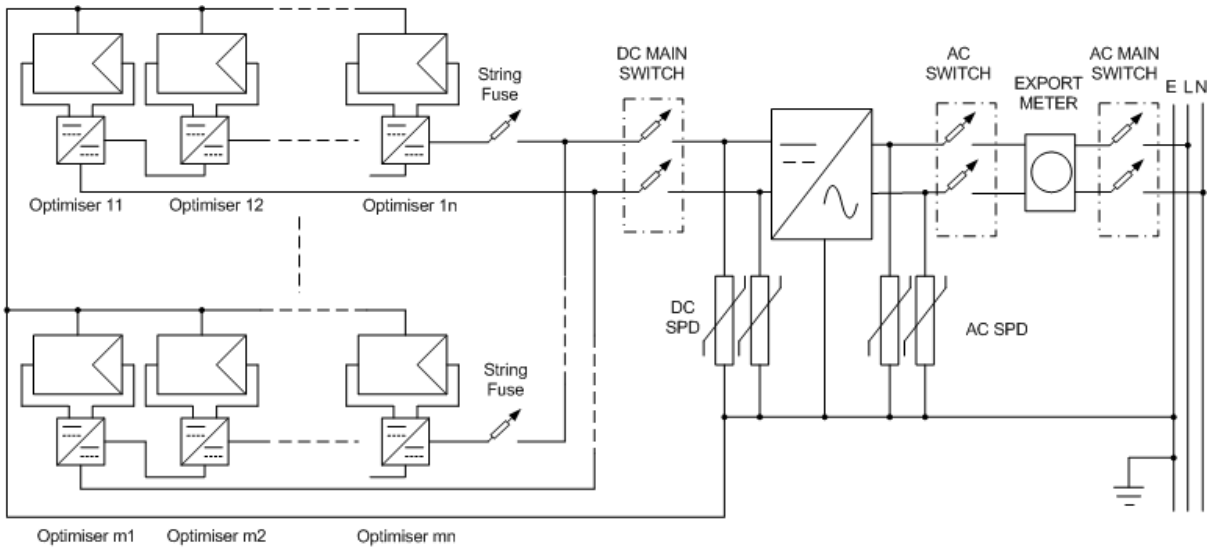
SCHEMATIC DIAGRAM OF DC POWER OPTIMISER



Note: The above circuit diagram is for single-phase system. For three-phase system, the AC components and wiring are slightly different.

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 of 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
5. Checklist for Earthing & Lightning Arrestor
6. Checklist for PV Module
7. Checklist for Power Optimiser
8. Checklist for Inverter
9. Checklist for AC Distribution Box
10. Checklist of Cable identification and cable routing inspection
11. Cable insulation test
12. String fuse continuity and string open circuit voltage test
13. 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	
Contact address	
Contact phone number	
Email address	

Installation details	
Date of completion of installation	
Date of connection to grid	
Import meter reading (kWh) before connection to grid	
Export meter reading (kWh) before connection to grid	
Remarks	

1.2 CHECKLIST FOR GENERAL INSPECTION

Table 1.2 Checklist for General Inspection			
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily)		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each sub-array connected to one inverter	Inverter No.	Sub-array No.
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 complies with standards and are correctly selected & not damaged ☐ vi. Equipment accessible for inspection, operation & maintenance ☐ vii. Equipment & accessories are connected as per approved drawing ☐ Protective measures for special locations have been addressed (if applicable) ☐ viii. Equipment & protective measures appropriate to external influence ☐ ix. System installed to prevent mutual detrimental influence ☐ x. All cables are identified and connected as per approved drawing ☐ xi. All cables are selected for current carrying capacity and voltage drop as per approved design ☐ xii. Conductors routed are in safe zone or protected against mechanical Damage ☐ xiv. All tagging are appropriate. ☐ xv. All signage 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.	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 Insulated 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	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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 No.	Sub-array No.

