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Zambian Standard

PHOTOVOLTAIC SYSTEMS DESIGN AND INSTALLATION - Code of Practice for Off Grid Systems

ZAMBIA BUREAU OF STANDARDS

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TECHNICAL COMMITTEE RESPONSIBLE

This Zambian Standard was prepared by the Photovoltaic Systems Technical Committee (TC 5/6) upon which the following organisations were represented:

Chloride Zambia Ltd
Department Of Energy
Energy Regulation Board
Muhanya Solar Ltd
Rural Electrification Authority
Saro Agro Industries Ltd
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FOREWORD

This National Standard has been prepared by the Photovoltaic Systems Technical Committee (TC 5/6), in accordance with the procedures of ZABS. All users should ensure that they have the latest edition of this publication as standards are revised from time to time.

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The preparation of this Standard has been undertaken by the Photovoltaic Systems Technical Committee (TC 5/6). The revision of this standard was necessary to ensure that technological advancements are taken into consideration.

In the preparation of this standard, the following publications were consulted:

- EED1(3), Botswana standard code of practice for photovoltaic energy systems design and installation, Part 1: Buildings
- SAZS 536: Zimbabwe standard code of practice for design, sizing and installation of battery based photovoltaic systems.
- NRS 052: South Africa Standard specification for photovoltaic systems for use in individual homes.
- “Universal technical standard for solar home systems” Thermie B SUP 995-96, EC-DGXVII,

ACKNOWLEDGEMENT

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Zambian Standard

PHOTOVOLTAIC SYSTEMS DESIGN AND INSTALLATION – Code of Practice for Off Grid Systems

1 SCOPE

This Zambian Standard provides requirements for design and installation of off grid photovoltaic energy systems for structures such as domestic, school, office and industrial buildings.

2 NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. All standards are subject to revision and, since any reference to a standard is deemed to be the latest reference to the latest edition of that standard, parties to agreements based on this standard are encouraged to take steps to ensure the use of the most recent editions of the standards indicated below. Information on currently valid national and international standards may be obtained from the Zambia Bureau of Standards:

ZS 403 Batteries for use in photovoltaic systems – Specification

ZS 404 Charge regulators for photovoltaic system using lead-acid batteries

ZS 407 Lighting Devices for use in photovoltaic systems

ZS 418 Electrical safety code – Code of practice

ZS 791 Wiring of Premises – Code of Practice

ZS IEC TS 61836 Solar photovoltaic energy systems – Terms and Symbols

3 DEFINITIONS AND NOMENCLATURE

3.1 Definitions

For the purpose of this standard, all definitions in ZS IEC 61836 and electrical terms in the current Institution of Electrical and Electronic Engineers (IEE) Regulations shall apply including the following:

3.1.1 Ampere-hour (Ah)
A unit of measurement that quantifies as an amount of current flow in Amperes for an amount of time in hours.

Note: A current of 1 amp drawn from a battery for 10 hours would consume 10 amp-hrs of charge from the battery. Fundamentally, it is a measurement of electrical charge.

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3.1.2 Array current (l)
This is the current produced by a photovoltaic array under standard test conditions.

3.1.3 Battery
Conforming to ZS 403.

3.1.4 Charge Controller
Conforming to ZS 404.

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3.1.5 Client
A person or organisation that requires a photovoltaic system for a specific load.

3.1.6 Contractor
A person, organisation or company that is licensed by a regulatory body to undertake design and or install a photovoltaic system for a third party.

3.1.7 Daily load (L_D)
The maximum measured or estimated demand over a period of 24 hours

3.1.8 Essential services
These are services that are deemed to be of particular importance to maintain in a continuous functional state.

Note: These services include domestic refrigerators, appliances in health facilities (vaccine refrigerators, spotlights for surgical work etc.), communication radios, security lights, alarm systems, etc.

3.1.9 Non-essential services
These are services other than essential services.

Note: These services may be general lighting in houses and institutions, radio and other domestic appliances.

3.1.10 Off-grid system
A solar photovoltaic system that is not connected to the utility grid.

3.1.11 Peak Sun Hours
The number of hours per day during which direct solar irradiance averages 1000W/sq.m at a location.

3.1.12 Photovoltaic Array
A mechanically integrated assembly of solar modules or panels held together with support structure but exclusive of foundation, tracking, thermal control and other components, as required, to form an electric power producing unit.

3.1.13 Photovoltaic Cell –
A cell that converts solar radiation into electrical energy

3.1.14 System autonomy
The total period during which the system shall provide power to its regular load without solar energy input.

3.2 Nomenclature

3.2.1 A: Ampere

3.2.2 AC: Alternating current

3.2.3 DC: Direct current

3.2.4 h: Hour

3.2.5 kW: kilowatt

3.2.6 PV: photovoltaic

3.2.7 UV: ultra violet

3.2.8 V: voltage

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3.2.9 Wp: watt peak

4 SYSTEM DESIGN

4.1 General

The layout of the installation shall be shown in the drawings as well as in the detailed specifications. The contractor shall ensure that the drawings and specifications are followed during installation. These shall be designed to fulfill the needs of the client as to location of components and switches but with a minimum of connections and length of wire that cannot cause energy loss and/or reduced effectiveness of the photovoltaic system.

NOTE 1: A system design specified for a client by a contractor should be in a form that may be readily explained to a non-technical client.

NOTE 2: In the case of a client-specified installation, it is the responsibility of the contractor to inform the client of any parts that do not conform to this Standard.

4.2 System sizing calculations

Determination of component specifications for a functional system shall depend on client requirements.
All system performance and output specifications shall be made available to the client as design guarantee.
The contractor shall also provide the client with standard electrical drawings conforming to IEEE standards and ZS 791.
The contractor shall be required to keep a record of the calculations on the design of the PV system but shall not be obliged to provide these calculations to the client.

