Solar PV System Installation and Maintenance

Level-III

Learning Guide -33

Unit of Competence	Select wiring Systems and Cables for Low Voltage General Electrical Installations
Module Title	Selecting wiring Systems and Cables for Low Voltage General Electrical Installations
LG Code	EIS PIM3 M09 LO1 LG-33
TTLM Code	EIS PIM3 TTLM 0920v1

LO1:- Prepare to select wiring systems and cables for general electrical installations

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Determining the extent and nature of the electrical installation
- Identifying and understanding electrical installation safety and other regulatory requirements
- Determining cable routes & lengths
- Determining the conditions of wiring system operation

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Determine the extent and nature of the electrical installation
- Identify and understanding electrical installation safety and other regulatory requirements
- Determine cable routes & lengths
- Determine the conditions of wiring system operation

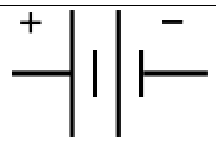
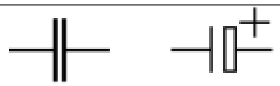
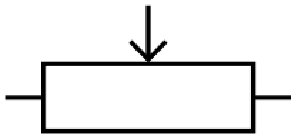
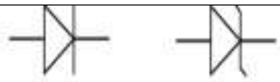
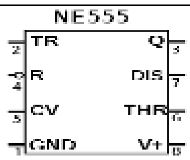
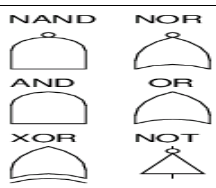
Learning Instructions:

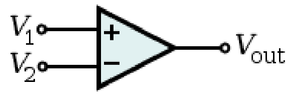
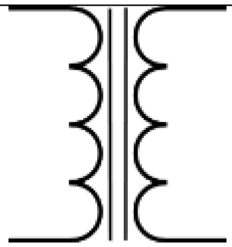
1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks

1.1 Installation of lighting fixture and outlet

A light fixture or luminary is an electrical device that contains an electric lamp that provides illumination. All light fixtures have a fixture body and one or more lamps. The lamps may be in sockets for easy replacement or in the case of some LED fixtures, hard-wired in place. Fixtures may also have a switch to control the light, either attached to the lamp body or attached to the power cable. Permanent light fixtures, such as dining room chandeliers, may have no switch on the fixture itself, but rely on a wall switch.

Table 1:Basic Electrical Symbols

Battery	✓ 
Capacitor	✓ 
Resistor	✓ 
Variable resistor(Potentiometer)	✓ 
Diode	✓ 
Inductor	✓ 
Integrated Circuit	✓ 
Logic Gates	✓ 

Operational Amplifier	✓ 
Switch	✓ 
Transformer	✓ 

Types of Electrical Wiring

We know that an electrical circuit is a closed path through which electricity flows from the phase or hot wire to the device or apparatus and then back the source though the neutral wire. Along the way, the electricity path may consist of fixtures, switches, receptacles, junction boxes, etc. So the wiring may be routed through these elements before actually making connections with apparatus or devices.

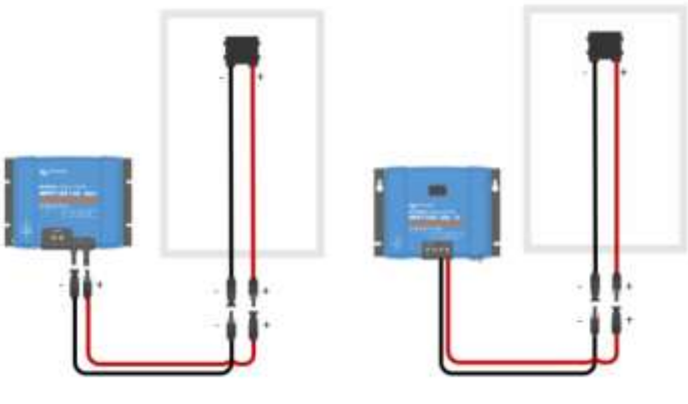


Figure 1: Solar Module wiring [Wiring-Unlimited, Victron]

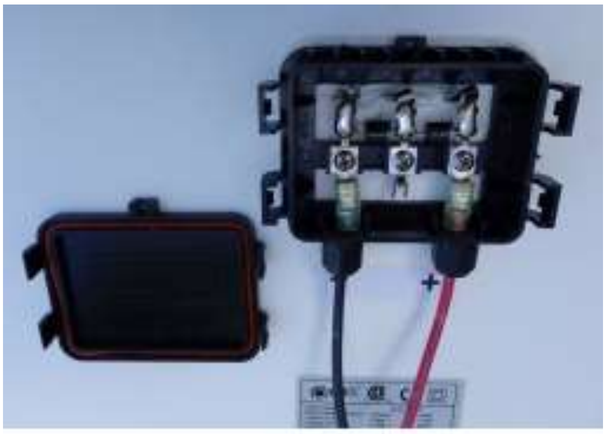


Figure 2: Solar Module wiring [Wiring-Unlimited, Victron]

Majorly, the wiring is divided into two types, namely parallel wiring and series wiring depending on the way the devices are powered or connected to the supply.

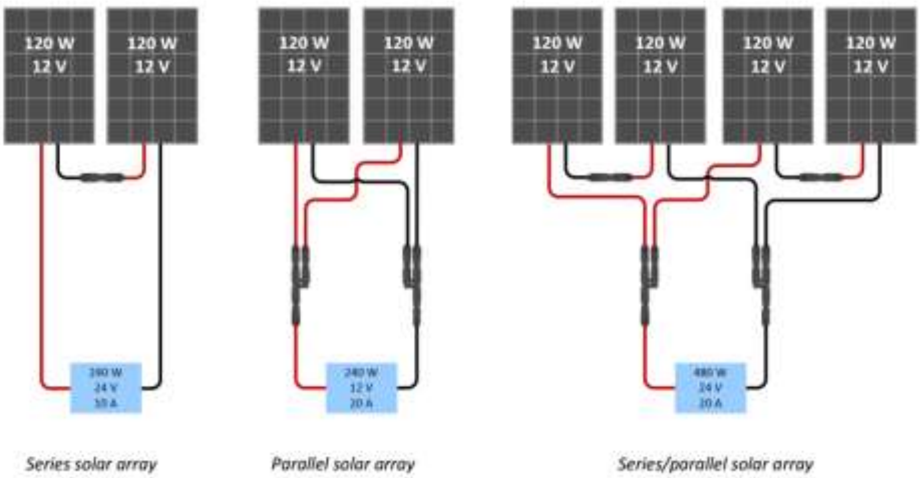
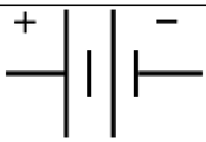


Figure 3: Solar module Connections [Wiring-Unlimited, Victron

Self-Check – 1	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	This is a symbol of Fuse. 
2	This is a symbol of Diode. 
3	Majorly, the wiring is divided into two types, namely parallel wiring and series wiring.
4	A light fixture or luminaire is an electrical device that contains an electric lamp that provides illumination.
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	1 points
Unsatisfactory	Below 1 points

Answer Sheet

Score = ___________

Rating: ____________

Name

Date

2.1 Electrical Safety

Electrical safety is a system of organizational measures and technical means to prevent harmful and dangerous effects on workers from electric current, electric arc, electromagnetic field and static electricity.

