ECOWAS Certification for Sustainable Energy Skills (ECSES)

Guidelines for Conducting the Examination for Certification as Certified Off-Grid Solar PV Technician

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1. Introduction

The Examination Institute (EI) shall follow the procedures in this document when conducting a Regional Certification Scheme Examination in co-operation with the Regional Certification Body.

The EI shall conduct both a written examination and practical examination for each examination participant.

The EI nominated assessor shall assess the participant while the practical examination is being conducted and assess/mark the written examination script after the examination is completed. The practical examination comprises two compulsory components:

- Practical Examination 1 involves the installation of a system which is observed by the EI assessor.
- Practical Examination 2 which is a one-on-one interview between the EI assessor and the examination participant.

To become a certified technician, the examination participant must:

- obtain a minimum score of 70% in the written examination;
- obtain a minimum score of 70% in practical examination 1; and
- answer all questions in practical examination 2 to the satisfaction of the EI assessor.

2. Preparing for the Examination

The written examination will be electronically provided to the EI by the RCB a few days before the actual examination. On the days leading up to the examination the EI shall:

- Print the number of examination papers required so that there is one per examination participant;
- Prepare for the practical examination by ensuring all the required equipment is available; and
- Ensure all the assessors selected are available to conduct the examination.

On the day before the examination the EI shall ensure the room(s) to be used for the examination is(are) ready. Each participant should have their own desk and there should be a space between each participant's desk. If there are insufficient desks or the desks are long, then there should be a minimum of 1 one chair between each of the participant such that the participants are approximately 1 metre apart.

3. Conducting the Written Examination

The procedures for conducting the examination are as follows:

- When the participants arrive the EI shall check the identity of the participant and confirm that the person undertaking the examination is the same person that applied to do the examination.
- The participants should all take their seats prior to the commencement time of the examination.
- The participants shall be reminded that there is to be no talking or passing of any material to another participant during the examination. This will be deemed as cheating and if any participants actively participate in the activity they will be removed from the examination room and will not be allowed to undertake the examination in the future. If only one participant was trying to read another participants paper or attempt to talk with another participant, then only that person would be deemed as cheating. Determining whether it was only one or both participants is at the discretion of the EI assessor who observed the cheating.
- Once all participants are seated the examination script and the survey (**schedule V** refers) shall be distributed. The paper must remain closed.
- Once every participant has the paper they shall then be allowed 10 minutes to read the paper. At the end of the 10-minute mark they will be allowed to start answering the questions.

- The maximum time allowed for completing the written examination is four (4) hours. Once the examination has started the EI shall note the time and the examination will stop exactly (4) hours after the start time.
- A participant can enter the examination room and commence the examination up to thirty (30) minutes after the start of the examination but that participant will still have to stop at the nominated time for finishing the examination.
- The participants shall be told when there is 30 minutes to go and then again when there is 15 minutes to go.
- At the conclusion of the examination all participants must stop writing.
- After **all** the examination scripts are collected the participants shall then be reminded to complete the survey form with respect to the written examination. This survey must be handed in after the practical examination is completed.
- If some participant finished the examination early they will be allowed to leave after they hand in the examination script.
- No participant can leave the examination in the last 30 minutes, so as not to disturb those trying to finish.

4. Marking the Written Examination

Table 1 provides the maximum number of point available for each written examination question. The written examination comprises fifty-three (53) questions, thirty (30) will be multiple choice and twenty-three (23) will comprise short written answers. A total of eighty-eight (88) points is allocated to the written examination and a participant require a minimum mark of 62 (70%) to pass the written examination.

When marking the examination, the multiple-choice questions will either be right or wrong. For the questions with short written answers, sample answers are provided. However, it is at the discretion of the examination assessors whether they allocate the full marks to the answer.

A sample examination mark recording sheet is provided in Annex 1. This shall be completed for each examination participant.

Table 1: Number of points for each examination question

Examination number	Job task Analysis Domain/Section	Points
	1. Working safely with Photovoltaic systems	
1	1.1 Maintain safe and appropriate work habits	2
2	1.3 Adequately ensure safe and accepted practices for the protection of personnel and property	2
3	1.4 Possess knowledge related to health and safety hazards and prevention	2
4	1.5 Apply appropriate codes and standards concerning installation, operation, safety, and maintenance of PV systems and equipment	2
5	1.6 Identify safety hazards for personnel and property associated with PV installations	2
6	1.7 Ability to administer first aid in case of accidents	1
	2. Understanding Solar Energy and PV System Basics	
7	2.1 Demonstrate knowledge of correct units for electrical potential (voltage), electrical flow (current), electrical resistance, power, and energy	2
8	2.2 Demonstrate knowledge of basic electric circuit theory and be able to identify series, parallel and series/parallel circuits	2
9	2.3 Understand Ohm's and Power Laws to be able to calculate energy loads	1

10	2.4 Demonstrate understanding of differences between AC and DC power, power factor and true power vs. real power	1
11	2.5 Demonstrate necessary knowledge for proper orientation and inclination of solar array	2
12	2.6 Demonstrate understanding of the term “peak sun hours” (irradiation) and the impact of irradiation on battery charging and overall energy generation	1
13	2.7 Interpret the technical specifications and output characteristics of photovoltaic modules (e.g. Isc, Voc, Imp, Vmp, Pmax) and the controller, the inverter and battery	1
14	2.8 Demonstrate understanding of the factors which influence the output characteristics of photovoltaic modules (irradiance, temperature, load, etc.)	1
15	2.9 Demonstrate understanding of the effect on array output (current, voltage, power) of connecting modules in series, parallel and series/parallel configurations	2
16	2.10 Understand the disadvantages of using dissimilar modules in the same array	1
17	2.11 Demonstrate the impact of shading on overall production of solar energy	2
18	2.12 Understand the installation techniques for pole mounted as well as roof mounted PV arrays	1
19	2.13 Interpret and explain different PV module and battery technologies, criteria for battery selection and majors factors affecting battery performance characteristics	1
20	2.14 Understand the operating principles of charge controllers and explain the major controller features (e.g. low voltage disconnect)	1
21	2.15 Understand basic operating principles of an inverter and list factors which affect efficiency and reliability of inverters	1
22	2.16 Know how to properly use electric measuring instruments.	2
	3. Understanding PV Design	
23	3.1 Confirm system design matches client expectation, e.g. load assessments, site drawings	1
24	3.2 Review and confirm compatibility of chosen major system components with sizing requirements	2
25	3.3 Locate and evaluate desired PV array and equipment locations	2
26	3.4 Identify and assess any site specific safety hazards associated with the installation of the system	1
27	3.5 Verify the appropriate module/array layout, orientation and mounting method for ease of installation, electrical configuration and maintenance	2
28	3.6 Verify suitable locations for battery bank, including ventilation and access requirements?	2
29	3.7 Understand selected conductor type, ampacity, ratings and run distance	2
30	3.8 Confirm location, size and type of selected grounding method and overcurrent protection is appropriate for the application	2
31	3.9 Verify the compliance of protective elements between the different components of a photovoltaic system	1
	4. Installing Mechanical and Electrical PV Components	
32	4.1 Demonstrate necessary mounting techniques for attaching modules to array frame and array frame to its supporting structure	2