For the purpose of this standard and where disputes arise, the method given in Annex A shall be used for calculating the requirements for a functional system. In the absence of actual insolation data for each location, a peak sun hour value of 4.5 hours shall be used in the calculations of Annex A.

NOTE: Calculations of requirements for a functional system shall depend on whether the system is considered as essential service or non-essential service. Essential services and non-essential services systems shall be installed as totally separate systems. If a combination of Essential services and non-essential services are connected to the same system, it shall be sized as if all services are essential services, unless otherwise proved with calculations that the design of a combined system will satisfy the requirements of both types of services.

4.2.1 System autonomy

The autonomy of a system depends mostly on the depth of discharge of the batteries under normal daily loads. If a battery is only discharged by a small fraction of its total capacity each day it will clearly provide more days of operation than a battery that is discharged by a large fraction each day.

Since the overall life of a battery is affected by the depth of its regular daily discharge, the life being inversely proportional to the depth of discharge, careful consideration must be given to the sizing of the batteries in relation to the system load requirements.

4.2.2 Essential services

The system autonomy shall be at least three days at the designed amp-hour load.

4.2.3 Non-essential services

The client and the contractor shall agree upon the autonomy of these services.

4.3 Conductors

The size and the length of the conductors are of critical importance to proper performance of the solar

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systems. When laying out circuits, best practice is to keep the number of wire junctions to a minimum and length of conductors as short as practical. The wiring tables in Annexes B and C shall be followed rigorously and the requirements below shall also be complied with.

4.3.1 Capacity

The rated current carrying capacity listed in Annex B at any temperature for any given wire cross- section shall not be exceeded.

4.3.2 Battery/load voltage drop

The total voltage drop between the battery and any appliance shall not be more than 4% of the nominal voltage when all appliances in the circuit are drawing their operating current (refer to Annex C for maximum lengths of various cable sectional areas at different loads). In the case of refrigerators, pumps or other appliances that have electric motors starting under load, the peak starting current of the appliance shall be considered as the operating current. Where the peak starting current is not specified it would be assumed to be at least two times the normal operating current of the appliance.

Note 1: An inverter shall be handled as part of the load.

Note 2: 0.5V for a 12V system
1.0V for a 24V system
2.0 V for a 48V system

4.3.3 Battery/PV-module voltage drop

The voltage drop between the PV module array and the battery shall in no case exceed 4% of the nominal voltage when the maximum current from the module is present in the circuit. For the purposes of this standard, the maximum current from the module is assumed to be the short circuit current. The total voltage drop includes those caused by the wires, connections and regulator included in the module to battery circuit.

4.3.4 Minimize junction losses

In order to avoid using long cable runs with large numbers of “T” and “star” junctions, the load shall be split into several circuits from the regulator, where possible.

4.3.5 Use of existing 220 V AC wiring

Where there is existing wiring intended for 220 V AC already installed, it may be used only if the wiring complies with all conditions listed in this section of this code and is specified in relation to colour, circuit and application. The DC component of the wiring should be clearly marked as DC.

4.3.6 Connection of conductors (Joints)

Connections shall preferably depend on a screw directly compressing the conductor. Twisted wire connections (connections which depend on crimped lug connectors or which depend on "wire nuts" which are added to twisted wire connections) shall not be used for joints. However, crimped lug connectors may be used for termination. Solder joints are acceptable if the solder clearly flows freely around all conductors being joined and the total current through the junction is less than 16 A. All connectors must have a current carrying capacity equal to or greater than that of the circuit of which they are a part.

Joints should be inside a junction box, light fixture or other space intended for electrical connection. If that is not possible, the connection should be covered with insulating tape, insulating tubing or other material that will prevent accidental contact with the electrical circuit.

4.4 Switches

DC rated switches are recommended for the DC circuit. The switch rating shall be able to carry the maximum current expected to flow in the switched circuit. If it is necessary to use an AC rated switch, the rating should be at least two times the maximum current expected to flow in the circuit.

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All switches should have a clear indication of their operating state (ON or OFF). Where particularly required, special time switches, photosensitive switches, remote relay switches etc, may be used. In service, no switch shall have a voltage drop of more than 0.05V across the switch terminals when operating at its rated capacity.

4.5 DC socket outlets

Appliances not permanently wired into a circuit shall be connected to the wiring through socket outlets where not otherwise specified. Only DC socket outlets should be used and they should have a capacity of at least 15 Amperes. It must not be possible to insert a power plug in such a way as to reverse polarity connection. It must not be possible to insert a DC plug into a 220 V AC socket outlets or to insert the plug of a 220 V AC appliance into the DC socket outlets. All outlet types must be clearly labelled.

Under no circumstances should standard mains type sockets and plugs be used. Any DC appliance with a mains type plug attached constitutes a high risk to the user and the appliance if the appliance is plugged into a 220 V outlet. Plugging a 220 V AC appliance into a DC solar system may cause fire or damage to both the solar system and the appliance.

4.6 Appliances

All appliances that are connected to a solar electric system shall be designed to operate from a DC voltage level of the solar system or fitted with a conversion device that will efficiently provide the correct operating service conditions for the appliance. The contractor shall advise the client regarding suitable appliances for use with the installed system and their manner of connection.

All appliances to be connected to the DC system shall be specially designed for such voltage or provided with suitable and efficient adaptors and/or inverters for safe functioning.

Note: Appliances can include radios, fans, spotlights, rechargeable torches, refrigerators, special instruments etc.

4.7 Photovoltaic module specifications

Only panels specified for non-grid connections should be used for applications under this standard

Note 1: The system design should conform to the manufacturer's uses if specified.

Note 2: Photovoltaic modules with by-pass diodes may be deemed more suitable for this application.

4.8 Batteries

4.8.1 Type

Batteries shall conform to ZS 403.

