Photovoltaics in Buildings

Safety and the CDM Regulations

In Association with

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Department of Trade and Industry

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Photovoltaics in Buildings
Safety and the CDM Regulations

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1 SAFETY OF PHOTOVOLTAIC INSTALLATIONS

Photovoltaic (PV) installations can be made inherently safe, as can most building services installations, provided any hazards associated with their installation and use in buildings are adequately addressed.

The process of improving safety during construction, operation and maintenance requires:

- compliance with the requirements of the law
- following manufacturers' recommendations
- following best practice.

This booklet is aimed mainly at designers and installers of large PV installations integrated with buildings. It provides:

A simple guide to the *Construction (Design and Management) Regulations*,1994 (CDM Regulations)[1] with regard to the design, installation, operation, maintenance, decommissioning and disposal of PV installations in buildings.

A commentary on the UK legislative framework with particular reference to CDM Regulations (see section 2 below).

Hazards and risks relating to PV installations (see section 3).

PV issues that must be addressed in the Health and Safety Plan (see section 4).

PV issues that must be addressed in the Health and Safety File (see section 4).

Most of the safety advice is also relevant to small installations that may be exempt from the Regulations.

2 UK HEALTH AND SAFETY LEGISLATION AND CDM REGULATIONS

The legislative framework for the management of health and safety during construction processes is principally based on the *Health and Safety at Work etc. Act* 1974. The *CDM Regulations* detail certain requirements of the Act. Other complementary regulations include the *Electricity at Work Regulations* and the *Management of Health and Safety at Work Regulations*.

The principal objective of the Regulations is to ensure proper consideration and management of health and safety issues throughout each stage of construction, from feasibility to completion, and through the life of the facility until final demolition or disposal.

The CDM Regulations apply to all construction projects with a few exceptions*. Their purpose is to avoid, minimise and combat health and safety risks suffered by workers and others engaged in all types of construction work or affected by such work. These risks cover design, construction, maintenance, cleaning, refurbishment, demolition and disposal.

The Regulations place substantial duties on clients, designers and contractors in the planning and management of projects. The Regulations introduced two new roles: the planning supervisor and principal contractor. Two new documents: the Health and Safety Plan and the Health and Safety File, were also introduced.

The client, the person for whom the project is carried out, has a fundamental role in setting the tone of the project as far as health and safety is concerned.

The client has to appoint a planning supervisor to co-ordinate and manage health and safety during the design and planning stages. The client must also appoint a principal contractor to co-ordinate and manage health and safety issues during the construction work. The role of the client is described in the HSE information sheet: *Construction sheet No.39*.[2]

Designers must consider the need to design in a way which avoids or reduces risks during construction, maintenance or cleaning to the health and safety of workers and others who are affected by such work. If it is not reasonably practicable to eliminate risk, then the risk should be reduced. Information on residual risks must be provided to the planning supervisor for inclusion in the Health and Safety Plan or the Health and Safety File. The role of the designer is described in the HSE information sheet: *Construction sheet No. 41*.[3]

The planning supervisor has overall responsibility for co-ordinating the health and safety aspect of the design and planning phase. The planning supervisor must also ensure that the HSE is notified of the project, that there is co-operation between designers, and that designers comply with their duties with regard to health and safety.

A pre-tender Health and Safety Plan is prepared before arrangements are made for the principal contractor to carry out or manage construction work and a Health and Safety File is prepared and handed over to the client at the end of the project. The planning supervisor must also advise the client when the regulations require him to do so. The role of the planning supervisor is described in the HSE information sheet: *Construction sheet No. 40*.[4]

* *Construction projects that last 30 days or less or involve 500 or less days of work on site and employ less than 5 people on site are exempt from the regulations unless demolition or dismantling are involved. Work carried out by a contractor directly for a private householder on his own residence is not covered, except that it may be notifiable to the Health and Safety Executive (HSE). All construction project design work is covered. See the CDM Regulations for full details.*

Positioning modules using suction lifters

The principal contractor should take account of project-specific requirements with regard to health and safety when preparing and submitting tenders or other similar offers. The principal contractor must develop the Health and Safety Plan and co-ordinate the activities of all contractors and subcontractors to ensure they comply with the developed Health and Safety Plan and relevant health and safety legislation. The principal contractor also has a responsibility in relation to the provision of relevant information to the planning supervisor for preparation of the Health and Safety File. In some PV projects, particularly retrofits, the specialist PV contractor may take on the role of principal contractor and should therefore be aware of the responsibilities this entails.