33	4.2 Demonstrate necessary working knowledge of how to fit PV arrays to roofs by interpreting layout diagrams and apply different methods of fixing PV arrays at optimum pitch and orientation to roofs typical within the country of installation	2
34	4.3 Demonstrate the safe handling of batteries and its appropriate placement to ensure good aeration	2
35	4.4 Choose the correct layout, safe positioning and sound mounting techniques of all system components, e.g. charge controllers, inverters and appliances	2
	5. Installing Cables, Connectors and Protection Devices	
36	5.1 Discuss current carrying capacity and the implications for proper cable selection	1
37	5.2 Demonstrate the calculation and measurement of voltage drop in a conductor	2
38	5.3 Apply voltage drop and current carrying capacity calculations to select appropriate cables for a stand-alone PV energy system	2
39	5.4 Specify appropriate protection for all conductors in a circuit	2
40	5.5 Understand the need for and recognize the different modes of grounding (earthing) on a systems as well as component level	1
41	5.6 Perform safe techniques for laying, securing and terminating cables	2
42	5.7 Label, install and terminate electrical wiring, verify proper connections, continuity, voltage and polarity relationships	2
	6. Completing System Installation, Testing and Commissioning	
43	6.1 Visually inspect entire installation, identifying and resolving any deficiencies in workmanship	2
44	6.2 Check system mechanical installation for structural integrity and weather sealing	2
45	6.5 Apply procedures for connecting and disconnecting the system and equipment from all sources	2
46	6.6 Explain to end-user safety issues associated with operation and maintenance of system	2
47	6.7 Complete system documentation and transfer system documentation package to end-user/operator	2
	7. Conducting Maintenance and Trouble Shooting Activities	
48	7.1 Identify maintenance needs on system and component level, design appropriate maintenance plan and demonstrate proficiency in selecting and using of required tools	2
49	7.3 Verify system operation by measuring system performance and electric parameters, by comparing with specifications and expected performance parameters, by performing diagnostic procedures and by recommending corrective actions	2
50	7.4 Identify performance and safety issues and perform corrective measures	2
51	7.5 Verify effectiveness of corrective actions by retesting system operations and electrical parameters	2
52	7.6 Compile and maintain records of system operations, performance and maintenance	1
53	7.7 Demonstrate knowledge of the environmental impacts	1
	TOTALS	**88**

5. Conducting the Practical Examination Guideline

The practical examinations assess 24 competencies as detailed in Table 2. The four competencies highlighted in grey are only assessed in the practical examinations that are undertaken during each regional examination.

Table 2: List of Competencies Assessed in Practical Examinations

Domain/Section
1. Working safely with photovoltaic systems
1.1 Maintain safe and appropriate work habits
1.2 Demonstrate safe and proper use of required tools and equipment
1.5 Apply appropriate codes and standards concerning installation, operation, safety, and maintenance of PV systems and equipment
1.6 Identify safety hazards for personnel and property associated with PV installations
2. Understanding solar energy and PV system basics
2.2 Demonstrate knowledge of basic electric circuit theory and be able to identify series, parallel and series/parallel circuits
2.5 Demonstrate necessary knowledge for proper orientation and inclination of solar array
2.12 Understand the installation techniques for pole mounted as well as roof mounted PV arrays
2.16 Know how to properly use electric measuring instruments
3. Understanding PV design
3.5 Verify the appropriate module/array layout, orientation and mounting method for ease of installation, electrical configuration and maintenance
4. Installing Mechanical and Electrical PV Components
4.1 Demonstrate necessary mounting techniques for attaching modules to array frame and array frame to its supporting structure
4.3 Demonstrate the safe handling of batteries and its appropriate placement to ensure good aeration
5. Installing Cables, Connectors and Protection Devices
5.3 Apply voltage drop and current carrying capacity calculations to select appropriate cables for a stand-alone PV energy system
5.5 Understand the need for and recognize the different modes of grounding (earthing) on a systems as well as component level
5.6 Perform safe techniques for laying, securing and terminating cables
5.7 Label, install and terminate electrical wiring, verify proper connections, continuity, voltage and polarity relationships
6. Completing System Installation, Testing and Commissioning
6.1 Visually inspect entire installation, identifying and resolving any deficiencies in workmanship
6.2 Check system mechanical installation for structural integrity and weather sealing
6.3 Check electrical installation for proper wiring practice, polarity, earthing, and integrity of terminations

6.4 Activate system and verify overall system functionality and performance; compare them with expectations
6.5 Apply procedures for connecting and disconnecting the system and equipment from all sources
7. Conducting Maintenance and Trouble Shooting Activities
7.2 Perform visual inspection of entire installation, check mounting systems, ventilation, cable runs and connections/ junction boxes
7.3 Verify system operation by measuring system performance and electric parameters, by comparing with specifications and expected performance parameters, by performing diagnostic procedures and by recommending corrective actions
7.4 Identify performance and safety issues and perform corrective measures
7.5 Verify effectiveness of corrective actions by retesting system operations and electrical parameters

Sections 6, 7, 8 and 9 describe the process for conducting four practical examinations. For each practical examination the document details:

- The hardware (equipment) that is required for completing the specified practical examination.
- The tools, testing and other measuring equipment that is required for completing the practical examination.
- The assessment activities that the examination participants must perform to demonstrate that they have the competencies with respect to the regional job task analysis.
- How the examination assessors undertake the assessment of the examination participant including the assessments forms used to record the outcomes.

Practical examinations number 1 (PE1) and 2 (PE2) are to be conducted during every regional examination. These assess 23 of the competencies.

When assessing the examination participant for PE1 the highest possible points that can be obtained is seventy-one (71). An examination participant must obtain a minimum point score of 49 (70%) to pass practical examination 1.

PE2 consists of a series of questions that the examination participant will be asked by the EI assessor. The examination participant must answer all questions to the satisfaction of the assessor to pass this practical examination.

Practical examinations number 3 (PE3) and 4 (PE4) have been prepared as possible additional practical examinations. If it is found that there is sufficient time in the four-hour examination period allocated for the practical's then these should be included.

For examinations PE1, PE3 and PE4 an examination centre should have sufficient material for a minimum of 4 examination participants to undertake the examination concurrently.

For the security of the examination, all practical examination documents provided to the course attendee must be returned to the examination assessor at the conclusion of the examination.