4.8.2 Housing

Batteries shall be housed in boxes, racks or cupboards safe enough to prevent accidental short-circuits, and are corrosive resistant to electrolytes. Metal racks may be grounded to enhance safety. Enclosures shall be adequately ventilated to prevent gas build-up, and shall have a minimum of 20mm space between the top of the battery and the top of the enclosure.

If more than one battery is going to be used it is recommended that the same type, capacity, age and usage cycle of battery be used.

It is also recommended that in a PV system using batteries it should not have more than 3 parallel strings if no battery balancing device is integrated into the battery bank. This is to avoid affecting the longevity of the batteries

Where a battery shall be secured in a box, the box shall be made of wood or acid resistant material. If the

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box is made of wood, it shall be well preserved and protected against insects, rodents or termites, rot and acid. The battery box or rack must be anchored.

4.9 Regulators and circuit breakers/ fuses

4.9.1 **C**harge controller

4.9.1.1 Type

The charge controller shall conform to ZS 404.

4.9.1.2 Over-charge and over-discharge protection

Charge controller shall be designed to protect the batteries against over-charging as well as over-discharging. The specific voltages at which the charge controller disconnects and reconnects will depend on the type of battery, the size of PV module and the appliances involved. The rated current capacity of the charge controller shall be high enough to pass the maximum current possible from the module. During the discharge cycle, it should be capable of continuously passing the maximum current which will be required to operate all attached appliances simultaneously. Unless an appliance has an integral low voltage cut off (such as some power inverters and DC refrigerators) all must be connected to the battery through the charge controller. The charge controller should be located as close to the battery as possible to reduce the problem of false battery voltage readings due to voltage drops in the connecting wiring. If a mounting of less than 1 metre from the battery is not possible, the contractor should either increase the connecting wire size (gauge, Refer to Annex C) substantially or use a charge controller that has separate voltage sensing wires that are not affected by the voltage drop in the main current carrying conductors.

4.9.1.3 Warning of over-discharge

A system warning of over-discharge shall be included. It shall indicate that there will be a disconnection and the warning shall be noticed some minutes in advance.

4.9.1.4 Bypass of over-discharge protection

Essential service circuits may be provided with a switch to facilitate bypass of the over-discharge protection or to bypass the charge controller completely. Warning for low battery shall however be included as for non-essential services.

4.9.1.5 Circuit breakers/fuses

A means of protecting the system from damage due to high currents resulting from shorting of the wiring connected to the battery must be included. This may be a DC type fuse or DC type circuit breaker. Individual circuits from the battery shall have a maximum rated capacity of 25 Amperes where not otherwise specified. Each circuit shall be so designed that the peak demand does not exceed 80 % of the rated capacity of the fuse or circuit breaker.

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5 INSTALLATION

5.1 General

Care shall be taken to perform the actions needed to install the solar system with appropriate attention and skill to avoid damaging the structure's appearance or its integrity. In general, the visible parts of the installation should be completed in a manner that does not detract from the general appearance of the part of the structure in which the parts are placed.

The installation shall not be considered complete until the premises have been tidied up and any repairs to walls, roofs, ceilings or other parts of the building, which may have been damaged as part of the installation process, have been made good.

Upon completion, the final appearance of the installation should be consistent with the general appearance of the building upon which the installation was made.

5.2 Personnel

All installations shall be made by qualified and certified personnel. These personnel shall be registered with the relevant statutory body responsible for regulating technical staff in this field.

5.3 Wiring

5.3.1 General

All wiring shall be enclosed by standard PVC electrical conduit as per ZS 418. However, surface mounted twin cabled conductors might be used for wiring where a conduit is not used. The mounting of such cables and/or conduit shall conform to the same standards used for conventional house wiring. All systems will require earthing.

5.3.2 Use of existing 220 V AC wiring

This shall comply with the requirements of **clause 4.3.5**.

5.3.3 Cables and conduits

5.3.3.1 Surface mounted cabling

Surface mounted cabling shall be installed using the appropriate fasteners at suitable intervals to prevent sagging.

5.3.3.2 Attachment of cables

Attachment of cables or conduit to concrete, bricks or mortar surfaces etc. shall be made with appropriate fasteners. Attachment of cables to metal sheeting or similar material shall be made by use of toggles.

5.3.3.3 Underground cables

Where cables must pass underground and cross public land, the cables should be laid a minimum of 0.6 metres below the surface and be enclosed in a conduit and indicated with markers such as coloured plastic tape that is at least 50 mm wide or lined with bricks or slate 0.2 m above the cable. Where the cables pass underground and cross only private land belonging to the client, the cable may be laid a minimum of 0.3 meters below the surface and enclosed in a conduit and marked as above. Where the cable is laid without conduit, the insulation must be specifically intended for direct burial. Underground cables should be used to cross all areas having vehicular traffic in preference to overhead cables.

5.3.3.4 Suspended cables

The ground clearance of any suspended cable shall be at least 2.7 m above the highest ground below the span. All suspended cables shall be held in position by suitable brackets and strain relief to prevent mechanical wear and stress on the electrical connections. For any span in excess of 7 metres, cable in its crossing must be supported by a catenary and solidly attached at each end of the span by fasteners capable of handling at least three times the static stress caused by the combination. The cable should be securely attached to the catenary at least every metre of the span. All cabling exposed to the weather must either be enclosed in a protective tube or be rated for exterior use and must be ultra violet resistant.

5.3.3.5 Cables through roofing

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Wiring from a roof mounted module must pass through either the ridge of the roof or if near an edge, the catenary must be laid so it does not penetrate the roof at all. Any holes made through the roof should only be made if absolutely necessary, as high up on the roof as possible and only through the ridges of corrugated materials, where applicable. The penetrations should be by way of feed through tubing specifically intended for wiring passing through a roof. They must be sealed against leaks using exterior grade silicone sealant or other permanent weather resistant sealing material that resists ultra violet degradation.