2.2 ElectricalCurrent

Basically, electrical hazards can be categorized into three types. The first and most commonly recognized hazard is electrical shock. The second type of hazard is electrical burns and the third is the effects of blasts which include pressure impact, flying particles from vaporized conductors and first breath considerations.

- Electrical Shock

  Electric shock occurs when the body becomes part of an electrical circuit. Shocks can happen in three ways:
- A person may come in contact with both conductors in a circuit.
- A person may provide a path between an ungrounded conductor and the ground.
- A person may provide a path between the ground and a conducting material that is in contact with an ungrounded conductor.

  The extent of injury accompanying electric shock depends on three factors.
- The amount of current conducted through the body.
- The path of the current through the body.
- The length of time a person is subjected to the current.
- A severe shock can stop the heart or the breathing muscles, or both.
- The heating effects of the current can cause severe burns, especially at points where the electricity enters and leaves the body. Other effects include severe bleeding, breathing difficulty, and ventricular fibrillation.

2.3 Electrical Hazards Awareness

Current is the killing factor in electrical shock. Voltage is important only in that it determines how much current will flow through a given body resistance. The current necessary to operate a 10 watt light bulb is eight to ten times more current than the amount that would kill a person. A pressure of 120 volts is enough to cause a current to flow which is many times greater than that necessary to kill.

2.4 Electrical Emergencies

Electrical accidents may occur at almost any time or place. Timely response and treatment of victims is a major concern. You must use your best judgment in an electrical emergency. When an electrical accident occurs, due to the effect of muscle clamping, a victim is often incapable of moving or releasing the electrical conductor. Attempts to rescue an accident victim may pose as great a hazard for the rescuer as it does for the victim. Caution should be a primary consideration during any electrical accident or emergency. There should always be an emergency response plan for scheduled electrical maintenance or work. A worker with an electrical injury may have any of a number of signs and symptoms.

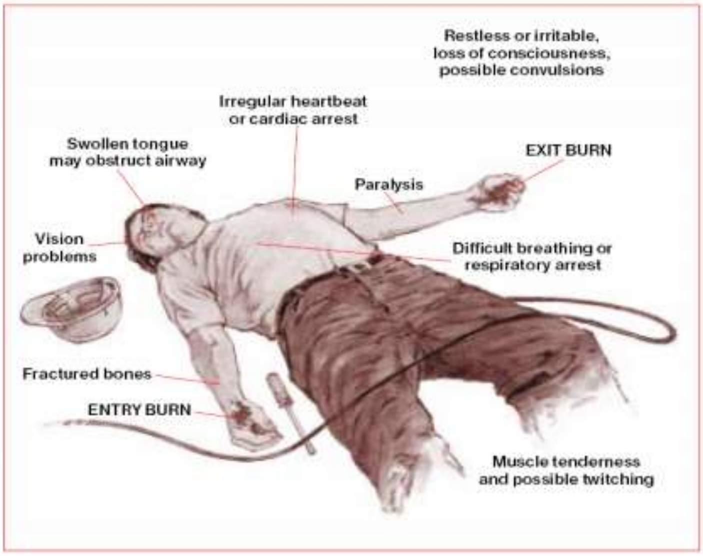


Figure 4: **Worker with an Electrical Injury**

2.5 Basic Electrical Safety Rules

An electrically safe work condition will be achieved and verified by the following process:

- Determine all possible sources of electrical supply to the specific equipment. Check applicable up to date drawings, diagrams and identification tags.
- After properly interrupting the load current, open the disconnecting device(s) for each source.
- Where it is possible, visually verify that all blades of the disconnecting devices are fully open or that draw out type circuit breakers is withdrawn to the fully disconnected position.
- Apply lockout/tag out devices in accordance with a documented and established policy.
- Use adequately rated voltage detector to test each phase conductor or circuit part to verify they are de-energized.
- Where the possibility of induced voltages or stored electrical energy exists, ground the phase conductors or circuit parts before touching them
- Electrical power tool safety
- Use the tool only for its designed purpose.
- Read the Owner's Manual and follow manufacturer's safety instructions.
- Remember electric-powered tools must have a three-wire plug with ground or be double insulated.
- Use of electric-powered tools with GFCI breakers will drastically reduce the possibility of electric shock or electrocution.
- Wear appropriate PPE.
- If an extension cord is required, make sure it is for the correct wattage and has the proper plugs.
- Verify condition of the cord and plugs and check for rated use: indoor or outdoor.
- Ensure the power switch is "OFF" before plugging or unplugging tools
- Never disconnect power by pulling on the cord – use the PLUG.
- Never carry a tool by the cord.
- Unplug the cord before making adjustments, changing/replacing parts/accessories.

- Inspect tool before each use.
- Do not use electric-powered tools in damp or wet locations
- Keep the cord away from heat, oil/chemicals, sharp edges and ensure it doesn't become a tripping hazard

Figure 5: Figure Damaged Insulation and Plug

- Safety Precautions Every Electrician Should Know
- Don't touch someone who's been electrocuted!
- Know your Electrical Code.
- Always use GFCIs in damp or wet work areas.
- Inspect & maintain your electrical tools.
- Follow proper lockout/ tag out procedures.
- Wear the right safety gear.
- Choose the right ladder.
- Avoid power lines.
- General Precautions:
- Your safety is your personal responsibility.
- Always follow the correct procedures.
- Never take shortcuts.
- Take responsibility and clean up if you made a mess.
- Clean and organize your workspace.
- Ensure a clear and easy route to emergency exits and equipment.
- Be alert and awake on the job.

Self-Check - 2	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Electrical workers are frequently in close proximity to energized parts where power arcs can occur
	True or false:
2	Current is the killing factor in electrical shock.
	True or false:
3	Electrical safety is a system of organizational measures and technical means to prevent harmful and dangerous effects on workers
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	3 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = ____________

Rating: _____________

Name

Date

3.1 Determining cable routes & lengths

The reason for the loss of pressure is that the small pipe has too high a resistance and a lot of the pressure is used up just keeping the water flowing in the pipe.

In an electrical system, if the wires are too small, voltage is lost and appliances may not be able to get enough electricity to work properly. The reason for the loss of voltage is that the wires have too high a resistance and a lot of the voltage is used up just keeping the electricity moving in the wire.