i.	Mounting structure and jointing materials as per approved drawing	☐
ii.	Foundation dimension 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	☐
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 CHECKLIST FOR DC JUNCTION BOX OR STRING MONITORING BOX

Table 1.4 Checklist for DC Junction Box or String Monitoring Box			
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. If not applicable, write 'NA' in the box)		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each box connected to one inverter	Inverter No.	Box No.

i.	DC Junction/String Monitoring Box connection diagram is available Inside the cover ☐
ii.	Wiring as per the approved schematic ☐
iii.	String fuses or DC circuit breakers are available in the box ☐
iv.	Metal casings are earthed as per design document ☐
v.	All boxes are properly fixed at appropriate location as per design document ☐
vi.	Surge protection 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	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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 No	Lightning arrestor No.

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 appear to be 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	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. If not applicable, write 'NA' in the box)		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each string	Structure No.	String No.

i.	PV modules are fixed on the structure as per design drawing	☐
ii.	All PV modules are properly levelled on the structure	☐
iii.	PV modules conform to relevant IEC standards as per design document	☐
iv.	All inter-module connectors are properly crimped & securely connected	☐
v.	Polarity of all PV modules are correctly connected	☐
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 DC POWER OPTIMISER INSPECTION

Table 1.7 Checklist for DC Power Optimiser			
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. If not applicable, write 'NA' in the box)		Date of inspection: (dd_mmm_yyyy)
Instructions	This form shall be filled-up for each string	Structure No.	String No.

i. DC Power optimisers are fixed on the structure as per design drawing ☐

ii. DC Power optimisers conform to relevant standards as per design document ☐

iii. Inter DC Power optimisers connectors are properly crimped & securely connected ☐

v. DC Power optimisers are correctly connected with correct polarity ☐

vi. Non-metallic isolator is present between each DC Power optimiser frame & structure (if they are made from different metals) ☐

vii. Installation of DC Power optimisers are done as per manufacturer's guidelines ☐

Comments:

1.8 CHECKLIST FOR PV MODULE INSPECTION

Table 1.8 Checklist for PV module			
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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 No.	Sub-array No.

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 correctly 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:

1.9 CHECKLIST FOR INVERTER INSPECTION

Table 1.9 Checklist for inverter			
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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 No.	

i.	Inverters are installed as per manufacturer's guideline	☐
ii.	Sufficient ventilation is available around the inverters (as per manufacturer's guideline)	☐
iii.	Inverters conform 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 and N (for three-phase inverter) are in proper order	☐
ix.	The connections for L and N are in proper order (for single-phase inverter)	☐
x.	Inverter for outdoor use should have an IP rating of IP65	☐
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 SEDA guideline	☐

Comments:

1.10 CHECKLIST FOR AC DISTRIBUTION BOX

Table 1.10 Checklist for AC Distribution Box (ACDB)			
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. If not applicable, write 'NA' in the box)		Date of inspection: (dd_mmm_yyyy)
Instruction	This form shall be filled-up for each ACDB	ACDB No.	

i.	ACDB's are properly fastened to the ground/wall as per design document	☐
ii.	Sufficient free space available around each ACDB (ground mounted)	☐
iii.	ACDB is properly earthed as per design document	☐
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 are rated with IP65 for outdoor use	☐

Comments:

1.11 CHECKLIST OF CABLE IDENTIFICATION AND CABLE ROUTING INSPECTION

Table 1.11 Checklist for cable identification & route inspection		
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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:		

1.12 CABLE INSULATION TEST

Table 1.12 Cable insulation test		
Format No		Date of inspection: (dd_mmm_yyyy)
Description	**References**	
Test point	**All 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 DC cables except for inter-module connection cables.	