5.3.3.6 Thatched roofs (flammable materials)

Where cables are attached to a building with a thatched roof, the cables shall not pass through the thatch or the thatching material. Attachments must be made to house framing materials or to a specially made supporting structure and cables be enclosed in PVC or metal conduit.

Note: the contractor must ensure that the cabling is independent of the thatching material. This should allow for the thatching material to be replaced from time to time without disturbing the wiring.

5.3.3.7 Through-wall cabling

Access holes for cables through walls shall be sealed using appropriate wall filler. Holes that penetrate external walls shall slope downwards slightly towards the outside to prevent the ingress of water.

5.3.4 Jointing of Cables

All cable joints shall be contained within a suitable junction box. Light fittings, switches and socket outlets may be used as junction boxes where these are practicable.

Note: Cables can be joined by the use of junction boxes, block connectors or soldering (with insulating sleeves).

5.4 Switches

This shall comply with the requirements of **clause 4.4**.

5.5 Socket outlets

5.5.1 General

Appliances shall be connected to the wiring through socket outlets where not otherwise specified in design system. Socket outlets and lights can be connected to the same circuits provided other requirements of this standard code of practice are complied with.

5.5.2 DC socket outlets

All DC sockets outlets must comply with provisions in Clause 4.5 of this document.

5.5.2.1 Polarity Convention

Unless otherwise specified, all installations that have DC sockets shall be wired so that the larger diameter pin in the plug is always Positive in polarity. Wiring shall have RED or BROWN as the Positive polarity colour and BLACK or BLUE as the Negative polarity colour. With marked ripcord, the marked conductor is always Positive.

Note: the colours marked for positive and negative may vary depending on the manufacturer. However the symbols remain as stated above and therefore shall take precedence.

5.5.3 Inverter outlets (AC 220V)

Where it is necessary to operate a 220 V AC appliance from a DC photovoltaic system, an inverter will be

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required. If the 220 V AC is provided through any exterior circuitry that circuitry and its earthing must conform to all ZS 418.

Since inverters tend to have high current input requirements (generally about 20 times the current required by the connected 220 V AC appliance), the wires connecting the inverter to the battery shall have adequate capacity to carry the current required by the inverter input safely without imposing any electrical or thermal hazard

NOTE: The inverter should be as close as possible to the battery or in accordance with manufacturer's recommendations.

5.6 Lightings

The following types of lights may be used:

5.6.1 Indoor (not exposed to weather)

Where lamps are fitted next to flammable materials such as thatch, a fireproof shield should be placed between the lamp and the flammable material. Light fittings should be at least 0.3m from the flammable materials. All connections to the lamp shall be enclosed within the lamp fixture body or in a separate, closed junction box.

5.6.1.1 Fluorescent lamps

They shall conform to ZS 407 and should be used for general space and task lighting.

5.6.1.2 Halogen bulbs

They should be used in adjustable or portable fixtures for task lighting or spotlights.

5.6.1.3 Incandescent lights

Incandescent lights shall not be used unless for specific purposes.

5.6.2 Outdoor (exposed to weather)

All fixtures installed outdoors are to be specifically designed for outdoor exposure and must be weather-proof, insect-proof and constructed of non-corroding materials such as plastic, stainless steel or aluminium.

5.6.2.1 High intensity lights

Sodium vapour or other monochrome high intensity lights may be used for security lights, streetlights etc. However, it is recommended that more energy efficient alternatives are used.

5.6.2.2 Lighting devices

Lighting devices used in a solar system shall conform to ZS 407.

5.6.3 Insect Precautions

Where lamps with enclosures or diffractors are used, they shall be capable of being opened for cleaning by the client, as small insects will always accumulate inside. Open lamps are preferable in this respect.

5.7 Appliances

The contractor shall advise the client on suitable appliances and precautions in their use in

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relation to the system design and further advise on energy efficiency.

5.8 Photovoltaic modules

5.8.1 General

Refer to Clause 4.7 of this document.

5.8.2 Position

Where avoidable, no objects should be present at the module location that can cause shade on any part of the modules at any time of the day or year. Should shading be unavoidable, module size should be increased in compensation or system load reduced correspondingly.

Modules shall not be installed in such a way that they shade other modules during the sun peak hours.

5.8.3 Orientation and tilt

The module should be installed facing north at an angle between 15 and 25 degrees to the horizontal plane depending on the latitudinal location of the installation. The module should be oriented between 10 degrees west and 20 degrees east of magnetic north.

5.8.4 Lightning protection

Lightning protection shall be provided for all PV systems to prevent potential hazards to humans and the system. In order to provide the shortest possible path for the lightning induced surges to reach the earth, the module frames and the array support structure shall be directly connected to the grounding electrode. This connection shall be made using minimum 16 mm^2 bare copper wire as a grounding conductor.

5.8.5 Support structure

The support structure for modules shall be made to withstand winds up to 120 km/h. The structure should be made of materials that are non-corroding or of steel that is protected against corrosion. When the module is fitted to the support, there should be no twisting of the module frame or bending of the module that would cause stress on the glass or the edge seals of the module.

5.8.5.1 Roof mounting

Where roof mounting is used, the system for mounting should be such as to prevent the likelihood of leaking or deterioration of roofing materials. For modules mounted on the roof itself, a minimum of 100 mm of space shall be maintained between the bottom of the module frame and the highest part of the roof under the module in order to allow the free flow of water down the roof and to allow for ventilation of the back of the module to prevent buildup of heat.