The entire Photovoltaic system should be diagrammed before installation. This should include the wiring of modules in the array or sub-arrays, controllers, AC and DC load centres, batteries, inverter, grounding and circuit protection. The wiring process is the time to consider safety features such as fuses, circuit breakers, Ground fault interrupters and grounding rods and wires. Also efficiency and cost concern will affect many specific choices, such as the sizes and types of wires to use. [GSES/2014/ Chapter 11]

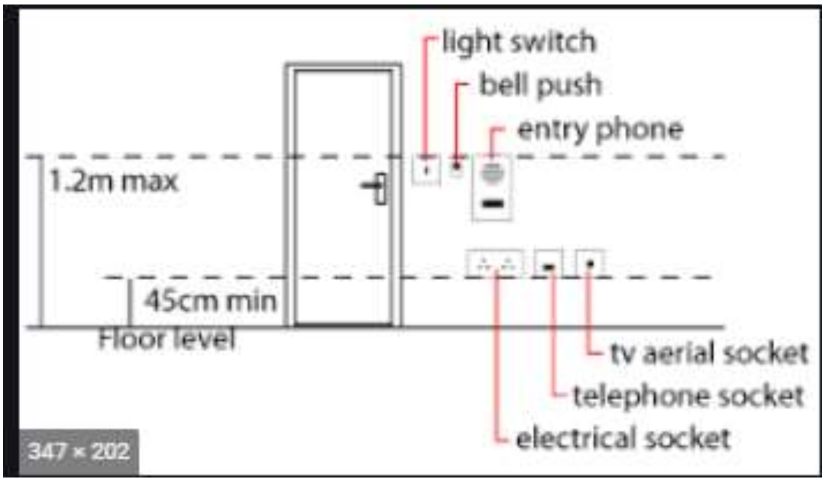


Figure 6: Cable routes diagram

3.2 Wiring Rule [(Dobelmann & Klauss-Vorreiter, 2009)]

- Never put in wires that are longer than are absolutely needed.
- The maximum voltage drop for 12 Volt solar system wiring should not exceed 0.5 Volts. For a 24 V system, it should not exceed 1.0 Volts. The three things which determine the loss of voltage in a wire are:
- the amount of electricity which flows in the wire

- the wire size (in mm2)
- the wire length (in meters)
- Always use the right kind of wire for the job. Buried wire must have underground rated insulation. Wire exposed to sunlight must have exterior grade insulation. Wire with interior grade insulation should not be buried nor exposed to the sun for long periods.

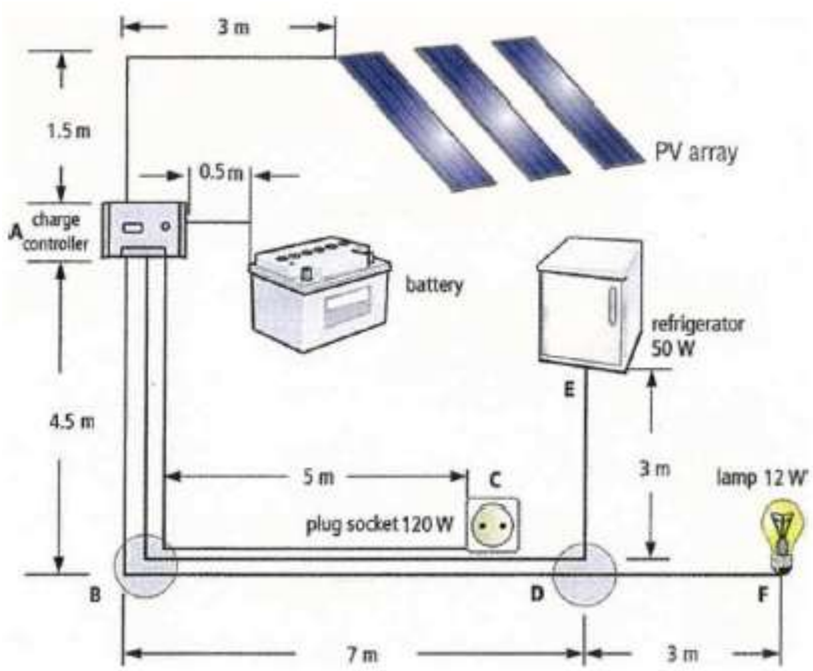


Figure 7: Wire length. [(Dobelmann & Klauss-Vorreiter, 2009)]

More electrical pressure (Volts) must be present to force a certain current (Amperes) through a long wire than a short one of the same size. To get this increased voltage, more batteries and panels must be installed at extra cost. To save cost, wires should be kept as short as possible. Short wires save both on wire cost and by lowered power loss.

3.3 Voltage drops from wiring

The reason for the power loss in wire is its resistance (Ohms). It takes force (Volts) to push electricity through the wire and the more resistance the wire has, the more force must be used. The amount of Voltage necessary to push the electricity through a wire is called the voltage drop of the wire.

Table 2: Colour identification of cores of flexible cables and cords

Number of cores	Function of core	Colours of core	Colour
1	Phase	Brown	
	Neutral	Blue	
	Protective	Green & yellow	
2	Phase	Brown	
	Neutral	Blue	
3	Phase	Brown	
	Neutral	Blue	
	Protective	Green & yellow	
4 or 5	Phase	Brown or black	 
	Neutral	Blue	
	Protective	Green & yellow	

Self-Check - 3	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

A)

N°	Questions and answers
1	A common reason for poor performance of solar systems is wire that is too small**.**
	True or false:
2	The smaller the wire, the more electrical pressure (voltage) must be available to force a certain current through the wire
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = ___________

Rating: ____________

Name

Date

Information Sheet 4	Determining the conditions of wiring system operation

3.1 Electrical wiring

Electrical wiring is an electrical installation of cabling and associated devices such as switches, distribution boards, sockets, and light fittings in a structure. Electrical wiring is the electrical power distribution through the wires in a perfect manner for economic use of wiring conductors inside a room or building with better load control.

Wiring is subject to safety standards for design and installation. Allowable wire and cable types and sizes are specified according to the circuit operating.

- Determining conductor size
- Typically amp city and sizing is determined by the designer and provided on the plans
- De-rating of conductors may need to be determined if the cable routing is revised by field personnel or final job layout
- De-rating process is documented in the NEC. Generally requires a review of installation conditions and cable rating.
- Conductor insulation and jacket types
- Insulation and Jacketing identified in Standard Specifications
- XLP or XLPE (Cross linked Polyethylene) –moisture resistant, flexible, use in wet environments (pull boxes and conduits)
- THHN or THHW (Thermoplastic High Heat resistant Nylon, Heat and Water resistant Nylon) –Suitable for dry or wet locations, high thermal stability, high strength.
- PVC (Poly-Vinyl Chloride) –Low heat resistance, not resistant to sunlight, Not appropriate for wet locations, low flexibility. Rated for Wet location in accordance with NEC 310.104(A)

Self-Check - 4	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Electrical wiring is an electrical installation of cabling and associated devices
	True or false:
2	Electrical wiring is the electrical power distribution through the wires in a perfect manner for economic use of wiring conductors
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = ____________

Rating: _____________

Name

Date

Solar PV System Installation and Maintenance

Level-III

Learning Guide -34

Unit of Competence	Select wiring Systems and Cables for Low Voltage General Electrical Installations
Module Title	Selecting wiring Systems and Cables for Low Voltage General Electrical Installations
LG Code	EIS PIM3 M09 LO2 LG-34
TTLM Code	EIS PIM3 TTLM 0920v1

LO 2:- Select wiring systems and cables for general electrical system

Instruction Sheet	Learning Guide:-34

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Selecting wiring systems for suitable environment.
- Selecting cable conductor sizes
- Selecting circuit protective devices
- Selecting earthling system components
- Obtaining evidence that selected electrical equipment fulfil safety

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Select wiring systems for suitable environment.
- Select cable conductor sizes
- Select circuit protective devices
- Select earthling system components
- Obtain evidence that selected electrical equipment fulfil safety

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks

1.1 Types of wiring systems: (Stokes & Bradley, 2009)

- Conduit, trunking and bus bar systems
- Cables

1.2 Important considerations in selection of wiring systems

1.2.1 External influences

- Temperature
  - ✓ Ambient temperature
  - ✓ Heat Sources
- Water
  - ✓ High humidity
- Sold bodies
  - ✓ Solid foreign bodies including dust
- Corrosion
  - ✓ Corrosive and polluting substances
- Mechanical impact/ Mechanical Stress

Self-Check – 1	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Corrosion is an internal influence
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	1 points
Unsatisfactory	Below 1 points

Answer Sheet

Score = ___________

Rating: ____________

Name

Date

2.1 Selection of cable[(GSES, 2014)/chapter11]

Cable Selection

Cables can be solid or stranded. Normally, DC currents in Photovoltaic systems are higher than typical AC situation and therefore wire size must be larger. Photovoltaic installers often use stranded wires. Solid wire become stiff and difficult to work with in large sizes. As per IEC 62548: Design requirements for Photovoltaic (PV) arrays, cables used within the PV array shall:

- Be suitable for DC application
- Have a voltage rating equal to or greater than the PV array maximum voltage
- Have a temperature rating according to the application
- If exposed to the environment, be UV- resistant, or be protected from UV light by appropriate protection, or be installed in UV-resistant conduit,
- Be water resistant
- Cables shall be flame retardant as defined in IEC 60332-1-2.