The Health and Safety Plan provides the basis for health and safety during the construction phase. The pre-tender Health and Safety Plan provides information about significant health and safety risks of the project which the principal contractor will have to manage during the construction stage. The information in the pre-tender Health and Safety Plan will normally come from the client and the designer. The construction stage Health and Safety Plan should address health and safety risks to persons carrying out the construction work and others who may be affected by it. It should also set out the arrangements for management of health and safety and for monitoring compliance with the plan. The pre-tender Health and Safety Plan is described in the HSE information sheet: *Construction sheet No. 42.*[5]

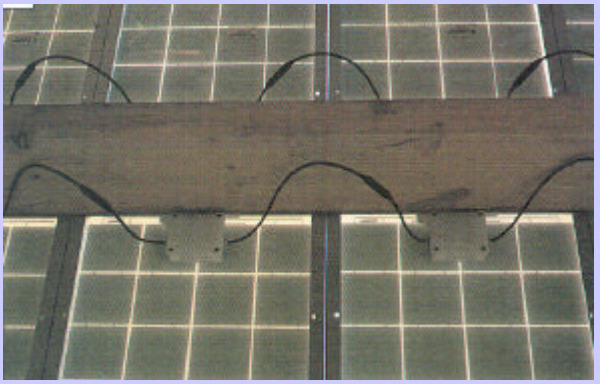
The Health and Safety Plan during the construction stage is described in the HSE information sheet: *Construction sheet No. 43.*[6]

The Health and Safety File must contain the information needed by the client or end user about the risks that have to be managed during operation, maintenance, repair, cleaning or demolition. It should be kept up to date by the occupier whenever changes are made. The Health and Safety File is described in the HSE information sheet: *Construction sheet No. 44.*[7]

CDM Regulations place substantial duties on the:

- Client
- Designers
- Planning supervisor
- Principal contractor (who also provides
  - ⇒ Health and Safety Plan
  - ⇒ Health and Safety File).

Working from scaffolding



Electrical connections to modules

3 HAZARDS RELATING TO PV INSTALLATIONS

Many of the potential hazards relating to PV installations are very similar to those that exist in similar construction processes. There are some that are unique to PV installations, particularly those relating to electrical aspects. Hazards must be identified on each installation and risk assessments must be specific to that installation. However, many hazards are common and the following checklist is provided to assist the user. This checklist is not comprehensive and does not obviate the need to locate hazards on each individual installation. In addition to hazards listed here, some installations may include batteries which can also present a number of hazards. These would be common to UPS installations and advice can be found from suppliers.

MATERIALS

Check		
	Weight	Modules may be heavy. There is a tendency to use larger modules of 2m square or more. The weight of these may exceed 50kg. Particular care may be required in carrying. Glass panels of this size in roofing and vertical cladding are usually toughened and would break into harmless pieces if damaged. PV modules are usually made of toughened glass but are, by design, laminated and may therefore fall as a single piece if damaged.
	Strength	The support system may fail if only designed for glazing. Modules will not support a person's weight.
	Bulk	The size of larger modules causes additional handling hazards as with any large glazing unit.
	Sharp edges	Edges of modules may be sharp, particularly where glass edges are exposed.
	Toxicity	No PV module releases sufficient toxic materials to cause any harm during installation or maintenance. A small proportion of PV modules contain cadmium, the oxides of which are toxic in very small doses. Some of these may release toxic dust if crushed during disposal.

ELECTRICAL

	Voltage	PV modules and any wiring connected to them will be live whenever they are exposed to light. Whenever sufficient voltage is developed by a number of cells in series, there is a risk of shock. Any series arrangement of 40 or more cells could develop the 20V dc touch voltage normally considered to give a risk of shock. Hazards of dc are greater than ac because the electric arc produced when opening a dc circuit can be much greater. Higher voltage dc may be used in PV systems because it can lead to reduced wiring size and higher inverter efficiency. This is still technically referred to as 'low voltage' up to 900V dc between conductors and earth, or 1500V dc between conductors. Many PV specialists consider 80V dc to be the maximum that can be safely accommodated. Damaged modules or installations may expose high voltage conductors. Voltage must not appear on the output of the inverter in the event of a mains supply failure as this could be fed back to other installations.
	Current	When conductors of opposite polarity come into contact, current flows and heat are generated. A short-circuit through equipment or the human body allows significant current to flow and to generate enough heat to burn. When dc conductors in a circuit are pulled apart, the current can continue to flow in an arc in the air space between the conductors. This can propagate over several millimetres depending on voltage. The arc generates heat that can burn anything in contact, such as human skin. Fuses or circuit breakers cannot be used to provide protection in PV module wiring because fault current is little more than normal running current.
	Earthing	Lethal voltages can be developed on the dc installation if the earthing is inadequate, as with any electrical installation.

ENVIRONMENTAL

	Exposure	PV systems are installed where the sun is brightest and no shade exists, and consequently where exposure to solar radiation is greatest. Exposure to cold, wind and rain may also be a hazard.
	Reflection	As with many cladding materials, the glass cover of PV panels can reflect a significant proportion of incident sunlight, which could cause eye damage if unexpectedly intercepted.
	Insects	Wasp and other insect nests are sometimes found in PV installations.
	Temperature	Metal and PV panels left exposed in the sun can reach temperatures of up to 80°C.

