

PHOTOVOLTAIC SYSTEMS

Syllabus

1 Photovoltaic systems

- 1 Identify typical photovoltaic (PV) installations
 - a) grid connected
 - b) building integrated
 - c) non-integrated
- 2 State typical expected outputs of a domestic PV system and its proportion relative to typical domestic electricity consumption.
- 3 Describe the major components and system layout of a grid connected PV system

2 Standards, Regulations/Guidelines, Codes of Practice

- 1 Identify relevant statutory regulations
 - a) Electricity at Work Regulations 1989
 - c) Building Regulations
 - d) Health and Safety at Work etc Act 1974
 - e) Control of Substances Hazardous to Health Regulations 1988
- 2 Identify and apply guidelines and Codes of Practice
 - a) Engineering recommendations G77/1, G59/1, G83
 - b) Department of Trade and Industry guidelines '*Photovoltaics in Buildings: Guide to the installation of PV systems*' and '*Photovoltaics in Buildings: Testing, Commissioning and Monitoring Guide*'
 - c) BS 7671 IEE Wiring Regulations for Electrical Installations
 - d) HSE Guide GS38 Electrical test equipment for use by electricians.

3 PV safety

- 1 Describe methods of verifying and securing (locking off) circuit isolation.
- 2 Describe precautions to be taken and procedures to be followed to prevent electric shock
 - a) identify hazards arising from the use of electrical equipment
 - b) apply general safety rules in respect of checking of cables, leads and plugs, earthing and use of portable equipment and reduced voltage equipment
 - c) recognise that PV cannot be switched off and that measures are necessary to ensure contact cannot be made with live connections
 - d) recognise that voltage is generated at low light levels and can lead to risk of electric shock
 - e) identify PV modules as current limiting devices not damaged by short circuits and therefore not liable to be protected by fuses.
- 3 Describe the characteristics of DC wiring
- 4 State the requirements for the correct use of circuit identification, notices and labelling
- 5 List the general rules for observance of safe practices including

- a) being alert
 - b) maintaining personal hygiene
 - c) protecting oneself and other people
 - d) knowing emergency and site evacuation procedures to cover
 - i) fire
 - ii) explosion
 - iii) toxic atmosphere
 - iv) security alerts
 - e) reporting all hazards and notifying appropriate authority
- 6 Identify suitable access equipment for working at height and on roofs
- a) appropriate staging and trestles
 - b) safe angles for ladders
 - c) methods of securing ladders
 - d) safety requirements for tower scaffolds
 - e) guard rails and toeboards
 - f) personal safety equipment when working on roofs
- 7 Recognise safe practices for handling, moving and storing PV modules.

4 System components

PV MODULES AND ARRAY

- 1 Recognise the main PV cell technologies and their characteristics
- a) Mono-crystalline
 - b) Poly-crystalline
 - c) Thin film
- 2 Recognise
- a) PV cell
 - b) module
 - c) string
 - d) array
- 2 Describe the following in respect of a photovoltaic module
- a) I/V (current/voltage) curve
 - b) open circuit voltage and short circuit current (V_{oc} and I_{sc})
 - c) maximum power current and voltage (I_{mpp} and V_{mpp})
- 3 State the significance of standard test conditions and recognise that actual power output in real conditions can vary substantially.
- 4 State the international standards with which PV modules should comply
- a) BS EN 61215, IEC 61215
 - b) BS EN 61646, IEC 61646
- 5 State the factors effecting the installation of a PV array
- a) inspection and storage of modules
 - b) siting of modules (orientation, angle of inclination, free from shade)
 - c) load bearing capacity
 - d) configuration of modules
 - e) fixing methods, integrated and non-integratedf) alignment and levelling of secondary structures to minimise stress on modules
 - g) maintaining the integrity of the roof (weather seal)
 - h) aesthetic considerations
 - i) environmental conditions

ROOFING

a)

DC SYSTEM

- 6 Calculate recommended minimum voltage and current ratings for DC components and cable
- a) plugs
 - b) connectors
 - c) switches
 - d) minimum cable sizing for main and string DC cables (V_{oc} and I_{sc})
- 7 State that the PV array must be isolated from the inverter by a double pole switch
- 8 State the class of protective insulation recommended for PV modules including systems with high open circuit voltages.
- 9 Describe short circuit proof installation
- 10 State the requirements for DC cabling in respect of
- a) minimum temperature rating requirements for string cables
 - b) UV and weather resistance requirements for DC cables
- 11 Describe the labelling requirements for a DC system including
- 12 Describe the use of string fuses and blocking diodes with reference to
- a) type of system
 - b) fuse ratings
 - c) point of installation
 - d) selection factors for a blocking diode
 - e) potential problems