Cable sizing

There are two major considerations in sizing cable for a photovoltaic system

- Ampacity and
- Voltage drop

Ampacity is the current carrying capacity of the wire, or its ability to carry current safely without overheating. Ampacity is based upon a wire's size or cross sectional area, the type of materials it is constructed of (e.g. copper, thermoplastic insulation), its length, and its temperature. Voltage drop in a wire is a function of three parameters

- Conductor cross sectional area (mm2),
- Length of wire and
- Current flow in the wire.

Voltage drop in a cable, which is the loss of voltage due to the wire's resistance, results in power losses in the cable. The greater the length of the wire, the greater its resistance to current flow.

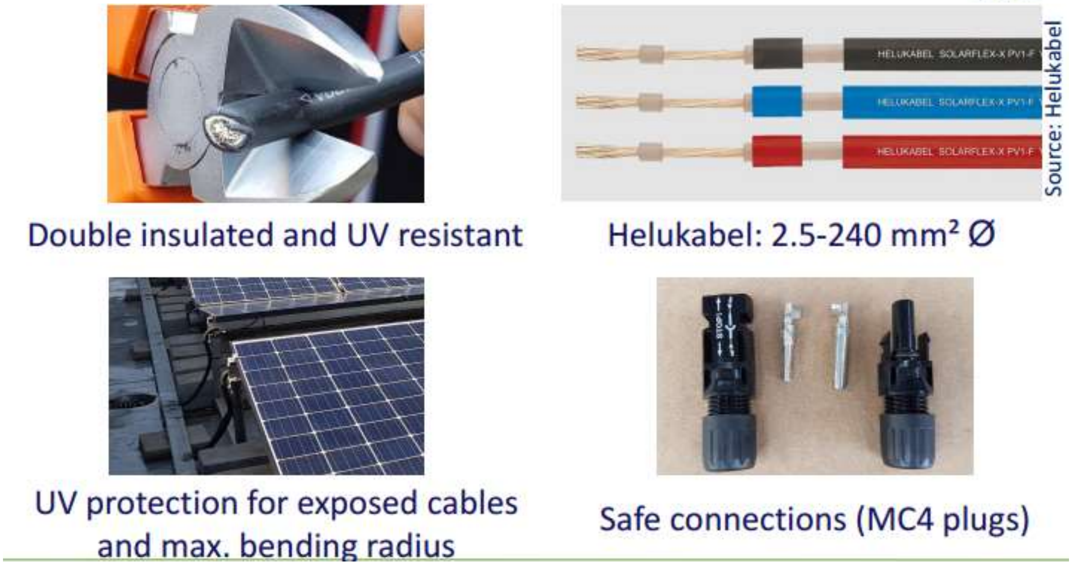


Figure 8: Selecting cable conductor sizes[DGS]

$$A = \frac{L \cdot P}{LF \cdot V^2 \cdot \kappa}$$

A	= cross section of cable
L	= length of cable (conductor positive and negative)
	= one way length x 2
P	= Power of the cable
LF	= loss factor (0.5%-3%)
V	= system voltage
κ	= Kappa – electric conductivity

$K_{Cu} = 56\ m / \Omega \cdot mm^2$

$K_{Alu} = 34\ m / \Omega \cdot mm^2$

Figure 9: Cable dimensioning [(Dobelmann & Klauss-Vorreiter, 2009)]

- Cable size ratings in Amps

Table3Cable size in Ampere rating

Cable size	Rating in Amps
1mm	8
1.5mm	10
2.5mm	13.5
4.00mm	17.5
6.00mm	23.5
10.00mm	32

- Current-Carrying Capacity

  How do you calculate current carrying capacity of a cable?

  - For Cu Wire Current Capacity (Up to 30 Sq.mm) = 6X Size of Wire in Sq.mm. Ex.
  - For Cable Current Capacity = 4X Size of Cable in Sq.mm, Ex. For 2.5 Sq.mm = 4×2.5 = 9 Amp.
  - Nomenclature for cable Rating = Uo /U.
  - Where Uo = Phase-Ground Voltage, U = Phase-Phase Voltage, Um = Highest Permissible Voltage.
  - Earth Fault-loop impedence

Earth fault loop impedance is the path followed by fault current when a low impedance fault occurs between the phase conductor and earth, i.e. “earth fault loop”. Fault current is driven round the loop by the supply voltage. The higher the impedance, the lower the fault current will be and the longer it will take for the circuit protection to operate. So in short it is the impedance of the earth fault current loop

Self-Check –2	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Cables can be Solid or Stranded
	True or false:
2	Ampacity is the current carrying capacity of the wire, or its ability to carry current safely without overheating
3	The greater the length of the wire, the greater its resistance to current flow.

Note: the satisfactory rating is as followed

Satisfactory	1 points
Unsatisfactory	Below 1 points

Answer Sheet

Score = ___________

Rating: ____________

Name

Date

3.1 Introductions

The circuit protection device is an electrical device used for preventing an unnecessary amount of current otherwise a short circuit. To ensure the highest security, there are many protection devices available in the market which offers you a total range of protection devices for circuits such as a circuit breakers. Protection devices for electrical circuits undertake two main utilities such as consistency and protection. In this, Protection is assured via detaching power supply, and it is the over current protection. To point out, various protection devices act as a protection agent and prevent us from many electrical damages. Generally, these devices remove fire hazards and electrocution.

Protection devices are useful for the protection of circuits. Usually, this protection is from extreme voltage or current. To mention, circuit protections are the electrical device that prevents the devices from the flow of unnecessary currents as well as the short currents.