6. Practical Examination One (PE1) - System Installation

Estimated time 4 hours

6.1 Hardware/Equipment Required for Each Examination Participant

- Two (2) solar PV modules with thirty-six (36) cells suitable for a 12 V system. It would be preferable that these modules have junction boxes that can be opened and have screw type terminals so that the modules can be hard wired (and reused). However, if that is not possible then joining connectors will be required for paralleling the modules.
- One (1) array frame with all associated hardware suitable for mounting the two solar modules.
- One (1) 12V DC nominal input inverter.
- Two (2) 12V nominal sealed lead acid batteries.
- One (1) solar controller with a minimum current rating of 3 times the selected module's short circuit current with a 10A rated load terminal.
- One (1) DC rated switch two-pole disconnector (PV array isolator) with a minimum current rating of 3 times the selected modules short circuit current—to be connected between the solar modules and the solar controller.
- Four (4) DC rated fuses (main battery fuses) and associated fuse holders (preferably switch fuses if possible). Two fuses with a minimum current rating of 3 times the selected module's short circuit current. These are to be located between the battery and controller. The second set of two fuses are to be rated to suit the maximum DC input current for the inverter. These are to be mounted between the batteries and inverter. However, if the inverter is small enough than possibly only one set of fuses will be required (sized to protect both the inverter cable and the solar cable). However, separate isolation devices will be required for the inverter and the solar controller.
- One (1) DC light switch.
- One (1) DC light.
- Sufficient rolls of DC rated multi-stranded cables required for:
    - Wiring the solar modules to the controller and possibly between the modules if the selected modules have accessible junction boxes.
    - Wiring the solar controller to the battery

  These should include 1 mm^2, 2.5 mm^2, 4 mm^2, 6 mm^2, 10 mm^2 and 16 mm^2
- Roll of earthing cable.
- Earth/ground clamp suitable for the selected array frame and an earth/ground rod.
- Screws and fastening equipment for mounting the array frame, solar controller, DC switch disconnector, fuse holders, DC lights and DC light switch.
- Cable clips for supporting the cables on the wall.
- One assembly board as per attached drawing which includes a simulated roof and wall for mounting the controller and the light and switch. (Refer to annex 2 for a drawing).
- All relevant product manuals.

6.2 Installation Tools required:

All the tools required to suit the installation of the selected equipment which would include as a minimum:

- Pliers
- Screwdrivers Philips head (or cross head) and flat blade suitable for fasteners and electrical connections.
- Cable cutters
- Cable strippers
- Spanners (wrenches)
- Allen key set – (depends on array mounting kit)

6.3 Testing and safety Equipment

1. Multimeter (20A DC rating) with a common input jack for the negative/neutral but then separate jacks for voltage measurement and current measurement.
2. Compass
3. Solar Irradiation Meter
4. Inclinometer
5. Spirit level
6. Googles
7. Hard Hat
8. Gloves

All the above, with the exception of the cables, should be stored as kits. One kit for each examination participant.

The examination document that will be provided to the examination participant is provided in Annex 3.

6.4 Part A: Mounting of the Equipment

One participant undertakes the mounting of the equipment, but is supported by one other examination participant when mounting the array frame onto the simulated roof.

The mounting of the equipment requires the examination participant to:

1. Draw a schematic of where the individual components will be mounted on the simulated wall/roof.
2. Mount the two solar modules onto the array frame.
3. Prior to mounting the array structure on the simulated roof the examination participant, using the compass, points the array frame in the correct direction for that site. This will be assessed by the examination assessor before the examination participant continues to:
4. Mount the array frame onto the simulated roof (would possible need support from one other participant).
5. Mount the PV array switch disconnector onto the simulated wall.
6. Mount the solar controller onto the simulated wall.
7. Mount the light and switch onto the simulated wall.
8. Place the two batteries onto the base of the wall structure.
9. Mount the inverter on the simulated wall or place it on the base of the wall structure.
10. Mount the batteries fuses onto the simulated wall.

During this session the examination assessor observes the examination participant and completes the assessment sheet provided in Annex 4. This part of the practical examination assesses the following competencies:

1.1 Maintain safe and appropriate work habits
1.2 Demonstrate safe and proper use of required tools and equipment
1.6 Identify safety hazards for personnel and property associated with PV installations
2.5 Demonstrate necessary knowledge for proper orientation and inclination of solar array
4.1 Demonstrate necessary mounting techniques for attaching modules to array frame and array frame to its supporting structure
4.3 Demonstrate the safe handling of batteries and its appropriate placement to ensure good aeration.

6.5 Part B Wiring the System

The examination participant must complete the cable section form as provided in Annex 3 and hand to the examination assessor. The examination assessor marks this at the time and then allows the examination participant to wire the system as follows:

1. Drawing a wiring diagram showing how all the individual system components will be interconnected electrically.
2. Select the correct cable for wiring the system as determined in the cable selection form.
3. Wire the two (2) solar modules to produce 12V output.
4. Wire the (2) batteries to produce 12V.
5. Wire between:
    - The solar module and solar controller via the switch disconnector (keep switch in off position)
    - Solar controller and the two batteries via the fuse holders (leave fuses out). The cable between each battery and the controller must be of equal length to ensure the same the same resistance and hence voltage drop between the controller and the battery bank.
    - The solar controller to light switch and then to the light.
6. Install an earth/ground bond on the array frame and interconnect with a earth/ground rod that is attached

During this the examination assessor is observing the course participant and completes the assessment sheet provided in Annex 5. This part of the practical examination assesses the following competencies:

1.1 Maintain safe and appropriate work habits.
1.2 Demonstrate safe and proper use of required tools and equipment
1.6 Identify safety hazards for personnel and property associated with PV installations
2.2 Demonstrate knowledge of basic electric circuit theory and be able to identify series, parallel and series/parallel circuits
3.7 Understand selected conductor type, ampacity, ratings and run distance
4.1 Demonstrate necessary mounting techniques for attaching modules to array frame and array frame to its supporting structure
5.3 Apply voltage drop and current carrying capacity calculations to select appropriate cables for a stand-alone PV energy system
5.5 Understand the need for and recognize the different modes of grounding (earthing) on a system as well as component level
5.6 Perform safe techniques for laying, securing and terminating cables

6.6 Part C: Testing and Commissioning of the System

The examination participant follows and completes the testing and commissioning sheet as provided in Annex 4.

This completed sheet is provided to the examination assessor who assesses and provides immediate feedback to the examination participant. If anything is incorrect the examination assessor informs the examination participant that he must undertake that test and commission again.