No.	Cable from (originating)	Cable to (terminating)	Insulation Resistance Value	Pass	Fail
				(Please tick ✓ in the box)	
1					
2					
3					

Comments:

1.13 STRING FUSE CONTINUITY AND STRING OPEN CIRCUIT VOLTAGE TEST

Table 1.13 String fuse and String Open Circuit Voltage test					
Format No			Date of inspection: (dd_mmm_yyyy)		
Description	**References**				
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. **ACCEPT** if • Voc measured of each string is less than 30V • 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 during inverter turn off as specified by manufacturer (V)	Voc measured (V)	Measured module temp (^0C)	Measured Irradiance (Wm^{-2})	Accept (A) or Reject (R)
1					
2					
3					
4					
…					
…					
Comments:					

1.14 ISOLATION DEVICE FUNCTIONAL TEST

Table 1.14 Isolation device test		
Format No		Date of inspection: (dd_mmm_yyyy)
Description	**References**	
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			

Signature		
Date		
Name		
Designation	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 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 DC Power Optimiser
3. Information about PV array
4. Information about inverter
5. Inverter functional test
6. Acceptance test

Conditions:

1. All tests **must be done in sequence**.
2. If one test in the sequence fails, the next test **shall not be performed**.
3. Failure of any test **nullifies** the entire Testing and Commissioning.

2.1 INFORMATION ABOUT PV MODULE

Table 2.1 Information about PV module				
Description		Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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	Voltage at maximum power (Vmp)		V	
8	Current at maximum power (Imp)		A	
9	Temperature coefficient for Pmp (γ_{Pmp})at STC		% per deg C	
10	Temperature coefficient for Voc (γ_{Voc}) at STC		% per deg C	
11	Temperature coefficient for Isc (γ_{Isc}) at STC		% per deg C	
12	Maximum system voltage		V	
13	Maximum reverse current		A	
14	Standard compliance. Please specify			
Comments:				

2.2 INFORMATION ABOUT PV ARRAY

Table 2.2 Information about PV array				
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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.		String No.

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 orientation (azimuth angle from South) Please state for each different angles (if any):	Inclination (deg)	Azimuth angle (deg)	
5	No. of strings per Array Junction Box/String Monitoring Box		pcs	
6	No. of Array Junction Box/String Monitoring Box		pcs	

Comments:

2.3 INFORMATION ABOUTDC POWER OPTIMISER

Table 2.3 Information about DC Power Optimiser					
Description		Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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	String No	
No.	Item		Details		Check (✓)
1	DC Power Optimiser model				
2	Nominal DC power rating			W	
3	Maximum DC power rating			W	
4	Maximum short circuit current			A	
5	Input: Minimum DC voltage			V	
6	MPPT voltage range			V	
7	Maximum DC current			A	
8	Output: DC voltage range			V	
9	Maximum DC current			A	
10	Highest efficiency			%	
11	Power tolerance			%	
12	Standard compliance. Please specify				
Comments:					

2.4 INFORMATION ABOUT INVERTER

Table 2.4 Information about inverter				
Description	Visual Inspection (Please tick ✓ in the box, if the job has been done satisfactorily. 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 (if available)		V	
7	No. of MPPT trackers (if available)		unit	
8	Inverter output voltage		V ±%	
9	Inverter frequency		Hz ±Hz	

Comments:

2.5 INVERTER FUNCTIONAL TEST

Table 2.5 Inverter functional test					
Inverter ID:			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**: 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:					

2.6 ACCEPTANCE TEST

Table 2.6 System acceptance test

Inverter ID:	Reference (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 mis-match : _____
   - Soiling index : _____
   - Maximum inverter efficiency : _____
   - Maximum efficiency of power optimiser : _____
   - Cable loss : _____
   - Shading factor : _____
   - Ageing factor : _____

Note: Acceptance Ratio (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.

Inverter No.	Irradiance (Wm^{-2})	Module temp (deg C)	Pac expected (W)	Pac measured (W)	AR	Accept (A) or Reject (R)
1						
2						
3						
…						
…						

If AR is not acceptable, please trouble shoot the system, rectify the fault. Repeat the test until all parties are satisfied.

Comments:

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

End of Document