5.8.5.2 Ground mounting

This method of mounting should be avoided whenever possible. Solid foundations shall be provided at each corner of the array with additional support as required by the design of the supporting structure. Modules shall not be mounted closer than 0.8 m from the ground to avoid shading by grass and other vegetation. Small arrays may alternatively be fixed to a single pole, appropriately secured into the ground and if necessary secured with stays. The location shall be chosen such that animals can cause no damage. The site should be fenced if necessary.

5.9 Batteries

Batteries shall be installed in boxes, racks or cupboards to protect the connections (terminals) against tampering or accidental short-circuiting while still being accessible for maintenance. At least 20 mm of free space shall be left between the batteries and the wall and the top of the battery container. The

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container shall be made of suitable, durable materials. Each battery shall be marked with the year and month of installation using a scribe or hot iron to permanently mark the plastic case of the battery. The terminals should be greased after connections. Where applicable to the battery type, the container shall be vented near its highest point to allow the dissipation of explosive hydrogen that may be released during the charging process. A label warning (of the type shown in Annex D3) of the possible presence of explosive gas and of corrosive acid should be affixed to the outside of battery boxes.

5.10 Charge controller and circuit breakers/fuses

5.10.1 Charge Controller

The charge controller shall be mounted such that it is not obscured by any object and that the reset button, if installed, is easily accessible. If the charge controller is mounted on a vertical surface, it shall be securely fastened to the surface by an appropriate means that will ensure it cannot fall off under normal operating conditions. The charge controller shall be installed such that it is not exposed to moisture, grease or dust and in accordance with clause **4.9.1** of this Standard.

If the charge controller is installed in a battery box, it shall not under any circumstances share the same compartment as the batteries. All display indicators should be visible from outside.

All cable connections to the charge controller shall be insulated.

5.10.2 Circuit breakers/fuses.

The fuse or circuit breaker shall be installed on the appropriate conductor of the battery in accordance with the manufactures specifications so that breaking the circuit will disconnect power from the battery to all external circuits. The fuse or circuit breaker may be installed in the battery box, the controller enclosure or a separate junction box. Fuses or circuit breakers shall be located where access is convenient for resetting or replacement.

5.11 Labels

Labels such as those in Annex D shall be affixed at appropriate places. In addition to the labels, the name of the installer and date of installation shall be provided in English or any other language alongside English.

6 INSPECTION AND TESTING BY CONTRACTOR

On completion of the installation, the contractor shall inspect and test the system in accordance with this code of practice and maintain records as provided for in Annex E.

The results of the measurements or the manner the system was installed can be used by an independent third party or regulatory body in the case of a dispute between the contractor and the client.

7 INSPECTION AND TESTING BY THIRD PARTY

On completion of the installation, a third party mandated by law to approve electrical installation shall inspect, test and certify that the system is in accordance with this code of practice. The inspection shall be conducted using annex E

8 MAINTENANCE AND SPARE PARTS

8.1 Maintenance

The contractor shall provide written details of the minimum and recommended maintenance needed to keep the solar PV system operating properly.

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8.2 Spare parts

Spare parts shall be supplied as agreed between the contractor and the client. Where spare parts are not supplied by the contractor, the client shall be advised where suitable replacement parts may be obtained.

9 WARRANTY

The contractor shall clearly explain and provide written notification of the nature and period of any warranties including both those provided by the contractor and those provided by manufacturers of the individual components. The following shall be minimum warranty periods: -

Table 1: Warrant period

Components	**Minimum warranty period**
Charge Controller	2 years
Inverter	1 year
Battery	1 year
Module	10 years
Fluorescent fittings	2 years
LED	30,000 hours
CFL	6,000 hours

The contractor shall provide an overall system warranty of at least one year. The warranty shall hold for defects in components or poor workmanship but shall not hold for abuse or misuse of the system by the client.

10 DOCUMENTATION

Documentation as set out in Annex A shall be provided at each system installed.

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ANNEX A
(Normative)
PV System Sizing

Table A1: Load Assessment

Load Assessment	Examples

Load Assessment

Separate Alternating Current (AC) and Direct Current (DC) loads before completing the load assessment worksheet as follows:

- ✓ Column 1: Appliances
- ✓ Write down all the electrical appliances to be powered by the PV system
- ✓ Column 2: Power rating
- ✓ Record the rated power, in Watts, of each item
- ✓ Column 3: Quantity
- ✓ Specify the number of each appliance to be powered by the PV System
- ✓ Column 4: Usage Hours
- ✓ Specify the time of use, in hours per day , for each appliance
- ✓ Column 5: Energy Consumption
- ✓ Multiply Column 2, Column 3 and Column 4 to determine the daily total energy consumption

For AC Loads

Determine system wiring losses (typically 5-10%)

Determine inverter losses (typical inverter efficiency 80-90%)

Then calculate the total energy requirement from Battery

$$Energy\ Required = \frac{(Energy\ reuired\ by\ DC\ load)}{(1 - Cable\ losses)} + \frac{Energy\ Required\ by\ AC\ load}{Inverter\ Efficiency}$$

Examples

Daily AC Loads

Appliances	**Power (W)**	**Quantity**	**Usage hours (h)**	**Energy Consumption (Wh)**
CFL Bulb	11	1	4	44
LED Bulb	11	1	4	44
CFL Bulb	11	2	6	132
TV	80	1	4	320
DVD player	25	1	2	50
CD player	10	1	8	80
CFL Bulb	11	1	4	44
CFL Bulb	11	2	12	264
	Peak Load = 170			Total Energy = 978

Daily DC Loads

Appliances	**Power (W)**	**Quantity**	**Usage hours (h)**	**Energy Consumption (Wh)**
Water Pump	96	1	4	384
Refrigerator	80	1	8	640
	Peak Load = 176			Total Energy = 1024

$$Energy\ Require = \frac{(1024\ Wh/day)}{(1-5\%)} + \frac{978\ Wh/day}{0.8} = 2300.4$$
Wh/day