During this the examination assessor is observing the examination participant, reviews and assesses the completed testing and commissioning sheet and completes the assessment sheet provided in Annex 5. This part of practical examination assesses the following competencies:

1.1 Maintain safe and appropriate work habits.
1.2 Demonstrate safe and proper use of required tools and equipment

1.6 Identify safety hazards for personnel and property associated with PV installations
2.7 Interpret the technical specifications and output characteristics of photovoltaic modules (e.g. Isc, Voc, Imp, Vmp, Pmax) and the controller, the inverter and battery
2.16 Know how to properly use electric measuring instruments
5.7 Label, install and terminate electrical wiring, verify proper connections, continuity, voltage and polarity relationships
6.1 Visually inspect entire installation, identifying and resolving any deficiencies in workmanship
6.2 Check system mechanical installation for structural integrity and weather sealing
6.3 Check electrical installation for proper wiring practice, polarity, earthing, and integrity of terminations
6.4 Activate system and verify overall system functionality and performance; compare them with expectations
6.5 Apply procedures for connecting and disconnecting the system and equipment from all sources

7. Practical Examination Two (PE2) - One on One Questioning

Estimated time 15-20 minutes each for 8 people 2 hrs to 2 hrs 40 minutes

While the practical examination is being conducted, the examination assessor asks the examination participants the following two questions provided and has the examination participant show how to use the multi-meter to measure current and then voltage. The examination assessor completes the one-on-one assessment sheet provided in Annex 6.

1. What risks are involved when installing and maintaining a PV system?

   Note: ***The first sample answer is based on the examination participant being aware of the dangers of using Maximum Power Point Trackers (MPPT's) when they allow an array to be wired with an open circuit voltage greater than DC 120V. What is unknown is whether the participants have been made aware of tis danger during their training or by their employer.***

   There are many risk/hazards when doing a solar installation but there are 2 that can kill you. These two answers are:

   - *First is electrocution from DC wiring when using MPPTs with arrays above 120V. The risk is wiring the solar modules since the array is live when in the sun. To make the work safe it is important that one of the module connectors used to connect two modules in series is left disconnected to all the hard wiring is completed. Only then should the module connector be connected thereby completing the solar array circuit.*
   - *2nd is falling from roof.*

   Other big risks relate to the batteries:

   - *If wet/flooded lead acid batteries are used then the risk is battery acid can splash into eyes or cause acid burns on the skin*
   - *Batteries can explode but this does require gassing which would not happen during the installation but could be an issue when system maintenance is being undertaken.*
   - *High current if the battery terminals are short circuited.*

   Others possible danger that it would be good to have the examination participants provide (and hence beware of) include:

   - *Trip hazards*
   - *Heat stroke-sunburn etc.*
   - *Lighting in storms*
   - *Rain and hence slippery roofs*
   - *Falling objects*
   - *Eye damage when drilling, swarf etc.*

- *Back injuries etc. when lifting*

To obtain the above answers sometimes requires prompting by the EI assessor.

2. What should the technician do when working on a system to minimise or remove these risks and what safety equipment could be used?

Being careful when climbing ladders and staying away from the edges of the roof.

Ideally some form of fall protection when working on roofs (barriers, harnesses) but realistically this is probably not being undertaken anywhere in the ECOWAS countries.

Access to roofs should be undertaken using an appropriate ladder which is supported.

Critical one with lead acid batteries is eye protection so that acid does not get in eyes, gloves are important. If no gloves used important hands are washed thoroughly after working with wet lead acid batteries. Some form of acid protective coat would also be good but appreciate again not used in many countries. Availability of fresh water for eye and skin washing

Other equipment:

- *Goggles when drilling*
- *Hard hat if there is a risk of something falling on head.*
- *Safety shoes if possible to protect objects breaking toes when objects fall.*
- *Non-slip shoes suitable for working on roofs.*
- *Drinking water to prevent dehydration and sunstroke.*

3. Can the participant correctly use the multi-meter for measuring current and voltage?

Many multi-meters on the market have three probe positions. The multi-meter will be supplied with one black probe with cable and one red probe with cable (normally).

The black is inserted into the common terminal while the red will be inserted:

- *In the voltage terminal when measuring voltage (V) and*
- *In the current (A) terminal when measuring current.*

Have the multi-meter switched off and the two probes not connected. Ask the examination participant to set the multi-meter for reading voltage first and then current.

This should be done prior to the examination participant starting to test the system.

This part of the practical examination assesses the following competencies:

1.2 Demonstrate safe and proper use of required tools and equipment
1.6 Identify safety hazards for personnel and property associated with PV installations
2.16 Know how to properly use electric measuring instruments

8. Practical Examination Two (PE3) – Pole Mounted Array

Estimated time 30 to 45 minutes

8.1 Equipment Required for Each Examination Participant

- Two (2) solar PV modules with thirty-six (36) cell suitable for 12 V system.
- One (1) pole mount array frame with all associated hardware suitable for mounting the two solar modules.
- One (1) pole designed to suit the pole mount array frame. The pole is required to be the typical height as used in practice.

8.2 Installation Tools Required

- Pliers
- Screwdrivers: Philips head and flat blade
- Cable cutters
- Spanners
- Allen keys – (depends on array mounting kit)
- Ladder

The document that will be provided to the examination participant is provided in Annex 7. This document is also the assessment document to be completed by the examination assessor.

The examination participant:

- mounts the pole mount array frame on the pole and then mounts the two modules on the frame.
- ensures that the array is pointing in the correct direction and tilt angle for the location.

For safety reasons the examination participant is supported by one of the other course participants and in particular by holding the ladder. The support person's role is to:

- help the examination participant mount the array frame on the pole.
- help the examination participant mount the modules onto the array frame.

During this session the examination assessor observes the examination participant and the assistant and completes the assessment sheet provided in Annex 7. This practical examination assesses the following competencies:

1.1 Maintain safe and appropriate work habits
1.2 Demonstrate safe and proper use of required tools and equipment
1.6 Identify safety hazards for personnel and property associated with PV installations
2.5 Demonstrate necessary knowledge for proper orientation and inclination of solar array
2.12 Understand the installation techniques for pole mounted as well as roof mounted PV arrays
4.1 Demonstrate necessary mounting techniques for attaching modules to array frame and array frame to its supporting structure.

9. Practical Examination Two (PE4) – Modules Wired in Series

Estimated time 15 to 30 minutes

9.1 Equipment Required for Each Examination Participant

- Quantity Four (4) of thirty-six (36) cell solar module suitable for 12 V system.
- It would be preferable that these modules have junction boxes so the modules can be hard wired however if that is not possible then joining connectors will be required for paralleling the modules.

9.2 Installation Tools Required

- Pliers
- Screwdrivers Philips head and flat blade
- Cable cutters
- Spanners
- Allen keys (depends on array mounting kit)
- Ladder

The document that will be provided to the examination participant is provided in Annex 8. This document is also the assessment document to be completed by the examination assessor.

The examination participant:

- places the 4 modules on the ground and wires the modules as nominal 24V system configuration.

This practical examination assesses the following competencies:

1.2 Demonstrate safe and proper use of required tools and equipment
2.2 Demonstrate knowledge of basic electric circuit theory and be able to identify series, parallel and series/parallel circuits.