Glass or ceramic fuses	Fuse	Holders
Wire fuse Up to approximately 60A Up to 250V AC or DC Fast or slow		

Blade type (automotive)	Fuse	Holder
Wire fuse Up to 120A 32 V DC Slow		

Midi	Fuse	Holder
Wire fuse 23 – 200A 32 Vdc Slow		

Cooper Bussmann MRBF	Fuse	Holder
Wire fuse 30 – 300A 58 Vdc Marine rated Can mount straight on positive busbar		

CNN fuse	Fuse	Holder
Wire fuse 10 – 800 A 48 Vdc, 125 Vac Fast		

Mega fuse	Fuse	Holder
Wire fuse 40 - 500A 32 Vdc Slow		

ANL fuse	Fuse	Holder
Wire fuse 35 – 750 A 32V dc Fast		

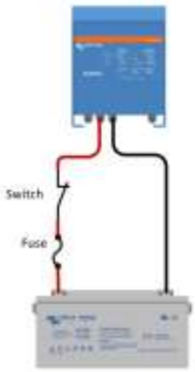
NH fuse	Fuse	Holder
Wire fuse Up to 1000A 500 - 690 Vac 440 - 550 Vdc Multiple speeds available		 Fuse Base Disconnect Switch

Circuit breaker (CB or MCB)	Fuse	Holder
AC or DC A variety of current ratings A variety of voltages A variety of speeds Mounts on DIN rail		

Figure 10: Over view of fuse types [Wiring-unlimited]

Battery Isolation switch

A battery isolation switch can be used to isolate the battery(or battery bank) from the rest of the electrical circuit. Or it can be used to isolate a DC source or DC consumer from an electrical circuit.



Types of isolator switches

- Battery Isolator switch for mobile systems (Usually 12 and 24 V)
- DIN mounted circuit breakers, for land based systems for battery and PV (usually 48V and up)

- NH fuse holder switch for high current land-based systems for battery and PV (usually 48 V and up)

Battery Isolator switch

High current DC MCB

NH fuse holders can be used as circuit breaker

Shunt

A shunt is added to a system to measure current flow. This is needed for system monitoring or to calculate battery state of charge. A shunt is a resistive element. When current passes through is a small voltage drop will occur over the shunt. If the current is small the voltage will be low, and if the current is large the voltage will be higher. If the current flow reverses, the voltage drop will change polarity. The voltage of the shunt is an indication of the amount of current and the direction of the current.

The shunt is typically located in the negative cable. The negative is chosen because that is safer.

Figure 11: Shunt

Short circuit protection is protection against excessive currents or current beyond the acceptable current rating of equipment and it operates instantly. As soon as an over current is detected, the device trips and breaks the circuit

A short circuit is when there is a low resistance connection between two conductors that are supplying electrical power to a circuit. This would generate an excess of voltage streaming and cause excessive flow of current in the power source. The electricity will flow through a 'short' route and cause a short circuit.

- **Circuit Breaker**

A circuit breaker is one kind of electrical switch used to guard an electrical circuit against short circuit otherwise an overload which will cause by excess current supply. The basic function of a circuit breaker is to stop the flow of current once a fault has occurred. Not like a fuse, a circuit breaker can be operated either automatically or manually to restart regular operation

- **DC circuit breaker**

DC circuit breaker, like their name suggests, is used for the protection of electrical devices that operate with direct current. The main difference between direct current and alternating current is that in DC the voltage output is constant, while in AC it cycles several times per second.

Figure 12: DC circuit breaker

- **AC circuit breaker**

AC circuit breaker Is a safety switch that protects our equipment from damage by turning off the power when an overload is detected It also protects our safety since overloaded circuit scan result in a fire.

Figure 13: AC Circuit Breaker

- **Fuse**

Among the all other protection devices of electrical circuit fuse has its unique purposes. It protects the current from over current through its metal strip which is to liquefy the current when the flow is high. Nowadays, various categories are useful in various applications such as response time, breaking capacity, current ratings, and specific voltage. Hence, it is one of the vital things that are useful as protection devices. In electrical circuits, **a fuse** is an electrical device used to protect the circuit from over current. It consists of a metal strip that liquefies when the flow of current through it is high.

The fuses are classified into several types based on the application namely **AC type fuse** and **DC type fuse**. Again these fuses are classified into several types. The following diagram illustrates the electrical fuse types chart based on the AC fuse and DC fuse

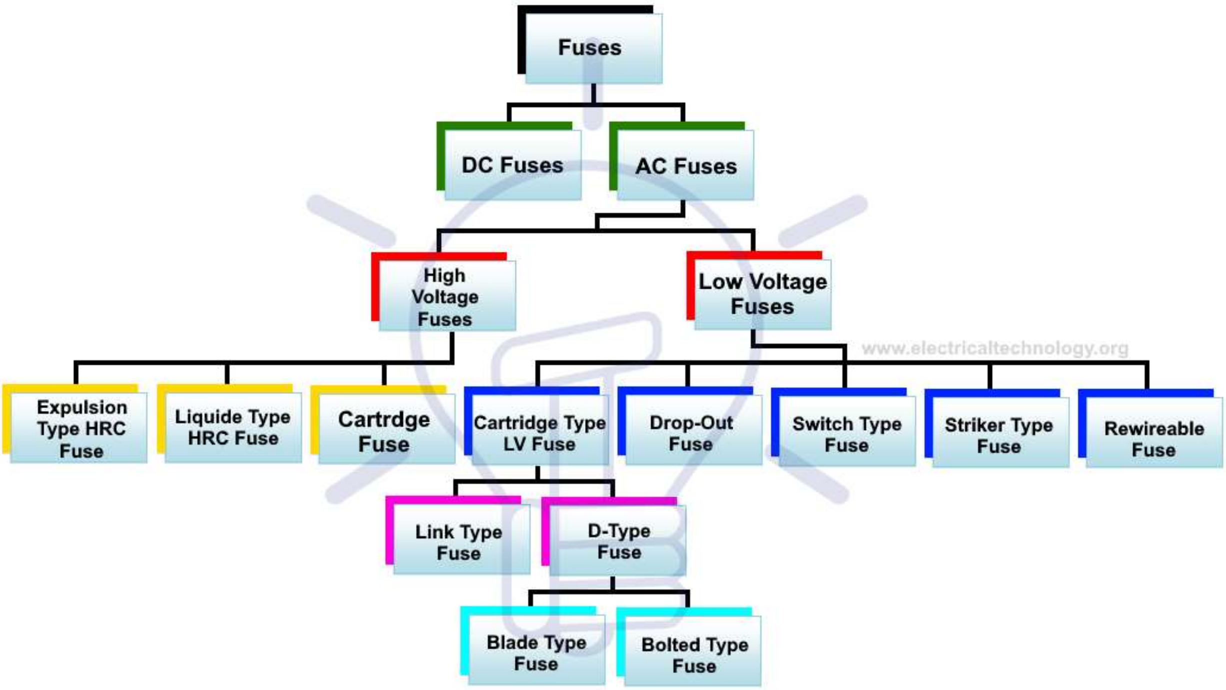


Figure 14: Fuse Selection Chart(https://www.electricaltechnology.org/)

Self-Check –3	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Fuse is a current interrupting device which breaks or opens the circuit by fusing the element when the current in the circuit exceeds a certain value.
	True or false:
2	AC circuit breaker is a safety switch that protects our equipment from damage by turning off the power
	True or false:

Note: the satisfactory rating is as followed

Satisfactory	2 points
Unsatisfactory	Below 2 points

Answer Sheet

Score = ___________

Rating: ____________

Name

Date

3.1 System Earthing [(GSES, 2014)]

A ground is the electrical connection made between one side of an electrical circuit and the ground or earth. This provides a low resistance path for current flow that in many cases will prevent shock-for certain types of accidents and equipment failures. The two types of grounding in any circuit

- The system ground
- The equipment ground

The System Ground is where one leg of a circuit is grounded. In the case of an AC circuit, this is the neutral leg. In the case of a PV DC circuit, it is usually the negative leg. By grounding the overall system, current surges from lighting and distribution accidents are shunted to the earth, thus protecting people and equipment from electric shock and damage.