INVERTER AND ELECTRICAL PROTECTION

- 13 State the function of inverters and the factors which selection
- a) type of inverter
 - i) string
 - ii) AC module
 - iii) single phase
 - iv) 3-phase
 - b) location
 - i) effect of weight
 - ii) length of DC cable
 - iii) environment
 - c) inverter sizing
 - d) compliance with G77/1
- 14 Describe protection types for small PV systems
- a) anti-islanding protection
 - b) over and under voltage protection
 - c) over and under frequency protection
- 15 State G59/1 requirements for large PV systems

EARTHING AND LIGHTNING PROTECTION

- 16 State earthing requirements in BS 7671 and BS 7430 with reference to
- a) array frame earthing
 - b) DC conductor earthing
 - c) inverter earthing
- 17 State lightning protection system requirements in BS 6651 with reference to
- a) type of system

- b) connection to array and mounting
- c) surge protection

AC SYSTEM AND METERING

- 18 State grid connection requirements in BS 7671 with reference to
 - a) meter installation
 - b) AC cabling
- 19 State AC switch disconnector requirement in accordance with BS EN 60947-3 and G77/1
- 20 State AC fault current protection requirements

PERFORMANCE MONITORING

- 21 List methods of performance monitoring

5 Approvals

- 1 State planning and approval requirements with reference to
 - a) local authorities
 - b) conservation areas and listed buildings
- 2 Describe the approval necessary for grid connection by a distribution network operator (DNO)
 - a) installation certificate as per BS 7671
 - b) application for connection
- 3 State that systems must comply with Building Regulations with respect to
 - a) strength of supporting structure and fixing method for modules
 - b) fire regulations and PV modules
 - c) weatherproofing of modules

6 Installation

- 1 Select tools and equipment required for undertaking installation
- 2 Describe sequence of operation for undertaking installation
- 3 State factors which effect the installation costs
 - a) type of system, roof integrated/mounting
 - b) cable routing
 - c) access to site/roof
 - d) equipment costs
 - e) component breakage through poor storage/handling
 - f) labour costs
 - g) commissioning costs

7 Commissioning and testing

- 1 State the completion requirements with reference to
 - a) cleaning of array
 - b) operational status of the inverter
 - c) checking of module fixings
 - d) general visual inspection of the system
- 2 Describe methods of visual inspection for
 - a) fixing and positioning of array

- b) connectors and junction boxes
- 3 State the testing requirements for weather sealing and structural integrity
- 4 Describe methods of connecting and commissioning monitoring systems.
- 5 State basic principles of diagnostic testing as
 - a) knowledge and understanding of relevant system
 - b) optimum use of resources expertise and experience
 - c) use of a logical approach
- 6 Describe safety inspection and DNO witnessing
- 7 State principles of commissioning in accordance with inverter instructions
- 8 Identify appropriate documentation necessary for testing.

- 9 Describe handover procedures and customer information requirements
- 10 State the commissioning and testing requirements with reference to
 - a) G77/1
 - b) G59/1
 - c) BS 7671
 - d) DTI document *'Photovoltaics in Buildings: Testing, Commissioning and Monitoring Guide'*
- 11 State the safety precautions to be taken when carrying out commissioning

8 Customer care

- 1 Recognise the importance of checking the awareness of customers for installation services
- 2 Describe the types of information which can be provided to customers through
 - a) installation specifications
 - b) manufacturers data
 - c) user instructions
- 3 Describe the following in relation to a Code of Practice
 - a) sales and promotion
 - b) warranties
 - c) service and repairs
 - d) installation
 - e) customer complaints

Annex: Practical assessment

Under real or simulated conditions the candidate must install and commission a basic grid connected PV system.

- 1 Ensure work area is safe before work commences
 - a) identify possible sources of hazard
 - b) ensure tools and equipment are fit for purpose
 - c) ensure circuit isolation
- 2 Select and use appropriate access equipment
 - a) examine, carry, erect and secure a 3m extension ladder
 - b) select, erect and dismantle a 3 lift tower scaffold system
 - c) transport modules and components
- 3 Carry out basic roofing techniques
 - a) battening
 - b) levelling of systems
 - c) tiling (plain tile and interlocking pan tile)
 - d) install flashing
 - e) position array on a sloping roof
- 4 Position fix and install at height
 - a) support structures
 - b) modules
 - c) cables
 - d) DC connectors
 - e) isolation switches
 - f) earthing protection
 - g) lightning protection
 - h) inverter
 - i) meter
 - j) customer display panel
- 5 Label in accordance with G77/1 and G59/1
 - a) junction boxes
 - b) switches
 - c) distribution board
- 6 Connect system to the grid through a domestic distribution board
- 7 Carry out measurement within modules and array of
 - a) open circuit voltage
 - b) short circuit current
- 8 Undertake fault diagnosis on modules and array
- 9 Undertake operational testing for an inverter

Annex: Test Rig Specifications

These specifications state the minimum requirements which must be met by organisations who wish to offer the City & Guilds course in the installation of domestic PV systems. The aim of the specification is to ensure uniformity throughout the delivery of the practical element of the course. Any deviation from this specification would render practical elements of the course invalid.