10. Preparing Examination Report

At the conclusion of the written and practical examination the EI shall obtain the completed survey forms from the examination participants. Theses should be reviewed and summarise an in particular noting any changes that should occur to the examination or examination process based on the feedback.

The EI shall then prepare a report on the examination for the RCB which includes: lessons learnt (if any); overview of the examination results and based on the survey of the examination participants any reasonable recommendation for improvement or changes.

The report along with all the examination scripts and results shall be sent to the RCB electronically.

Annex 1: Written Examination Assessment Sheet

Name of Examination Participant: _____

Certification Application Number:_____

Examination Location_____

Date of Written Examination_____

Total Mark _____

Question Number	Possible Points	Actual Points	Question Number	Possible Points	Actual Points	Question Number	Possible Points	Actual Points
1	2		19	1		37	2	
2	2		20	1		38	2	
3	2		21	1		39	2	
4	2		22	2		40	1	
5	2		23	1		41	2	
6	1		24	2		42	2	
7	2		25	2		43	2	
8	2		26	1		44	2	
9	1		27	2		45	2	
10	1		28	2		46	2	
11	2		29	2		47	2	
12	1		30	2		48	2	
13	1		31	1		49	2	
14	1		32	2		50	2	
15	2		33	2		51	2	
16	1		34	2		52	1	
17	2		35	2		53	1	
18	1		36	1				
Subtotal	28	0	Subtotal	29	0	Subtotal	31	
TOTAL							88	

Annex 2: Assembly Board

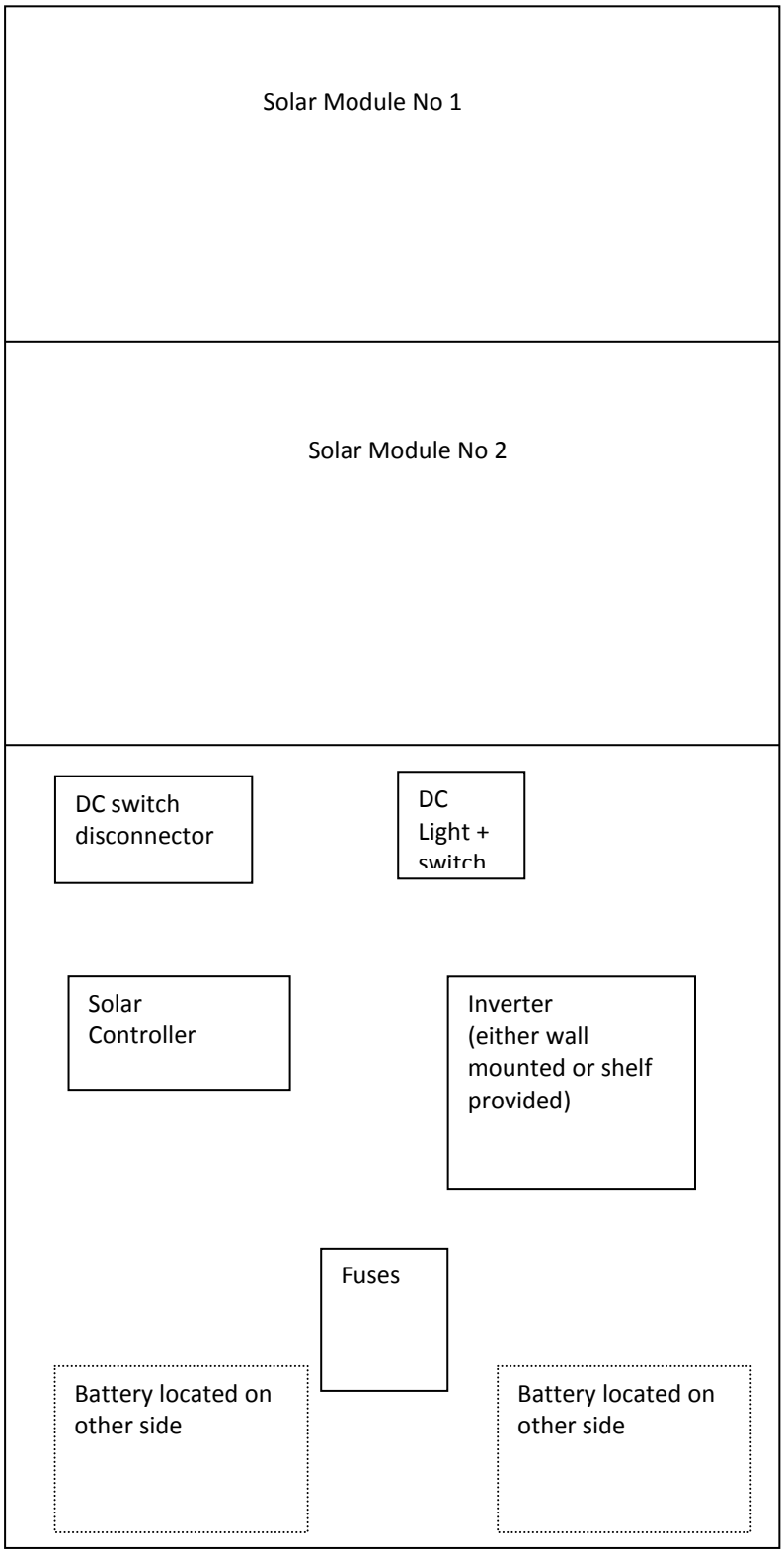
SYSTEM INSTALLATION TRAINING BOARD

This system installation training board is used to simulate the installation of a system. If possible a structure should come off the wall (see side view) that is used to simulate the "roof". The solar modules will be mounted on this simulated "roof" structure. If this is too difficult to build then it should be an array structure comprising angled aluminium which is then mounted onto the "simulated wall" of the training board and the modules are them mounted into this aluminium structure.