Earth or **ground** is the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the earth. In an electrical installation, an **earthing system** or **grounding system** connects specific parts of that installation with the Earth's conductive surface for safety and functional purposes. The common electrode used for Earthing is copper, which is used for grounding.

- **Grounding details**
  - ✓ System and equipment grounding conductors share the same electrode
  - ✓ There should be only one single point where the system ground and the equipment ground are bonded together
  - ✓ DC and AC sub system should share the same electrode
  - ✓ Equipment grounding wire should have the same ampacity as the over current device protecting the particular circuit
  - ✓ For lightening protection at the array, use system of grounding electrodes bonded together

- **Grounding Electrode**
  - ✓ Grounding electrode conductor needs to be as large as the largest conductor in the system and be at least $10mm^2$. (Cross section area).
  - ✓ If the solar array will be at a great distance away from the central ground rod for the system, a separate ground rod for the array structure can be driven close to the array. However there should be a bonding wire keeps both ground rods at the same voltage potential. If the two rods were not connected, a nearby lightening strike would result in a momentary surge of current in to the earth that would cause large differences in ground potential due to the resistance of the earth. The two ground rods would not both be a ‘’zero’ potential, and large induced currents will be created in the ground system. By having the wire connecting the two rods, the resistance of the earth is overcome, and the two rods stay at same potential and induced currents result.

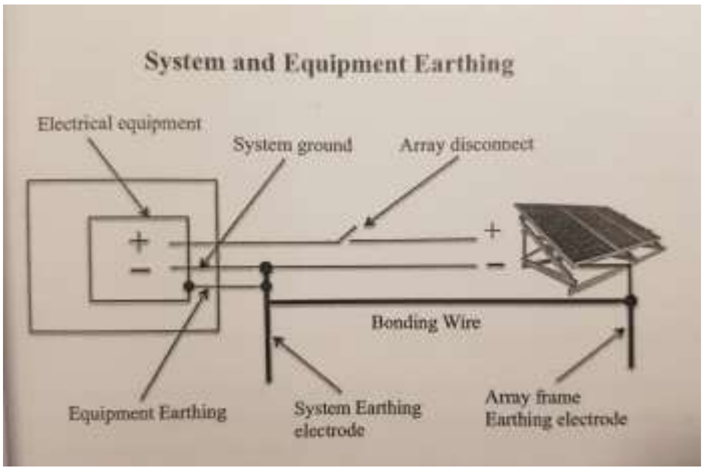


Figure 15: System and Equipment Earthing for Photovoltaic System [(GSES, 2014)]

- **Types of Grounding**
  - ✓ **EARTH**, is a direct physical Connection to the earth. This is usually done by driving a copper rod (earth stake) in to the ground. But, depend on age and location of the system this can also be a copper plate or copper strip buried in the ground, or the water mains or water pipes in the house.

- ✓ **Chassis** earth is a connection to a metal frame such as that of a vehicle or the metal hull of a boat. It can also be the metal case of electrical equipment.

✓ **Ground** is a common reference point in a circuit to which voltages are measured. As a result, a voltage may be above ground (positive) or below ground (negative)

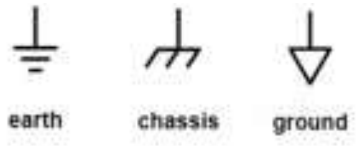


Figure 16: Grounding electrode

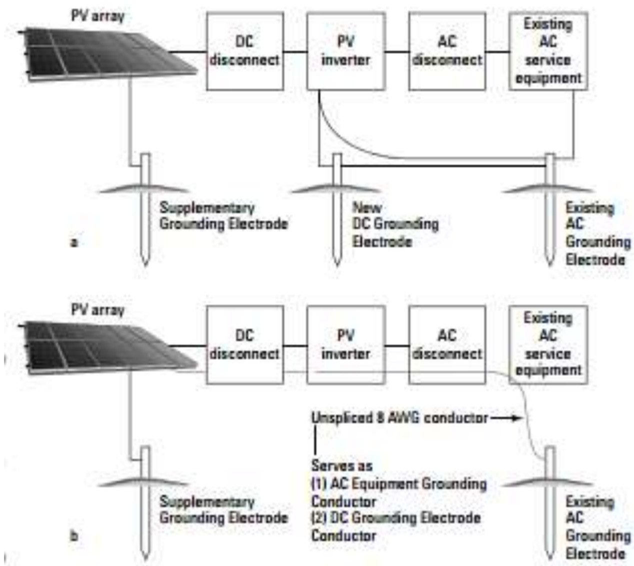


Figure 17: System Grounding options[Ryan/2010]

- **Materials required for earthing**.
- Meggar for Earth resistivity testing.

- Welding toolkit.
- Excavator for earth pit excavation.
- Copper wire or strip.
- GI or Copper plate.
- Pipe/Rod.
- Coke/Charcoal and Salt.
- PVC Wires.

Self-Check –4	Written Test

Instruction: Follow the below selected instruction

Say true if the statement is correct say false if the statement is wrong

N°	Questions and answers
1	EARTH, is a direct physical Connection to the earth.
2	Ground is a common reference point in a circuit to which voltages are measured.
3	Chassis earth is a connection to a metal frame such as that of a vehicle

Note: the satisfactory rating is as followed

Satisfactory	6 points
Unsatisfactory	Below 12 points

Answer Sheet

Score = ___________

Rating: ____________

Name Date

Information Sheet 5	Obtaining evidence that selected electrical equipment fulfil safety

5.1 Top five keys to workplace electrical

Electrical professionals can make their workplace safer by following safety regulations, establishing a safety program, and understanding electrical hazards. Electrical hazards, specifically shock, arc flash, and arc blast, can result in serious injury or death to electrical workers. Work environments that create the potential for these events put everyone, including owners, at risk. However, many of these individuals fail to recognize these risks, thanks to several incorrect and dangerous beliefs that are ingrained in the electrical industry culture. Electricians may think that an electrical-related accident or injury can't happen to them, or even worse, accept that the risks are just part of the job. When taken with many employers' insistence that work be done hot, this belief creates the potential for serious injury. In fact, these ideals will often persist until a major electrical incident occurs and the personal and financial repercussions spur a change in policy.

Effecting change in the electrical safety culture doesn't have to be a reactive process, though. Minimizing hazards like shock, arc flash, and arc blast is necessary for providing an electrically safe work environment. And the process of achieving this goal begins with the implementation and practice of five key electrical safety principles.

5.1.1 Electrical safety regulations and standards

The first key to electrical safety is to understand and follow safety regulations and standards is the "law of the land" for electrical safety regulations.

NFPA 70E-2000 "Standard for Electrical Safety Requirements for Employee Workplaces" has similar requirements. One difference, however, is that it uses the phrase "electrically safe work condition" instead of "de-energized." It defines an electrically safe work condition as a state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary. Part II 2-1.1.3 of the standard details the process for achieving an electrically safe work condition.

5.1.2 Electrical safety program

The second key electrical safety principle is to establish and follow an electrical safety program, which is the employer's responsibility. The electrical safety program must be well thought-out, documented, and most importantly, put into practice. To develop an effective electrical safety program, all levels of personnel at a company or facility must be involved and committed to the program. An essential part of any electrical safety program is training. NFPA 70E-2000 details other important requirements for an electrical safety program in Part II 2-3, including the following:

- Awareness of electrical hazards and self-discipline of employees.
- Identification of hazard/risk evaluation procedures.
- Identification of electrically safe work procedures, tools, and personal protective equipment.
- Identification of electrical safety principals, one of which is safety by design.