The following specification may be implemented in a number of ways and can involve a number of test rigs or one single test rig. The specifications have taken into account the likely resources available to institutions wanting to deliver the course.

1. Functioning PV System

A fully functioning PV system that operates in parallel with the electricity distribution network must be installed. The system operator must have a connection agreement from the local Distribution Network Operator and the system must be installed in accordance with relevant regulations and standards. In particular the system must comply with G77/1, G83 and BS7671.

The minimum requirements of the system are:

- a) A G77/1 and G83 compliant string inverter, NOT module inverters.
- b) Minimum 6 modules in series.
- c) Minimum of 70Wp per module (40Wp for thin film).
- d) Array configuration must match the inverter input range.
- e) The inverter must be located close to the array.
- f) The array must be positioned to maximise sunlight gain and have no or minimal shading.
- g) Appropriate DC and AC isolators must be installed adjacent to the inverter to enable isolation from the array and the electricity network.
- h) The system must be connected to a dedicated miniature circuit breaker (MCB).
- i) A lockable AC isolator must be installed adjacent to the consumer unit/distribution board.
- j) The system must be labelled in accordance with G77/1 and G83.

Safe access to the back of the array is required to enable students to connect module cabling and test string output. Access is also required to the inverter and DC & AC isolators to enable demonstration of live inverter operation.

2. Roof requirements

A roof must be provided to allow students to gain practical experience of the following:

- a) Roof access.
- b) Lifting equipment to height.
- c) Installing 2 different types of roofing tile/slate one of which must be an interlocking pantile.
- d) Installing a non-integrated/bolt-on/retrofit type PV system.

- e) Installing a roof integrated PV system.
- f) Installing flashing. This is especially applicable around a roof integrated PV system.

The roof must have the following specification:

- a) A slope of at least 30° pitch from the horizontal.
- b) The eaves of the roof must have a direct drop of at least 2m to ground level. See Figure ??
- c) The roof must be covered with either tiles, slates or interlocking pantiles.
- d) The sub-frame of the roof must be similar to that of a conventional roof and constructed from wood and include sarking (felting) and battening.
- e) Access to the roof must be by roofing ladder or crawl boards and scaffolding, or tower.

The functioning PV system can be used as a test rig for practising the installation of a PV mounting system as long as it meets the roof specification given above. The functioning PV system may also be removed to allow the installation of a different type of PV mounting system in the same place and to allow roof access and roofing skills to be practised. Due to the cost of PV modules, institutions may wish to undertake these activities on a separate test roof as the working PV modules may be damaged accidentally by students. If a separate test roof is to be used then the functioning PV system does not have to follow the roof specification given above.

2.1 Dummy Modules

Given the cost of PV modules institutions may opt to use dummy modules or factory rejects for students to practice system installation.

The specification for dummy modules is given below:

- a) Dummy modules must be a minimum size of 0.5m x 1m.
- b) Dummy modules must be constructed from glass of equivalent thickness to that of conventional PV modules. The aim is to ensure students are aware of the fragile nature of PV modules and their weight.
- c) Dummy modules must be framed in metal similar to that of typical off the shelf modules.
- d) Connection boxes or leads must be fixed to the back of the dummy modules to allow student to wire up modules into an array.

Note:-

A working PV system is still required to demonstrate a working array. Dummy modules are only to be used to demonstrate fixing methods and wiring. The dummy array must be installed on a roof of the same specification given under section 2.

2.2 PV mounting systems

Students must be able to practice the installation of two or more different PV mounting systems, the specifications for which follow:

- a) A non-integrated/bolt-on/retrofit type PV system and roof integrated PV system must be installed. These systems can be installed side by side on the same roof or one system dismantled and the other installed in its place.
- b) The array must be installed on top of the roof specified in section 2.
- c) The area covered by the modules of each system must exceed an area of 1m^2 and contain at least 4 modules in configuration of 2 modules wide and 2 modules tall.
- d) The roof onto which the demonstration mounting systems are to be installed must be sized to allow the demonstration of flashing and tiling around system. This is especially applicable for roof integrated PV systems where manufacturers' guidelines must be followed.

The institution may opt to have a number of test rigs, however it is imperative that there is at least one functioning PV system and a roof with the same specification as given in section 2 for the installation of integrated and non-integrated PV mounting systems. A separate mock up roof at ground level may be used for teaching purposes to demonstrate close up the fixing of systems and roofing skills.