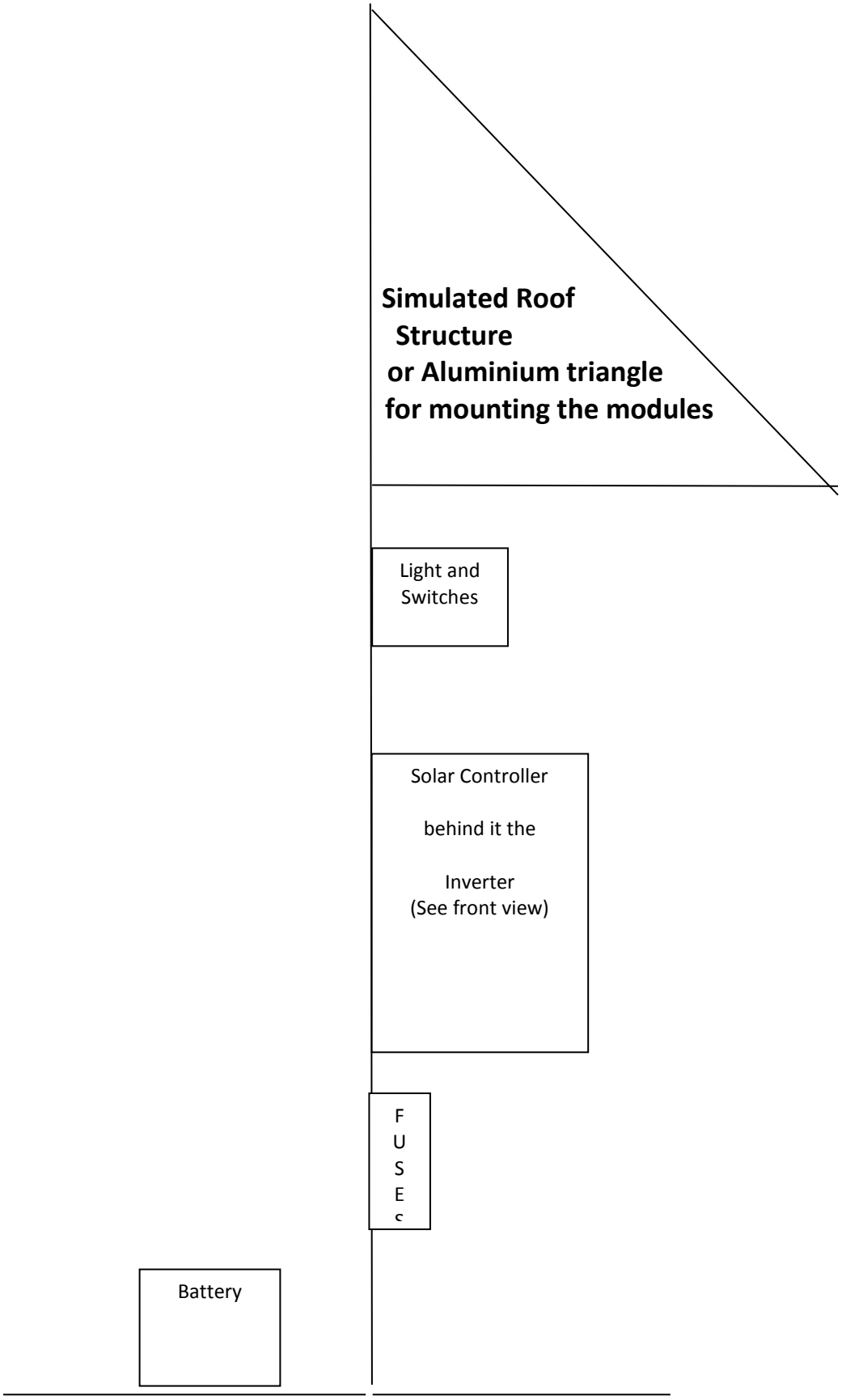
The vertical board then simulates a wall and the inverter, solar controller and associated switchgear are all mounted on this simulated "wall".

Due to the weight of the batteries they are mounted on the base or simulated "floor" of the training board.

Front view


Solar Module No 1
Solar Module No 2
DC switch disconnector
DC Light + switch
Solar Controller
Inverter (either wall mounted or shelf provided)
Fuses
Battery located on other side
Battery located on other side

Side view


Simulated Roof
Structure
or Aluminium triangle
for mounting the modules
Light and
Switches
Solar Controller
behind it the
Inverter
(See front view)
F
U
S
E
s
Battery

Annex 3: Practical Examination 1

Name of Examination Participant: _____

Certification Application Number:_____

Examination Location_____

Date of Practical Examination_____

This practical examination is divided into three parts:

1. Mounting system onto a demonstration wall and roof.
2. Wiring the system.
3. Testing and commissioning the system.

To successfully pass the examination participant must achieve a minimum score of 70%. The scoring is based on undertaking all the activities listed below.

A3.1 Part A: Mounting of the Equipment

The system to be installed by the examination participants comprises:

- Two (2) of thirty-six (36) cell solar module suitable for 12 V system.
- One (1) array frame.
- One (1) 12V DC nominal input inverter.
- Two (2) 12V DC nominal sealed batteries.
- One (1) solar controller.
- One (1) DC rated switch two pole disconnector (PV array isolator)
- Quantity four (4) DC rated fuses (main battery fuses) and associated fuse holders (preferably switch fuses if possible). Two fuses are to be located between the battery and controller. The second set of two fuses are to be mounted between the batteries and inverter. However, if inverter is small enough then possibly only one set of fuses will be required (sized to protect both the inverter cable and the solar cable), however separate isolation devices will be required for the inverter and the solar controller.
- One (1) DC light switch.
- One (1) DC light.
- Earth/ground clamp suitable for the selected array frame and an earth/ground rod.

The equipment is to be mounted onto the simulated wall and roof provided. When installing the array frame onto the simulated roof, the examination participant will seek the assistance of one other examination participant.

Activities Assessed

The mounting of the equipment requires the examination participant to;

1. Draw a schematic of where the individual components will be mounted on the simulated wall/roof.
2. Mount the two solar modules onto the array frame.
3. Prior to mounting the array structure on the simulated roof the examination participant, using the compass, points the array frame in the correct direction for that site. This will be assessed by the examination assessor before the examination participant continues to:
4. Mount the array frame onto the simulated roof (would possible need support from one other participant).
5. Mount the PV array switch disconnector onto the simulated wall.
6. Mount the solar controller onto the simulated wall.

7. Mount the light and switch onto the simulated wall.
8. Place the two batteries onto the base of the wall structure.
9. Mount the inverter on the simulated wall or place it on the base of the wall structure.
10. Mount the battery fuses onto the simulated wall.

A3.2 Part B: Wiring the System

Activities Assessed

Assume the distance between the solar array and the solar controller in real life is 10 metres. The maximum voltage drop that is allowed between the array and controller is 3%.