5.1.3 Electrical hazards

Understanding and identifying shock, arc flash, and arc blast is the third key electrical safety principle. Of these, electrical shock is the most common and well known. However, few are aware of the hazards presented by an electrical arcing fault and the resulting arc flash and arc blast. An arc fault is initiated by current passing between two conducting metals through ionized gas or vapour caused by a flashover or other conductive material, such as a screwdriver. When an arc fault occurs, it produces an explosion with a significant amount of destructive energy.

5.1.4 Safety by design

The final electrical safety principal is to increase electrical safety by design. One of the design considerations for electrical safety is to isolate the circuit. The use of isolation equipment to support preventive maintenance and repair for proper implementation of lockout/tag out procedures is an essential provision for electrical safety. The key electrical safety principles focus on the protection of owners, employers, and employees. To ensure a safer workplace, electrical professionals must change their existing cultures, beliefs and practices and follow electrical safety standards and regulations.

5.1.5 Electrical Safety: Tips to Prevent Workplace Electrical Injuries

Every workplace today operates on electricity, so workplace electrical injuries are a real threat in any location. All electrical systems used in offices have the potential to cause serious harm, especially if improperly used or maintained.

Humans are good conductors of electricity. This means if the open electric circuit comes in contact with our body, we'll get a shock. The electric current will pass through our body from one point to another causing great pain, burns, damage to the tissues, nerves and muscles. This could even lead to death.

5.2 Types of Workplace Electrical Injuries

The four types of injuries that can occur due to electricity are:

- Electric shock
- Burns
- Falls
- Electrocution

5.3 How Injuries Can Happen

- Direct contact with exposed electrical circuits or energized conductors.
- Electricity arcs (due to exposed energized conductors or circuit) circulating in the air can pass through a person who is grounded.
- If the skin gets in touch with the heat generated from electric arcs, it burns the internal tissues.
- The light emitted from an electric arc flash (UV and IR) can cause damage to the eyes.
- When the potential pressure is released from an arc flash, there is an arc blast, which can collapse your lungs, cause physical injuries, or create noise that can damage hearing.

5.4 Common Electrical Hazards

Most injuries are a result of the following:

- Poorly installed, faulty and/or ill-maintained electrical equipment.
- Faulty wiring.
- Overloaded or overheated outlets.
- Use of flexible leads and extension cables.
- Incorrect use of replacement fuses.
- Use of electrical equipment with wet hands or near the source of water.

Self-Check –5	Written Test

Instruction: Follow the below selected instruction

Say true or false

1	The final electrical safety principal is to increase electrical safety by design
2	Electrical Safety is tips to Prevent Workplace Electrical Injuries
3	Most injuries are a result of faulty wiring.

Note: the satisfactory rating is as followed

Satisfactory	6 points
Unsatisfactory	Below 3 points

Answer Sheet

Score = ___________

Rating: ____________

Name Date

Solar PV System Installation and Maintenance

Level-III

Learning Guide -35

Unit of Competence	**Select wiring Systems and Cables for Low Voltage General Electrical Installations**
Module Title	**Selecting wiring Systems and Cables for Low Voltage General Electrical Installations**
LG Code	**EIS PIM3 M09 LO3 LG-35**
TTLM Code	**EIS PIM3 TTLM 0920v1**

LO3:-Document electrical installation

Instruction Sheet	Learning Guide:-35

This learning guide is developed to provide you the necessary information, knowledge, skills and attitude regarding the following content coverage and topics:

- Obtaining safety requirement evidence for electrical equipment form manufacturers /suppliers
- Clarifying and documenting reasons for selection
- Documenting electrical installation arrangement and specifications

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Obtain safety requirement evidence for electrical equipment form manufacturers /suppliers
- Clarify and documenting reasons for selection
- Document electrical installation arrangement and specifications

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the information Sheets
4. Accomplish the Self-checks

Information Sheet 1	Obtaining safety requirement evidence for electrical equipment from manufacturers /suppliers

3.1 Obtaining safety requirement evidence for electrical equipment from manufacturers /suppliers

Manufacturers always provide safety requirement on their products on how to install them, use, trouble shoot and maintain them. Installers should follow safety rules and instructions. Installers should handover all the installation, user and product manual to the user for future after sales services. The below instruction is from Victron Energy company safety requirement and instruction for their products. Such documents should be kept In a safe place where technicians can find it easily at the time of maintenance or system check up time.

victron energy

MATERIAL SAFETY DATA SHEET
Lithium-Ion HE Batteries

MSDS CREATION DATE: 06 March 2017
MSDS REV DATE: 31 October 2018

SECTION 1: PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: Lithium HE battery 24V/100Ah
Lithium HE battery 24V/100Ah
Lithium HE battery 24V/200Ah
PRODUCT CODES: BAT524110300, BAT524115300, BAT524120300
COMPANY NAME: Victron Energy
ADDRESS: De Paal 35
1351 JG Almere
CONTACT: Reinout Vader
PHONE: +31 (0)36 535 9700
CHEMICAL NAME: Lithium Nickel Manganese Cobalt Oxide (NMC)
CHEMICAL FAMILY: Lithium Ion
CHEMICAL FORMULA: $LiNiMnCoO_3$
PRODUCT USE: Electrical

SECTION 2: COMPOSITION/INFORMATION ON INGREDIENTS

Component	Chemical name	CAS No.
Cathode	nickel-manganese-cobalt	207803-51-8
Anode	Graphite	7782-42-5
Electrolyte	Ethyl acetate	141-78-6
	Ethylene carbonate	96-49-1
	Dimethyl carbonate	616-38-6
	Lithium hexafluorophosphate	21324-40-3
Binder	Polyvinylidene difluoride	24937-79-9

Figure 18: sample safety instruction [Victron Energy]

https://www.victronenergy.com/upload/documents/MSDS-Lithium-HE-Batteries-EN.pdf

OPERATING INSTRUCTIONS for stationary vented lead-acid OPzS SOLAR batteries

victron energy
BLUE POWER

Bat. Type:	
Assembled by:	
Date:	
Start-up by:	
Date:	

Observe operating instructions and affix close within sight of the battery! Work on batteries only under instructions of skilled personel!

Smoking prohibited! Do not expose battery to open fame, glowing fire or sparks as explosion and fire hazard exists!

When working on batteries wear protective glasses and clothing!

Explosion and fire hazard! Avoid short circuits! Caution! Metal parts of the battery cells are always live, therefore do not place items or tools on the battery!

Electrolyte is strongly corrosive!

Monoblock batteries / cells are very heavy! Ensure secure installation! Only use suitable transport equipment!

Dangerous voltage!

Acid splashes in the eyes or on the skin must be washed out or off with plenty of water. Then see a doctor immediately. Acid on clothing should be washed out with water!

Safety requirements according to EN 50272-3

Non-compliance with operating instructions, repairs made with other than original parts, use of additives for the electrolyte (alleged "enhancing agents") render the warranty null and void.

1. Commissioning

a) Filled and charged batteries
Before commissioning all blocks must be inspected for mechanical damage, cells must be connected with the correct polarity and connectors firmly seated. The following torque apply for M10 screw connectors is:

20 ± 1 Nm

If necessary the terminal covers must be put on. Check the electrolyte level in all cells. If necessary top up to maximum level with purified water as under DIN 43530 Part 4. Before putting the battery in operation, plastic transport vent caps must be removed and replaced with ceramic cell plugs.
With charger off and loads isolated connect battery to the direct current power supplies maintaining correct polarity (positive terminal to positive post).
Switch on the charger and charge as under section 2.2.

b) Dry charged (DC) batteries
Instructions for the initial charging of a dry charged stationary OPzS and SOLAR (TOPzS) batteries:

- Unscrew the sealed vent plugs and fill the cells with pure dilute sulphuric acid, specific gravity 1,230 0,01kg/1 read at 20 (68 F), up to about 25 mm below top of lid for SPgBG multi-block hard rubber containers and 50 mm below of lid for OPzS translucent containers or max level marked on the label. The temperature of the filling acid should be between 10°C and 25°C (50 - 77 F).
- Insert the original plastic vent plug with Removed sealing foil on the top or place the special ceramic vent plug.
- Start charging for not less than 2 and not more than 12 hours elapsed after the last cell has been filled with the acid.
- Apply the 0,5 x 110(5A/100Ah) current.
- Charge for 8 hours and then keep the battery on open circuit for 1-2 hours.
- Continue the charging for a few hours, until the battery is fully charged, i.e. until constant voltage and constant specific gravity have been reached. The specific gravity of the acid in a fully charged cell is 1,240 0,01 kg/l read at 20°C (68 F). If during the charging the temperature of the acid exceeds 55°C (131 F) reduce the charging current by 50%.
- 0,5 h after charging discharge the battery at 10 hour rate of current until the cell voltage drops to average value 1.80 Volts. Allowable minimum voltage of a single cell is 1,70V.
- Recharge the battery according to the operating instructions 2.2.
- 24 hours after recharging adjust electrolyte level to the "max" mark on the label.
  Activation and test results must be kept as part of battery documentation. Non-compliance with this request renders the warranty null and void.

2. Operation

For the operation of stationary battery, installations EN 50272-2 apply

2.1 Discharging

Never allow the final discharge voltage of the battery to drop below that assigned for the discharge current. Charge immediately after discharge as well as partial discharge. Recommended DOD (Depth Of Discharge) for normal operating is up to 80% of CN.

2.2 Charging

All charging procedures with their limit values may be employed as stated below:
DIN 41773 (IU characteristic)
DIN 41774 (W characteristic)
DIN 41776 (I characteristic).
Depending on charger type and charging characteristic alternating currents flow through the battery superimposing onto the direct current. These alternating currents and the reaction of the loads lead to an additional warming of the battery and strain on the electrodes with possible resulting damage (see 2.5).
Depending on the system at hand, charging may be carried out under the following modes:

a) Stand-by parallel operation and floating operation.
Here the load, direct current and battery are continuously connected in parallel. There by the charging voltage is at the same time the operating voltage of the system. With stand-by-parallel operation the direct current is at any time capable of supplying the maximum load current and the battery charging current. The battery only supplies current when the direct current source fails. The charge volt age should be set at 2,23 V +/-1% x number of cells measured at the battery's terminals. To reduce the recharging time a charging stage can be applied in which the charging voltage is 2,35 to 2,4 V x number of cells (stand-by parallel operation with recharging stage). Automatic changeover to the charging voltage of 2,23 V+/- 1% x number of cells follows after few hours on the voltage 2,35-2,4 V x number of cells. With the floating operation the direct current source is not able to supply the maximum load current at all times.
The load current intermit tently supersedes the nominal current of the direct current source. During this period the battery supplies power. It is not fully charged at all times. Therefore, depending on the load the charge voltage must be set at 2.23 to 2.30 V x number of cells.

b) Switch mode operation
When charging the battery is separated from the load. Towards the end of the charging process the charge voltage of the battery is 2,6 - 2,75 V/cell. The charging process and parameters must be monitored (see Sections 2.4, 2.5 and 2.6).

On reaching a fully charged state the charging process must be stopped or switched to float charge as under Section 2.3.

Link:https://www.victronenergy.com/upload/documents/Manual-Stationary-batteries-EN.pdf

3.2 Testing instruments

The following items are used for basic measurement of voltages, currents, and components in the circuit under test.

- Voltmeter(Measures voltage)
- Ohmmeter(Measures resistance)
- Ammeter, e.g. Galvano meter or Millia meter (Measures current)
- Multi metere, VOM (Volt-Ohm-Millia meter) or DMM (Digital Multi meter) (Measures all of the above)
- LCR meter- inductance (L), capacitance (C) and resistance (R) meter (measure LCR values)

Self-Check – 1	Written Test

Instruction: Follow the below selected instruction

The following are true or false items, write true if the statement is true and write false if the statement is false.

N°	Questions and answers
1	Safety information is important for the installer and for the user
	True or false:
2	Manufacturers always provide safety requirement on their products

Note: the satisfactory rating is as followed

Satisfactory	1 points
Unsatisfactory	Below 1 points

Answer Sheet

Score = ____________

Rating: _____________

Name

Date

2.1 Documentation

- System Data
- Nameplate data –Rated power, manufacturers, Models and quantities of PV modules and inverters
- Cover page data- contact information for the customer, system designer and system installer, relevant project dates
- Wiring diagrams (single line diagrams with equipment information)
- Data sheets of all installed equipment
- O & M information
  - ✓ Procedures for verifying correct system operation
  - ✓ A check list of what to do in case of a system failure
  - ✓ Emergency shut down and isolation procedure
  - ✓ Maintenance and cleaning recommendations
- Test results and commission data
- System sizing documents for selecting solar PV installation equipment

Self-Check - 1	Written Test

Instruction: Follow the below selected instruction

Say true if the statement is write say false if the statement is wrong

N°	Questions and answers
1	**Documentation includes system Data, Nameplate data etc.**

Note: the satisfactory rating is as followed

Satisfactory	10 points
Unsatisfactory	Below 5 points

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet 3	Documenting electrical installation arrangement and specification

3.1 Documenting electrical installation arrangement and specifications

A renewable energy ready home not only involves important design considerations and additions to the building itself but a transfer of this information to the future homeowner. Builders are encouraged to provide the homeowner the following documents

- Copy of the installed system specifications and guides
- Fully completed check list
- Architectural drawings detailing the proposed array location and square footage
- Electrical drawings and riser diagram of PV system components that detail the dedicated location for the mounting of the balance components
- Shading study with percent monthly or adjusted annual shading impacts
- Site assessment record generated by online tools indicating that the proposed site meets a minimum solar resource potential.
- Code-compliant documentation of the maximum allowable dead load and live load rating of the existing roof.
- Operation and maintenance information
- Installer contact details

Self-Check –3	Written Test

Instruction: Follow the below selected instruction

Say true if the statement are true say false if the statement are wrong

1	**Builders are encouraged to provide the homeowner Fully completed check list.**
	:

Note: the satisfactory rating is as followed

Satisfactory	10 points
Unsatisfactory	Below 5 points

Answer Sheet	Score = ___________ Rating: ____________

List of Reference materials

Dobelmann, D. J., & Klauss-Vorreiter, A. (2009). Promotion of the Efficient Use of Renewable Energies in Developing Countries. DGS e.V. International Solar Energy Society/German Section.

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