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Table A2: Critical Design

Critical Design	Examples
✓ Find monthly mean solar insolation data in kWh/m^2/day or Peak Sun shine hours (psh) for installation sites ✓ Divide daily DC energy requirement by available solar insolation values for different tilt angles (The solar panels should be installed facing North between an angle of 10° to 15° in Zambia and free from shading at all times) ✓ The critical design month is the month with the highest ration of load to solar insolation. It defines the optimal tilt angle that results in the smallest array possible.	960 kWh/m^2/day, 6hours

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Table A3: Battery Sizing

Battery Sizing	Examples
Determine DC system voltage, typically 12V for small (< 1kWh and 24V for intermediate daily loads) Determine the maximum number of consecutive cloudy weather days expected in your area, or the number of days of autonomy you would like your system to support	Using 24V since energy is more than 1kWh System Autonomy = 3 days
$Battery\ Capacity\ (Ah) = \frac{(Energy\ Consumption\ (Wh) x\ Sytem\ Autonomy}{(Depth\ of\ Discharge\ x\ System\ Voltage}$	$Battery\ Capacity\ (Ah) = \frac{(2300.4\ (Wh) x\ 3}{(0.2\ x\ 24\ V)} = 1437.7\ Ah$
Depth of discharge typical values = 0.2-0.8 Select deep discharge batteries, if possible Divide the total battery capacity by the battery amp-hour rating and round off to the next highest number. This is the number of batteries wired in parallel required	Using a 12 V, 600Ah battery
$Number\ of\ Parallel\ Batteries = \frac{Total\ Battery\ Capacity}{Battery\ amp-hour\ rating}$	$Number\ of\ Parallel\ Batteries = \frac{1437.7Ah}{600\ Ah}$ = 2.4 = 3
Divide the nominal system voltage (12V, 24V or 48V) by the battery voltage and round off to the next highest number. This is the number of batteries wired in series.	
$Number\ of\ Batteries\ in\ Series = \frac{Nominal\ System\ Voltage}{Battery\ Voltage}$	$Number\ of\ Batteries\ in\ Series = \frac{24}{12} = 2$
Multiply the number of batteries wired in parallel by the number of batteries in series, Total Number of batteries	$Total\ Number\ of\ Batteries = 2\ x\ 3 = 6$

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Table A4: PV Array Sizing

<table>
<tr><th>PV Array Sizing</th><th>Examples</th></tr>
<tr><td>✓ Estimate the battery Charging efficiency (80-90%)
✓ Estimate Soling factor for installation (typically 0.9 – 1)
✓ Calculate required charging current from PV array

Charging Current from Array= (Daily Demand on Battery)/(Critical Design Insolation x System Voltage x Battery Charging Efficiency x Soiling factor)</td><td>$Charging\ Current\ from\ Array = \frac{2300.4\ Wh/day}{4.5\frac{\frac{kWh}{m2}}{day} x\ 24V\ x\ 0.8\ x\ 0.9} = 29.6\ A$</td></tr>
<tr><td>Estimate maximum module temperature and rating reference temperature

Calculate required charging voltage from PV array</td><td>

Sample Electrical Characteristics		
Maximum Power	160	W
Current at Pmax (Imax)	4.55	A
Voltage at Pmax (Vmax)	35.1	V
Warranted minimum Pmin	152	W
Short-circuit current	4.8	A
Open-circuit voltage	44.2	V
Temperature coefficient of I_{sc})	(0.065±0.0015)	%/°C
Temperature Coefficient of Voc)	-(160±20)	%/°C
Temperature Coefficient of power	-(0.5±0.05)	%/°C
NOCT (AIR 20oC, Sun 0.8kW/m2; wind 1m/s)	47± 2	oC
Maximum series fuse rating	15	A (S, l); 20 a (U)

(Typical reference temperature 25°C); Maximum operating temperature 80°C

Temperature Coefficient: -0.18%/°C
$Charging\ Voltage\ from\ PV\ Array = 24 - (24x(-0.0018)x(80 - 25) = 30.9V$</td></tr>
<tr><td>Calculate Required Charging Power = 1.2 x Charging Current x Charging Voltage</td><td>$Charging\ Power\ Required = 1.2\ x\ 29.6\ x\ 30.9 = 913\ W$</td></tr>
</table>

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Select appropriate PV modules, e.g. For a 24 V system voltage Calculate (round up) number of PV modules in series $PV\ module\ in\ Series = \frac{Required\ Charging\ Voltage}{Module\ rated\ voltage}$	$PV\ module\ in\ Series = \frac{30.9V}{35.1V} = 0.88 = 1$
Calculate (round up) number of PV modules in parallel $PV\ modules\ in\ Parallel = \frac{Required\ Charging\ Current}{Module\ rated\ Current}$	$V\ modules\ in\ Parallel = \frac{29.6\ A}{4.55\ A} = 6.5 = 7$
Calculate total number of modules in array $Number\ of\ Modules\ in\ a\ PV\ array$ $= Number\ of\ Modules\ in\ Series\ x\ Number\ of\ modules\ in\ parallel$	$Number\ of\ Modules\ in\ a\ PV\ array = 1\ x\ 7 = 7$

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Table A5: Charge Controller Sizing

Charge Controller Sizing	Examples
Look up short circuit current of the PV module Calculate charge controller minimum power current $Charge\ Controller\ Minimum\ power\ Current = Short\ Circit\ Current\ of\ PV\ module\ x\ number\ of\ modules\ in\ parallel\ x\ 1.25$ Select appropriate charge controller	*Charge Controller Minimum Power Current = 4.8*7 * 1.25 = 42 A* Select appropriate charge controller, say 45A

Table A6: Inverter Sizing

Inverter Sizing	Examples
Calculate inverter minimum power size $Inverter\ Power\ Size = Power\ of\ All\ AC\ appliances\ x\ 1.25$	Inverter Power Size = 170 W x 1.25 = 212.5 W

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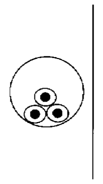
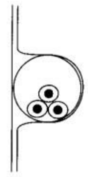
ANNEX B

(Normative)

Wire sizing chart for 12, 24 and 48 V systems

Maximum current carrying capacities in amperes of PVC insulated copper wire

Wire Cross Section Area	 Buried wiring			 Surface wiring		
Current (A) as a function of temperature and cross section						
mm^2	**35ºC**	**40ºC**	**45ºC**	**35ºC**	**40ºC**	**45ºC**
2.5	18.3	17.0	15.4	22.6	20.9	19.0
4.0	24.4	22.6	20.5	30.1	27.8	25.3
6.0	32.0	29.6	26.9	38.5	35.7	32.4
10.0	43.2	40.0	36.3	53.6	49.6	45.0
16.0	57.3	53.1	48.2	71.4	66.1	60.0
25.0	75.2	66.6	63.2	94.9	87.9	79.8

The table shows the maximum safe currents that may be carried by PVC Insulated cables of the given cross-sectional areas when wired in plastic or metal conduit at ambient temperatures of 35ºC, 40ºC and 45ºC respectively. Currents are shown for surface mounted conduit, and for buried conduit, (conduit may be buried within a wall or floor).

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ANNEX C

(Normative)

Maximum cable length, 12 V DC Solar photovoltaic system

Wire Size mm^2	DC Load in Watts								
	6	7	9	11	13	15	20	25	30
	Maximum cable length in meters for 0.5 V drop (distance from battery to modules or appliance)								
2.5	63	54	42	34	29	25	19	15	13
4	100	86	67	55	46	40	30	24	20
6	150	129	100	82	69	60	45	36	30
10	250	214	167	136	115	100	75	60	50
16	400	343	267	218	185	160	120	96	80
25	625	536	417	341	288	250	188	150	125

Wire Size mm^2	DC Load in Watts								
	35	40	45	50	55	60	65	70	75
	Maximum cable length in meters for 0.5 V drop (distance from battery to modules or appliance)								
2.5	11	9	8	8	7	6	6	5	5
4	17	15	13	12	11	10	9	9	8
6	26	23	20	18	16	15	14	13	12
10	43	38	33	30	27	25	23	21	20
16	69	60	53	48	44	40	37	34	32
25	107	94	83	75	68	63	58	54	50

Wire Size mm^2	DC Load in Watts								
	80	90	100	110	120	130	140	150	160
	Maximum cable length in meters for 0.5 V drop (distance from battery to modules or appliance)								
2.5	5	4	4	3	3	3	3	3	2
4	8	7	6	5	5	5	4	4	4
6	11	10	9	8	8	7	6	6	6
10	19	17	15	14	13	12	11	10	9
16	30	27	24	22	20	18	17	16	15
25	47	42	38	34	31	29	27	25	23

Note:
For solar refrigerators, pumps and other appliances that have a large motor that starts under load (fans not included), the Watts used in the table should be either the actual starting Watts for the appliance or, if that is not known, at least two times the operating Watts for the appliance.
The formula for determining the minimum copper wire cross section for any load so that the voltage drop is no more than 0.5 V is:

Wire size in mm^2 = 0.08 x Amperes in the wire x Metres distance to the battery along the wire path.

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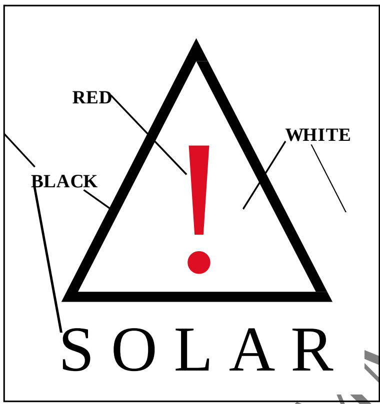
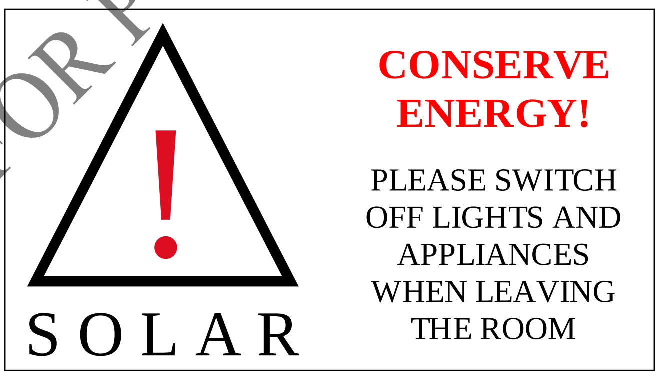
ANNEX D
(Normative)
Labels to be used in photovoltaic systems

D.1 General warning sign



D.2 Conserve energy sign

To be placed under all switches at the exit of a room.