Using the data sheets provided what is the Isc of one solar module ? _____A

What is the I_{sc} of the array that is being installed? _____A

What is the DC system voltage? _____V

Using the Tables 1, 2 and 3 what is the minimum sized cable to meet the current carrying requirement and the voltage drop? _____mm^2

Table A3.1: Current Carrying Capacity

Cable Cross Sectional Area	Free Air (touching) Current A
1mm^2	13
2.5 mm^2	22
4 mm^2	30
6 mm^2	38
10 mm^2	54
16 mm^2	71

Table A3.2: Maximum Cable Lengths in Metres for 12V System 3% Voltage Drop

Current (A)	1mm^2	1.5mm^2	2.5mm^2	4mm^2	6mm^2	10mm^2	16mm^2
1	9.8	14.8	24.6	39.3	59.0	98.4	157.4
2	4.9	7.4	12.3	19.7	29.5	49.2	78.7
3	3.3	4.9	8.2	13.1	19.7	32.8	52.5
4	2.5	3.7	6.1	9.8	14.8	24.6	39.3
5	2.0	3.0	4.9	7.9	11.8	19.7	31.5
6	1.6	2.5	4.1	6.6	9.8	16.4	26.2
7	1.4	2.1	3.5	5.6	8.4	14.1	22.5
8	1.2	1.8	3.1	4.9	7.4	12.3	19.7
9	1.1	1.6	2.7	4.4	6.6	10.9	17.5
10	1.0	1.5	2.5	3.9	5.9	9.8	15.7
11	0.9	1.3	2.2	3.6	5.4	8.9	14.3
12	0.8	1.2	2.0	3.3	4.9	8.2	13.1
13		1.1	1.9	3.0	4.5	7.6	12.1
14		1.1	1.8	2.8	4.2	7.0	11.2
15		1.0	1.6	2.6	3.9	6.6	10.5
16		0.9	1.5	2.5	3.7	6.1	9.8
17			1.4	2.3	3.5	5.8	9.3
18			1.4	2.2	3.3	5.5	8.7
19			1.3	2.1	3.1	5.2	8.3
20			1.2	2.0	3.0	4.9	7.9

Table A3.3: Maximum Cable Lengths in Metres for 24V System 3% Voltage Drop

Current (A)	1mm^2	1.5mm^2	2.5mm^2	4mm^2	6mm^2	10mm^2	16mm^2
1	19.7	29.5	49.2	78.7	118.0	196.7	314.8
2	9.8	14.8	24.6	39.3	59.0	98.4	157.4
3	6.6	9.8	16.4	26.2	39.3	65.6	104.9
4	4.9	7.4	12.3	19.7	29.5	49.2	78.7
5	3.9	5.9	9.8	15.7	23.6	39.3	63.0
6	3.3	4.9	8.2	13.1	19.7	32.8	52.5
7	2.8	4.2	7.0	11.2	16.9	28.1	45.0
8	2.5	3.7	6.1	9.8	14.8	24.6	39.3
9	2.2	3.3	5.5	8.7	13.1	21.9	35.0
10	2.0	3.0	4.9	7.9	11.8	19.7	31.5
11	1.8	2.7	4.5	7.2	10.7	17.9	28.6
12	1.6	2.5	4.1	6.6	9.8	16.4	26.2
13		2.3	3.8	6.1	9.1	15.1	24.2

14		2.1	3.5	5.6	8.4	14.1	22.5
15		2.0	3.3	5.2	7.9	13.1	21.0
16		1.8	3.1	4.9	7.4	12.3	19.7
17			2.9	4.6	6.9	11.6	18.5
18			2.7	4.4	6.6	10.9	17.5
19			2.6	4.1	6.2	10.4	16.6
20			2.5	3.9	5.9	9.8	15.7

1. Draw a wiring diagram showing how all the individual system components will be interconnected electrically.
2. Select the correct cable for wiring the system as determined above.
3. Wire the two (2) solar modules to produce 12V output.
4. Wire the (2) batteries for 12V.
5. Wire between:
   - The solar module and solar controller via the switch disconnector (keep switch in the off position)
   - Solar controller and the two batteries via the fuse holders (leave fuses out). The cable between each battery and the controller must be of equal length to ensure the same the same resistance and hence voltage drop between the controller and the battery bank.
   - Inverter to batteries via either the same fuses or the two fuses specific for the inverter.
   - The solar controller to light switch and then to the light.
6. Install an earth/ground bond on the array frame and interconnect with an earth/ground rod that is attached

A3.3 Part C: Test and Commission the System

Activities Assessed

Test and commission the system as per the testing and commissioning sheets provide. Complete the sheets and submit them to the examination assessor.

Annex 4: Testing and Commission Sheets

Examination Applicants name:	
Examination Applicants signature:	
Examination Testing and Commissioning date:	
Examination Location	
Equipment Data	
PV module manufacturer:	
PV module model number:	
PV module peak power rating:	W_p
PV Module rated short circuit current (I_{sc})	A
PV Module rated maximum power current (I_{mp})	A
PV Module rated open circuit voltage (V_{oc})	V
PV Module rated maximum power voltage (V_{mp})	V
Number of Modules:	
Battery manufacturer:	
Battery model:	
Battery Voltage	V
Battery Capacity	Ah
Solar controller manufacturer	
Solar controller model	
Controller solar input and output current rating.	A
Controller voltage ratings	V
Inverter manufacturer	
Inverter model	
Inverter Input current ratings	A
Inverter Input DC voltage rating	V
Inverter Power Rating	W or VA
Switch disconnector manufacturer	
Switch disconnector model	
Switch disconnector current rating	A
Switch disconnector voltage rating	V
Solar battery fuse current rating	A
Solar battery fuse voltage rating	V
Inverter battery fuse current rating (if there are a separate fuses for inverter and solar)	A
Inverter battery fuse voltage Rating (if there are a separate fuses for inverter and solar)	V
Testing of System (must be undertaken in sunshine) (System Not On Yet)	
Solar Irradiance at same angle of solar module	W/m^2
Module No 1: Isc	A
Module No 1: V_{oc}	V
Module No 2: Isc	A
Module No 2: V_{oc}	V

Continuity between PV array, DC switch-disconnector and controller:		
Array Positive (tick if correct)		
Array Negative (tick if correct)		
Correct polarity between PV array and solar controller		
Continuity between controller, fuse holders and battery		
Battery Positive (tick if correct)		
Battery Negative (tick if correct)		
Correct polarity between controller and battery		
Continuity between battery, fuse holders and inverter		
Battery Positive (tick if correct)		
Battery Negative (tick if correct)		
Correct polarity between inverter and battery		
Continuity between solar controller, light switch and lights		
Positive (tick if correct)		
Negative (tick if correct)		
Correct polarity between controller and light		
Turn System On - including lights		
Array voltage at Controller input		V
Array current		A
Battery voltage at controller		V
Voltage at light with light on (array turned off)		V
Inverter Output Voltage		V
Inverter Frequency		Hz
Solar charging the batteries		
Controller operating correctly (tick if correct)		
Inverter operating correctly (tick if correct)		
Lights operating correctly (tick if correct)		

Annex 5: PE1 - Installation Assessments Sheets

Name of Examination Participant: _____

Certification Application Number:_____

Examination Location: _____

Date of Practical Examination: _____

Total Mark: _____

Advice to Examination Assessor

- Examination assessor is to complete these forms while observing the examination participant for Parts A (mounting) and B (wiring).
- For Parts B (wiring) the examination assessor reviews the cable selection sheet completed by the examination participant.
- For Parts C (testing and commissioning) the examination assessor observes the examination participants ensuring they are doing it safely. The examination assessor completes this form after reviewing the test and commissioning sheets of the examination participant.
- If anything is not done correctly the examination assessor can explain what was wrong and asked the examination participant to redo it.
- To pass the installation assessment the examination participant shall obtain an assessment of 70%. Total is 71 marks. Therefore the pass mark is set at 49.
- The maximum marks for each activity are shown in brackets after the activity. If examination participant has performed the activity competently than allocate the mark as stated. If the activity has more than 1 mark allocated than allocate the full mark if examination participant performed the activity competently, but a lower mark could be allocated if there were some minor errors.
- During testing and commissioning there are 29 pieces of equipment information/data to be completed. A total of 5 marks has been allocated, which will be pro-rated based on number completed correctly.