4 RISK MANAGEMENT DURING PROJECT STAGES

The general requirements of the CDM Regulations apply. Those not familiar with them should consult one of the HSE publications mentioned above. These notes highlight key points specific to PV installations and are divided into issues to be addressed in the Health and Safety Plan and those to be addressed in the Health and Safety File.

HEALTH AND SAFETY PLAN

Work sector	client	designer	installer	facility manager/maintainer
Planning				
General	If the PV installation comprises the majority of the work, it may be appropriate to appoint PV specialists as planning supervisor and principal contractor. Ensure the planning supervisor has sufficient experience and resources to complete the work in safety and on time; look at examples of their work and discuss with previous clients. Brief the designer on what is required and expected.	As part of the briefing process, ensure that the client is aware of any hazards related to voltage and over-current that may occur during operation and maintenance and obtain information about any building occupation factors that might affect the risks.		
Integration with building		Ensure that the designer is aware of installation requirements of PV products, such as support, moisture protection, access for installation, commissioning and maintenance.	Identify parts of the building where activities may cause mechanical damage.	
Electrical		Modules should not be installed near ground level where mechanical damage is most likely. If that is unavoidable, they should be protected by crash barriers (taking care not to obstruct the solar radiation, ie insolation). Contact the Distribution Network Operator (DNO), at the local electricity company, not necessarily the company that bills you for electricity. The DNO needs time to investigate the effect local generation by the PV installation will have on the network.		
Access		Consider ways to minimise the need for access, particularly at high level, by making connections and fixings accessible from floors.		
Weight and bulk		Modules can be supplied in any size; balance the efficiency and architectural benefits of large modules with the installation difficulties of lifting and positioning at height.		
Detailed design				
General	Work with the designer to develop a design that suits your needs.	As part of the briefing process, ensure that the client is aware of any hazards that may occur during operation and maintenance and obtain information about any building occupation factors that might affect the risks.		
Support structure		Follow the recommendations of appropriate safety standards such as the Novem Guidelines [8].	Ensure structural strength appropriate for weight. Ensure sufficient edge support to keep modules in place in strong winds and when damaged. Ensure support mechanism is adequate, eg structural silicone fixing may not be enough.	
Electrical		Wiring standards such as BS7671[9] and its international equivalent, IEC60364, refer to installations of less than 120V dc as 'extra-low voltage' because they are unlikely to cause serious electric shock under normal conditions. Using extra low voltage can be considered as one method of avoiding electric shock. Reference to the new section IEC 60364-7-712, *Photovoltaic power supply systems* [10], may be helpful. Avoid shock by appropriate design and safe working methods of work.		
Mains failure protection		The inverter should incorporate a recognised technique for providing 'loss of mains' protection, eg frequency shift or vector shift, (see Electricity Association *Engineering Recommendations G59* [11] and *G77* [12]). Active techniques that distort the voltage waveform beyond the limits specified in the standard BS EN 61000-3-2[13], or that inject current pulses into the DNO's network, are not approved. The inverter must disconnect from the DNO's distribution system within 5 seconds, and must not reconnect until at least 3 minutes after the supply from the DNO has been restored.		

Work sector	client	designer	installer	facility manager/maintainer
Cabling	Allowance should be made for increased ambient temperature and the UV exposure of cables. Follow wiring regulations plus PV guidelines such as Novem [8], which states that the following methods should be considered for short-circuit protection: ♦ class II cables ♦ single-core cable with non-metallic sheath ♦ single-core cables with basic insulation only, laid separately ♦ conductors with basic insulation only and earthed screen, provided opposite poles are not in the same cable.			
	All dc cables must be installed to prevent short-circuit. The interconnecting cables of parallel-connected strings should be protected by suitable over-current protective devices, or they should be dimensioned to the maximum total system current. Where three or more strings or arrays are connected in parallel, each incoming string cable or array cable should be provided with overload protection. The dc string cabling should be capable of indefinitely conducting the short-circuit current. Cabling to two or more strings should have twice the string current rating.			
Cableways	Cables concealed in the structure may be contacted during maintenance work, so routes should be defined and marked.			
	Keep cables to clearly defined routes.			
Junction boxes	These should be readily accessible, and the following text should be permanently and clearly visible: 'This box contains live parts which cannot be deactivated'.			
Disconnectors	Switches, load-breaking switches, or disconnectors may be used, provided that their design is such that it is not possible to touch any live parts. Where disconnectors are used on module wiring (in combination with fuses or otherwise), the following text should be clearly visible inside the dc junction box: 'Disconnectors must be operated only under zero current condition'. A disconnection point with a load breaking capacity should be in front of the inverter so that it may be isolated.			

Tendering

Tendering	Ensure the Health and Safety Plan is specified.			
	Produce the Health and Safety Plan.			

Construction

Transport	Ensure access routes can carry load safely.			
	Keep to designated access routes.			
Lifting	Be careful when lifting and carrying heavy equipment by hand; lift with the legs and not the back to avoid back strains. Ensure ladders are firmly anchored. Ensure PV modules are held firmly; they can act as windsails on windy days. Use appropriate lifting gear and suction pads if necessary.			
Positioning and fixing	Wear comfortable but stout shoes with toughened but not steel toecaps: steel lowers the resistance of an electric current path. Keep personnel away from damaged modules.			
Working at height	Follow recommendations of HSE publications on roof working [14 & 15].			
Exposure	In summer consider the use of sunscreen and protective clothing, drink plenty of water and take a regular break in the shade. Wear tinted glasses to avoid glare. Wear gloves to protect against contact with hot or cold external components.			

Work sector	client	designer	installer	facility manager/maintainer

Cabling	Keep cables away from sharp edges. Use the specified method of protection. Install systems from the inverter isolator back to the module so that the module connections are the final action before closing the isolator to operate the system. Consider covering modules to prevent voltage generation during construction. Avoid using metallic tools near exposed live conductors in case they are dropped.
Co-ordination	Construction workers may not expect to find the façade electrically live during construction. Scheduling of the installation so that the PV installers are the only workers in the area during installation should be considered.

Commissioning

Monitoring	Provision of a monitoring installation can make commissioning easier.
Insolation measurement	Provide details of design parameters. Refer to the BSRIA/ETSU *Testing, Commissioning and Monitoring Guide* [16].
Output measurement	Use of remote instruments in a monitoring system can reduce the need to work at height on the installation. Use of remote instruments in a monitoring system can reduce the need to work on the live installation.
Mains failure simulation	Electricity Association *Engineering Recommendation G77* recommends that protection should be provided to isolate the inverter-connected PV generator from the DNO's distribution system when: ♦ operating voltage is greater than 253V phase to neutral (230V +10%) ♦ operating voltage is less than 207V phase to neutral (230V –10%) ♦ operating frequency is greater than 50.5Hz (50Hz +1%) ♦ operating frequency is less than 47Hz (50Hz –6%). Prevention of islanding must be proved for the benefit of the DNO since they may expect the network to be dead when they have isolated it from the supply grid.

Aerial view of PV roof at GTAC, Georgia, USA

HEALTH AND SAFETY FILE

Work sector	client	designer	installer	facility manager/maintainer

Handover

Operation and maintenance manuals	Operation and maintenance manuals must be properly specified.
	Manuals must be in English for UK installations; co-ordinate with other services if installed in the same project and include the following data as a minimum: ♦ design criteria ♦ record or as-built drawings ♦ general details of construction methods and materials used ♦ details of the structure's equipment and maintenance facilities ♦ maintenance procedures and requirements of the structure ♦ manuals produced by specialist contractors and suppliers which outline operating and maintenance procedures and schedules for plant and equipment installed as part of the structure ♦ details of the location and nature of utilities and services, including emergency and fire fighting systems.

Operation

Operation	Keep flammable materials away from connections. Ensure staff are aware of the special features of the building.
Operation and maintenance manuals	Manuals must be in English for UK installations; co-ordinate with other services if installed in the same project and include certain data as a minimum (see above).
Conditions	PV modules must comply with appropriate module standards, eg IEC 61215 [17] (crystalline silicon) or IEC 61646 [18] (thin-film silicon), which set levels of high temperature and reverse current tolerance.

Maintenance

Replacement	Plan for module replacement.
Disposal	Specify disposal method.
	Modules should not be disposed of with normal waste because burning or landfilling may release toxic compounds. Return to manufacturer or safe disposal agent if damaged.
Electrical inspection	A basic level of inspection is required to ensure safe and efficient operation. A PV system should be serviced at least once a year by a suitably qualified person. The following checks should be performed as a minimum: ♦ module fracture and moisture penetration ♦ damage to the dc cables ♦ status of the surge arrestors (where relevant) ♦ inverter functionality ♦ low-voltage system connection.
Electrical maintenance	Accept occasional PV shutdowns.
	Plan shutdown for maintenance.
Insects	Locate relevant safety equipment including fire extinguisher and telephone. Obtain schematic diagrams of the system and refer to them. Visually inspect the system before working on it. Avoid working near live conductors if possible. Before working on or near conductors check the voltage from any wire to any other wires, and to earth. Never disconnect a wire before you have checked the voltage and current. Do not trust switches to operate perfectly and do not 'believe' schematics. Always be prepared for the unexpected, eg wasps' nests, when opening or entering enclosures.

5 REFERENCES AND FURTHER READING

REFERENCES

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