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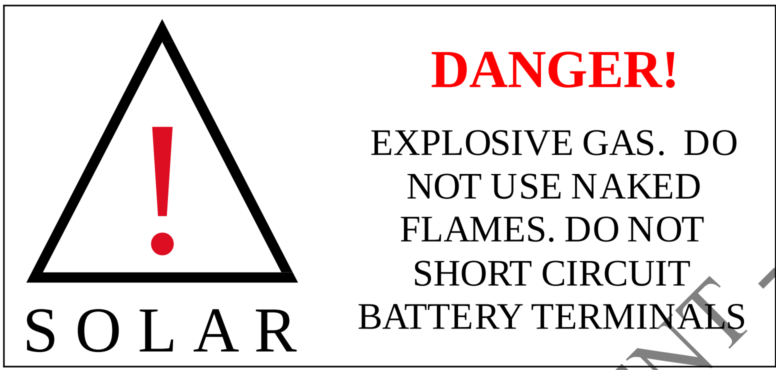
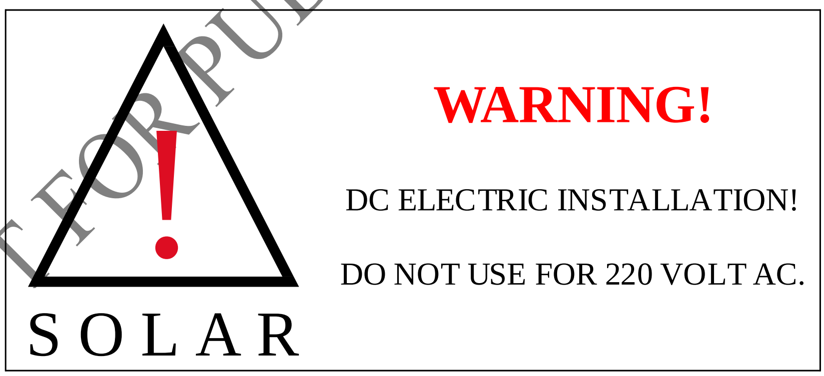
D.3 Danger sign

To be placed at the battery bank.



D.4 Warning sign

To be placed at the regulator.



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D.5 Warning sign

To be placed at all socket outlets.

Note: the same signs are applicable for 24V and 48V appliances with their voltages indicated on the warning signs.

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ANNEX E

(Normative)

Solar Photovoltaic Systems Installation Inspection Check List

Site Identification_____________________ **Date** ___/ ___/ ___ **Time**____________

Customer Name_________________ **Date Installed** ___/___/ ____ **Installed by**_________________

Ref. No.	Pass	Fail	Inspection Item
Panels			
Make_______________ Model_______________			Serial Number_____________ Power Rating (Peak Watt)_________
			Wall mount Roof mount Pole mount Ground mount
1.			Module conforms to relevant requirement.
2.			Tilt 15-20^{o} from horizontal for Northern half and 20-25^{o} for Southern half of Zambia
3.			Orientation – facing true North (within 10^{o} West and 20^{o} East of the magnetic North)
4.			Conduit continuous into regulator
5.			Security colour applied to the back and frame
6.			Mounting installed correctly and securely
7.			Panel mounted close to battery
8.			No shade likely between 0900 and 1500 hrs
9			Shade compensation has been factored in , if shade is likely to occur

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Battery Housing			
9.			Conduit continuous into battery box
10.			Ventilation of the battery box enclosure

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Battery			
Make_______________ Model_______________ Ah_________________			ID Number scribed into case________________________________
11.			Battery conforms to ZS 403
12.			Battery voltage 12.5 - 13.8V
13.			Hydrometer readings 1.250 - 1.275 (cell 1 is closest to the positive terminal) 1.________2._________3._________4________5_________6_________
14.			Connections tight and properly installed
15.			Connections greased against corrosion
16.			Electrolyte full in all cells
17.			All cells have clear electrolyte (no milky colour or floating materials in cells)
Charge Controller			
Make/Model__________ Amps ________________			Serial Number_________________
18.			Charge Controller conforms s to ZS 404
19.			Voltage at battery connections 11.5 – 14.5V for a 12V system 22.0 – 28.5V for a 24V system 44.0 – 57.0V for a 48 V system
20.			Voltage at panel connections 11.5 – 14.5V for a 12V system 22.0 – 28.5V for a 24V system 44.0 – 57.0V for a 48 V system
21.			Voltage at load connections 11.5 – 14.5V for a 12V system 22.0 – 28.5V for a 24V system 44.0 – 57.0V for a 48 V system

Status to show battery charging
Status to show battery is fully charged

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Charge Controllers *(continued)*			
22.			Securely and properly mounted
23.			Connections correct and tight
24.			"Battery on charge" LED indicator
25.			"Load disconnect" LED indicator
Inverter			
			All inverters to conform to relevant requirements.
			Battery status indicator
			Low voltage disconnect
			Status if inverter is “on” or “off”
			Over load indicator
			Low battery indicator
			Fault indicator
Light and Switches			
26.			All lighting devises conform to ZS 407
27.			All lights are operating properly
28.			Voltages drop at switches less than 0.05 volts with light on

29.			Customer agrees with location of lights and switches
30.			Lights mounted securely and no wiring is visible (conduit extends into light housing)
Power Point			
31.			Polarity of power points correct
32.			Power points functional
Wiring			
33.			No uninsulated conductors except the earth wire.
35.			Wire size adequate for panel size and distance from battery to panel

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Wiring (*continued*)			
36.			Wire size adequate for 10 A power point: 3 m at 2.5 mm^2 or 5 m at 4 mm^2
37.			All colour coding of wires correspond to proper polarity - switch included
38.			Conduit neat and mounted properly to building inside and out
39.			No twisted wire connections
General Condition			
40.			Any wall or ceiling damaged during installation has been repaired
41.			No customer complaints about the installation process
Customer Appliances			
			TV make___________Model__________Watts or Amps________W/A Diagonal size of screen____________inches/cm Operating voltage_________
			Radio make________Model_______Watts or Amps___________W/A Operating voltage________(number of batteries times 1.5V)
			Other appliance____ Make____________Model_Watts or Amps__________________W/A Operating voltage_________ **Other appliance____** Make____________Model_Watts or Amps__________________W/A Operating voltage_________ **Other appliance____** Make____________Model___________Watts or Amps________W/A Operating voltage

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Discrepancies	
Reference No.	Comments regarding failure to comply with the Code of Practice

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Customer (Signature) ______________________________

Installer (Signature)_______________________________

Inspector (Signature)______________________________