Activity	**(Mark**	**Comments**
Part A: Mounting Assessment (15 Marks)		
Schematic for showing where the equipment is to be located is correct. (3 marks)		
Correctly and safely Mounted Modules onto array frame (2 marks)		
Pointed array frame South (1 marks)		
Correctly and safely mounted array frame onto simulated roof (2 marks)		
Correctly mounted PV array switch disconnector (isolator) (1 mark)		
Correctly mounted solar controller (1 mark)		
Correctly mounted light and light switch (1)		
Correctly handled and safely installed the batteries onto the base. Nothing is to be mounted above the batteries. (2 marks)		
Correctly installed or placed the inverter		

ensuring it has suitable air gaps around the inverter as required by installation manual. (1 mark)		
Correctly installed the fuse holders. (1 mark)		
Sub-total for Mounting		
Part B: Wiring Assessment 32 marks)		
Wiring schematic is correct (7 marks)		
Correctly found the I_{sc} on the module date sheet (1 mark)		
Correctly determined the array I_{sc} (1 mark)		
Correctly selected the system's voltage (1 mark)		
Correctly used the voltage drop and current carrying tables to select the correct size cable to be installed between the solar array and the controller. (2 marks)		
Wired the two solar modules in parallel. (2 marks)		
Installed and connected the cables between the solar modules, the switch disconnector and the solar controller safely, correctly and neatly. (2 marks)		
Left the switch disconnector in the off position during the wiring and after completion (2 marks)		
Wired the batteries in parallel to have an effective 12V battery bank. To achieve this there must be the same length (and size) of cables between each battery and the fuse holders. Note there could be two sets of fuses (one for controller and one for inverter). (4 marks)		
Left the fuses out of the holders during the installation and after completion prior to commissioning. (2 marks)		
Installed and connected the cables between the batteries, the fuse holders and the solar controller safely, correctly and neatly. (2 marks)		
Installed and connected the cables between the batteries, the fuse holders and the inverter safely, correctly and neatly. (2 marks)		
Installed and connected the cables between the controller the light switch and the lights safely, correctly and neatly (2 marks)		
Installed and connected the earth bond onto the array frame and to the appropriate earthing (grounding) point frame safely, correctly and neatly (2 marks)		

Sub-total for Wiring		
Part C Testing and Commissioning (23 marks)		
Entering data on equipment (5 Marks)		
Solar Irradiance at same angle of solar module (1 mark)		
Module No 1: Isc (1 mark)		
Module No 1: V_{oc} (1 mark)		
Module No 2: I_sc (1 mark)		
Module No 2: V_{oc} (1 mark)		
Continuity between PV array, DC switch-disconnector and controller: (1 mark)		
Correct polarity between PV array and solar controller (1 mark)		
Continuity between controller, fuse holders and battery (1 mark)		
Correct polarity between controller and battery (1 mark)		
Continuity between battery, fuse holders and inverter (1 mark)		
Correct polarity between inverter and battery (1 mark)		
Continuity between solar controller, light switch and lights (1 mark)		
Correct polarity between controller and light (1 mark)		
Started system correctly (1 mark)		
System Operates correctly and all readings are as expected (4 marks)		
Sub-total for Testing and Commissioning		
TOTAL MARK		

Examination Assessors Name: _____

Signature_____

Date: _____

If the examination participant did not successfully prove competence in undertaking this assessment please provide any overall comments

Annex 6: PE2 - One-on-One Assessment Sheets

Name of Examination Participant: _____

Certification Application Number:_____

Examination Location: _____

Date of Practical Examination: _____

Advice to Examination Assessor

- For question 1 and 2 the examination assessor is to ask the questions and record the answers provided by the examination participant.
- For question 3 the examination assessor provides the multi-meter to the examination participant who then sets the meter correctly to measure current and then voltage.

To pass the installation assessment:

- The examination participant shall answer questions 1 and 2 to the satisfaction of the examination assessor; and
- Set the multi-meter to measure voltage and current correctly

1. What risks are involved when installing a PV system?

   _____

   _____

   _____

   _____

   _____

2. What should the technician do when working on a system to minimise or remove these risks and what safety equipment could be used?

   _____

   _____

   _____

   _____

3. Can the participant correctly use the multi-meter for measuring current and voltage?

   _____

   _____

   _____

   _____

The examination participant did/ did not successfully prove competence in undertaking this assessment.

Examination Assessor's Name: _____

Signature: _____

Date: _____

If the examination participant did not successfully prove competence in undertaking this assessment please provide your reasons:

Annex 7: PE3 - Examination and Assessment Sheet

Name of Examination Participant: _____

Certification Application Number:_____

Examination Location: _____

Date of Practical Examination: _____

Equipment required for each examination participant:

- Quantity Two (2) of thirty-six (36) cell solar module suitable for 12 V system.
- Quantity One (1) pole mount array frame .
- Quantity One (1) pole designed to suit the pole mount array frame.

This practical examination requires the examination applicant to:

- Mounts the pole mount array frame on the pole and then mounts the two modules on the frame.
- Point the array frame in the correct direction and also tilt angle for the location.

For safety reasons the examination participant is supported by one of the other course participants and in particular via holding he ladder. The support person's role is to:

- Help the examination participant mount the array frame on the pole.
- Help the examination participant mount the modules onto the array frame.

The examination participant did/ did not successfully prove competence in undertaking this assessment.

Examination Assessor's Name: _____

Signature_____

Date: _____

If the examination participant did not successfully prove competence in undertaking this assessment please provide your reasons:

_____

_____

_____

Annex 8: PE4 - Examination and Assessment Sheet

Name of Examination Participant: _____

Certification Application Number:_____

Examination Location: _____

Date of Practical Examination: _____

Equipment required for each examination participant:

- Quantity Four (4) of thirty-six (36) cell solar module suitable for 12 V systems.

.
This practical examination requires the examination applicant to:

- Place the 4 modules on the ground and wires the modules as nominal 24V system configuration.

The examination participant did/ did not successfully prove competence in undertaking this assessment.

Examination Assessor's Name: _____

Signature_____

Date: _____

If the examination participant did not successfully prove competence in undertaking this assessment please provide your reasons: