Solar PV System Installation and Maintenance

Level-II

Learning Guide -44

Unit of Competence	Install Wiring Systems in Conduit and connect Equipment
Module Title	Installing Wiring Systems in Conduit and connecting Equipment
LG Code	EIS PIM2 M07 LO1 **LG-44**
TTLM Code	EIS PIM2**TTLM 1019v1**

LO1:-Plan and prepare

Instruction Sheet	Learning Guide:-31

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- Performing work with in a safe system
- Identifying electrical isolation
- Carrying out isolation procedures
- Confirming the existing electrical supply
- Following agreed procedures to ensure the co-ordination of site services
- Identifying accurate electrical isolation
- Carrying out electrical Isolation regulations and approved procedures
- Measuring and marking wiring systems, wiring enclosures, tools and equipment
- Checking planned locations for any sensitivity

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:-**

- Identify work is performed within a safe system of work and any foreseeable hazards relating to the connection of wiring systems, wiring enclosures and equipment.
- Identify electrical isolation is accurately prior to connection when required
- Approve isolation procedures is carried out to ensure a safe connection in accordance with electrical regulations and procedures
- Confirm the existing electrical supply.
- Agree procedures are followed to ensure the co-ordination of site services and the activities of other trades.
- Identify the means of electrical isolation is accurately prior to commencing installation.
- approve isolation procedures are carried out to ensure a safe installation in accordance with electrical regulations and procedures
- measure and make all locations are out for wiring systems, wiring enclosures, tools and equipment in accordance with electrical regulations and to meet an agree specification
- check the planned locations are for their sensitivity, visually acceptable and are in accordance with other site services

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5 Sheet 6, Sheet 7, Sheet 8, and Sheet 9 in pages 3, 9, 14, 21, 29, 37, 43, 48 and 60 respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 4 Self-check 5 and Self-check 6, Self-check 7, Self-check 8, Self-check 9 in pages **8, 13, 20, 28, 36, 42, 47, 59, 66,** respectively
5. If you earned a satisfactory evaluation from the “Self-check” proceed to Operation Sheet1 in page 65
6. Lap test 1 in page 66

Information Sheet-1	Performing work with in a safe system

1.1. Introduction

The occupational safety and health ordinance, respectively every proprietor of an industrial undertaking and every employer, among other things, to provide system of work that are so far as reasonably practicable, safe and without risks to heath.

This guidebook intends to assist proprietors, employers, managers and others responsible for health and safety at work to understand the principles and to provide a framework for developing safe systems of work.

1.2. Safe systems of work

A safe system of work is formal procedure which results from systematic examination of a task in order to identify all hazards. It defines safe methods to ensure that hazards are eliminated or risks minimised.

1.3. Safe system of work needed

Many hazards are clearly recognisable and can be overcome by physically separating people from them, e.g. by using effective guarding on machinery.

A safe system of work is needed when hazards cannot be physically eliminated and some elements of risk remain. You should apply these principles to routine work as well as to more special cases such as:

- Cleaning and maintenance operations
- Making changes to work layouts, materials used or work methods
- Employees working away from base or working alone
- Breakdowns or emergencies
- Controlling activities of contractors on your premises
- Loading, unloading and movements of vehicles.

There are two categories of safe systems of work, **formal** and **informal**.

Examples of a **formal safe system** of work include standard operating procedure, method statement and permit to work.

Formal safe system of work will be required for activities that have been assessed and control measures introduced, but where significant residual risks remain. Examples of such tasks include:

✓ Maintenance and/or testing of assembly-plant machinery

Plant and Machinery Maintenance Plant and machinery maintenance is an important part of safety on a construction site. It is not as simple as just using plant and machinery indefinitely; it takes preparation, organization and attention to safety. In order to ensure workers are safe when working with plant and machinery, they need to be in good condition.

Figure 1: Plant Maintenance Company

Some of the aspects to consider when conducting plant and machinery maintenance are: Workers should be allocated responsibilities regarding how to maintain and properly use plant and equipment and they should be trained on how to effectively manage these responsibilities

✓ Window cleaning

Window cleaning, or window washing, is the exterior cleaning of architectural glass used for structural, lighting, or decorative purposes. It can be done manually, using a variety of tools for cleaning and access. Technology is also employed and increasingly, automation.

Commercial work is contracted variously from in-person transactions for cash or barter, to formal tender processes. Regulations, licensing, technique, equipment and compensation vary nationally and regionally.

Figure 2: Window cleaners

- ✓ **Lone working**

(LW) is an employee who performs an activity that is carried out in isolation from other workers without close or direct supervision. Such staff may be exposed to risk because there is no-one to assist them and so a risk assessment may be required. Lone workers are now often supported by cloud-based automated monitoring systems and specialised monitoring call centres.

Figure 3:Lone Worker Safety

1.4. Identifying the Risks

This will be a part of the risk assessment process. Where hazards have been identified for a particular activity, risks should be eliminated or minimised. Where this is not possible, a formal safe system of work should be developed for that activity.
The residual risks identified through this process will determine the control measures outlined in the safe system of work.

For example, a work activity is to be carried out in close proximity to an excavation site. The task, i.e. the excavation, may not be easy to eliminate although the associated risks might be minimised through effective design. There is a risk of persons falling into the excavation site since access to the site is necessary for other work being carried out at the same time. There is also the risk of collapse of the excavation for those working in the excavation. A safe system of work will be necessary to control these risks

Examples of an **informal safe system** of work include, verbal instructions, list of does and don'ts and accepted custom and practice.

There are five key steps to designing a safe system of work:

- Step 1: **Identify hazards, i.e. anything that may cause harm**

Employers have a duty to assess the health and safety risks faced by their workers. Your employer must systematically check for possible physical, mental, chemical and biological hazards.

- ✓ This is one common classification of hazards:
- ✓ Physical: e.g. lifting, awkward postures, slips and trips, noise, dust, machinery, computer equipment, etc.
- ✓ Mental: e.g. excess workload, long hours, working with high-need clients, bullying, etc. These are also called 'psychosocial' hazards, affecting mental health and occurring within working relationships.
- ✓ Chemical: e.g. asbestos, cleaning fluids, aerosols, etc.
- ✓ Biological: including tuberculosis, hepatitis and other infectious diseases faced by healthcare workers, home care staff and other healthcare professionals.

- Step 2: **Decide who may be harmed, and how**

Identifying who is at risk starts with your organisation's own full- and part-time employees. Employers must also assess risks faced by agency and contract staff, visitors, clients and other members of the public on their premises.

Employers must review work routines in all the different locations and situations where their staff are employed. For example:

- ✓ Home cares supervisors must take due account of their client's personal safety in the home, and ensure safe working and lifting arrangements for their own home care staff.
- ✓ In a supermarket, hazards are found in the repetitive tasks at the checkout, in lifting loads, and in slips and trips from spillages and obstacles in the shop and storerooms. Staff face the risk of violence from customers and intruders, especially in the evenings.
- ✓ In call centres, workstation equipment (i.e. desk, screen, keyboard and chair) must be adjusted to suit each employee.

Employers have special duties towards the health and safety of young workers, disabled employees, night workers, shift workers, and pregnant or breastfeeding women.

- Step 3: **Assess the risks and take action**

  This means employers must consider how likely it is that each hazard could cause harm. This will determine whether or not your employer should reduce the level of risk. Even after all precautions have been taken, some risk usually remains. Employers must decide for each remaining hazard whether the risk remains high, medium or low

- Step 4: Make a record of the findings
  - ✓ Employers with five or more staff are required to record in writing the main findings of the risk assessment. This record should include details of any hazards noted in the risk assessment, and action taken to reduce or eliminate risk.
  - ✓ This record provides proof that the assessment was carried out, and is used as the basis for a later review of working practices. The risk assessment is a working document. You should be able to read it. It should not be locked away in a cupboard.

- Step 5: **Review the risk assessment**

  A risk assessment must be kept under review in order to:

  - ✓ Ensure that agreed safe working practices continue to be applied (e.g. that management's safety instructions are respected by supervisors and line managers); and
  - ✓ Take account of any new working practices, new machinery or more demanding work targets.

Figure 4: Five key steps safe system of work

Self-Check -1	Written Test

I. Say true or false for the following questions

1. A safe system of work is formal procedure which results from systematic examination of a task in order to identify all hazards.
2. Hazards have been identified for a particular passive , risks should be eliminated or maximize.
3. Examples of an informal safe system of work include, verbal instructions list of does and don'ts and accepted custom and practice.
4. Lone workingis an employee who performs an activity that is carried out in isolation from other workers without close or direct supervision.
5. window washing, is the exterior cleaning of architectural glass used for structural, lighting, or decorative purposes

Note: **Satisfactory rating 3 & above points Unsatisfactory below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

2.1. Introduction

Also refers to certain transformers. Where the primary winding is electrically isolated from the secondary winding. Strangely enough it's known as an isolation transformer. One use of this is on building sites for safety

2.2. electrical isolation test

A Direct current (DC) or Alternating current (AC) resistance test that is performed between sub-circuit common and subsystem chassis to verify that a specified level of isolation resistance is met. Isolation testing may also be conducted between one or more electrical circuits of the same subsystem.

- **Analog isolation** circuitry protects the ADC from high voltages and transient voltages, but it can add gain, nonlinear, and offset errors to the signal before it reaches the ADC
- **Digital isolation** circuitry does not protect the ADC, and its advantages over analog isolation include lower cost, higher data transmission speeds, and greater accuracy because the signal is less altered prior to reaching the ADC.

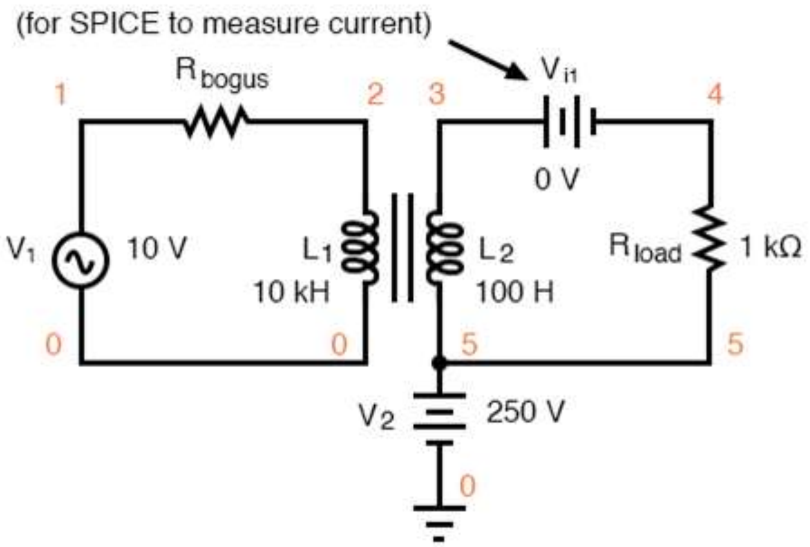

Figure 5: **Electrical Isolation | Transformers**

The test often reveals problems that occurred during assembly, such as defective/wrong component, improper component placement/orientation and wire insulation or insulator defects that may cause inadvertent shorting or grounding to chassis, in turn, compromising electrical circuit quality and product safety. Isolation resistance measurements may be achieved using a high input impedance ohmmeter, digital multimeter (DMM) or current-limited Hipot test instrument. The selected equipment should not over stress sensitive electronic components comprising the subsystem. The test limits should also consider semiconductor components within the subsystem that may be activated by the potentials imposed by each type of test instrumentation.

A minimum acceptable resistance value is usually specified (typically in the mega ohm (MΩ) range per circuit tested). Multiple circuits having a common return may be tested simultaneously, provided the minimum allowable resistance value is based on the number of circuits in parallel.

- ✓ **Five basic isolation test configurations exist:**

I. Single Un-referenced End-Circuit – isolation between one input signal and circuit chassis/common ground.
II. Multiple Un-referenced End-Circuits with a single return – isolation between several input signals and circuit chassis/common ground.
III. Subsystem with Isolated Common – isolation between signal input and common ground.
IV. Common Chassis Ground – isolation between circuit common and chassis (chassis grounded).
V. Isolated Circuit Common – isolation between circuit common and chassis (chassis floating).

2.3. Type of electrical isolation

a. Capacitive Isolation

Capacitive isolation, as seen in Figure below, uses an electrical field as the form of energy to transfer the signal across the isolation barrier. The electric field changes the level of charge on the capacitor. This charge is detected across the isolation barrier and the charge detected is proportional to the level of the measured signal.

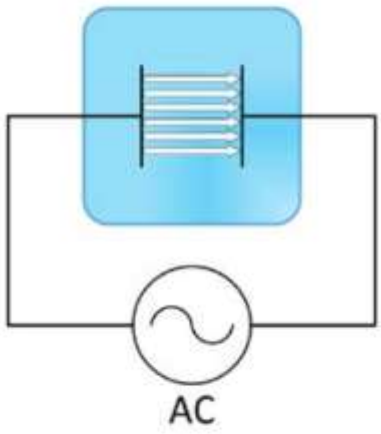

Figure 6: Inductive isolation uses a transformer, notated with the above symbol to transfer a signal across an isolation barrier.

b. Inductive Isolation

Inductive isolation uses a transformer, shown in Figure below, to transfer a signal across an isolation barrier. The transformer generates an electromagnetic field, proportional to the measured signal, as the form of energy to cross the isolation barrier.

Figure 7: Capacitive isolation uses an electrical field as the form of energy to transfer the signal across the isolation barrier.

As in capacitive coupling, inductive isolation can provide relatively high-speed data transmission rates. In addition to high-speed transmission, inductive coupling uses low power for the data transmission. However, inductive coupling is susceptible to interference from surrounding magnetic fields because it uses electromagnetic fields as the method to cross the isolation barrier. If external magnetic fields do interfere with the electromagnetic field produced by the transformer, this could affect the accuracy of the measurement.

c. Optical Isolation

Optical isolation uses an LED and a photo detector to transmit the signal information across the isolation barrier. The isolation barrier in optical isolation is typically an air gap and the signal is transmitted using light. The light intensity produced by the LED is proportional to the measured signal.

Because optical isolation uses light as the energy to transfer the measured signal across the isolation barrier, it gains the advantage of immunity from electrical- and magnetic-field Interference. This can make optical isolation an effective technique in industrial areas where strong electric or magnetic fields could be present. The advantages gained by using light are balanced by some disadvantages. Optical isolation typically has slower data transfer rates, which are limited to the LED switching speed. It also has relatively high power dissipation when compared to capacitive and inductive isolation.

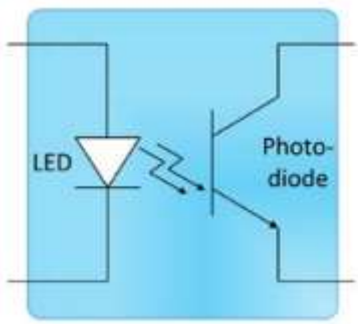

Figure 8: Optical isolation uses an LED and a photo detector to transmit the signal information across the isolation barrier

Table 1: Advantages and Disadvantages

Isolation Type	**Advantages**	**Disadvantages**
Capacitive	Fast date transmission rate Magnetic field interference immunity	Susceptible to electric field interference
Inductive	Fast date transmission rate Electric field interference immunity	Susceptible to magnetic field interference
Optical	Electric field interference immunity Magnetic field interference immunity	Slower data transmission rate Relatively high power dissipation

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Marching From column A and column B

A	B
1. Magnetic field interference immunity	A. Analog isolation
2. Electric field interference immunity	B. Capacitive
3. Magnetic & electric field interference immunity	C. Digital isolation
4. circuitry protects the ADC	D. inductive
5. circuitry does not protect the ADC	E. Optical

***Note:* Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

3.1. Introduction

An isolation procedure is a set of predetermined steps that should be followed when workers are required to perform tasks such as inspection, maintenance, cleaning, repair and construction. The following lock-out process is the most effective isolation procedure: shut down the machinery and equipment.

3.2. Isolation procedures

An isolation procedure is a set of predetermined steps that should be followed when workers are required to perform tasks such as inspection, maintenance, cleaning, repair and construction.

3.2.1. The following lock-out process is the most effective isolation procedure:

3.2.1.1. shut down the machinery and equipment

Scheduled Maintenance and Repair Wherever practical the WSA (Council) will make every reasonable attempt to notify the customer of a scheduled maintenance shutdown of the supply before the work commences. Where immediate action is required and notification is not practical, the WSA (Council) may shut down the supply without notice." Continuity of supply to customers shall have a very high priority. Shutdowns of mains shall be minimised wherever possible by isolating at the ferrule during changeover of services/stop taps. To avoid unnecessary shutdowns, and unless specific dispensation is received from Council, an appropriately designed self-tapping ferrule must be used to make live connections to pressured main supply or water mains.

3.2.1.2. identify all energy sources and other hazards

3.2.2. The different forms of energy are

3.2.2.1. Mechanical energy (Kinetic and potential)

Mechanical energy is the sum of potential energy and kinetic energy. It is the energy associated with the motion and position of an object. The principle of conservation of mechanical energy states that in an isolated system that is only subject to conservative forces, the mechanical energy is constant.

Figure 9: Mechanical Energy

3.2.2.2. Heat (Thermal energy)

Matter is made up of particles or molecules. These molecules move (or vibrate) constantly. A rise in the temperature of matter makes the particles vibrate faster. Thermal energy is what we call energy that comes from the temperature of matter. The hotter the substance, the more its molecules vibrate, and therefore the higher its thermal energy.

For example, a cup of hot tea has thermal energy in the form of kinetic energy from its vibrating particles. When you pour some milk into your hot tea, some of this energy is transferred from the hot tea to the particles in the cold milk. What happens next? The cup of tea is cooler because it lost thermal energy to the milk. The amount of thermal energy in an object is measured in Joules (J)

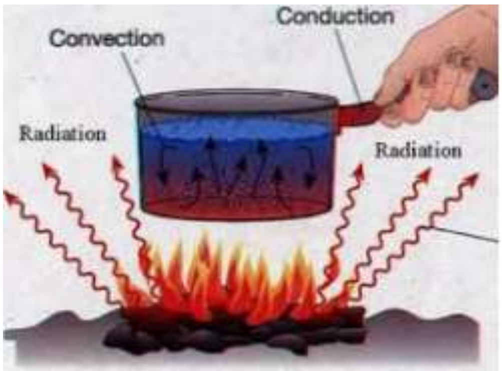

Figure 10: Forms of Energy, Transformations

3.2.2.3. Chemical energy

Is the potential of a chemical substance to undergo a transformation through a chemical reaction to transform other chemical substances. Examples include batteries, food, gasoline, and etc. Breaking or making of chemical bonds involves energy, which may be either absorbed or evolved from a chemical system.

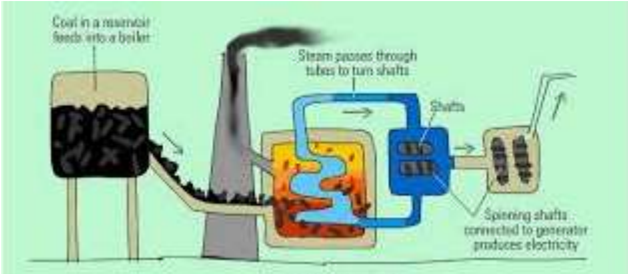

Figure 11: Example of chemical energy

3.2.2.4. Electrical energy

Matter is made up of atoms. In these atoms, there are some even small stuff called **electrons** that are constantly moving. The movement of these electrons depends on how much energy it has. This means every object has potential energy, even though some have more than others.

Humans can force these moving electrons along a path from one place to the other. There are special mediums (materials) called conductors that carry this energy. Some materials *cannot* carry energy in this form, and they are called insulators. We generate electrical energy whey we succeed in causing these electrons to move from one atom to the other, with the use of magnetic forces.

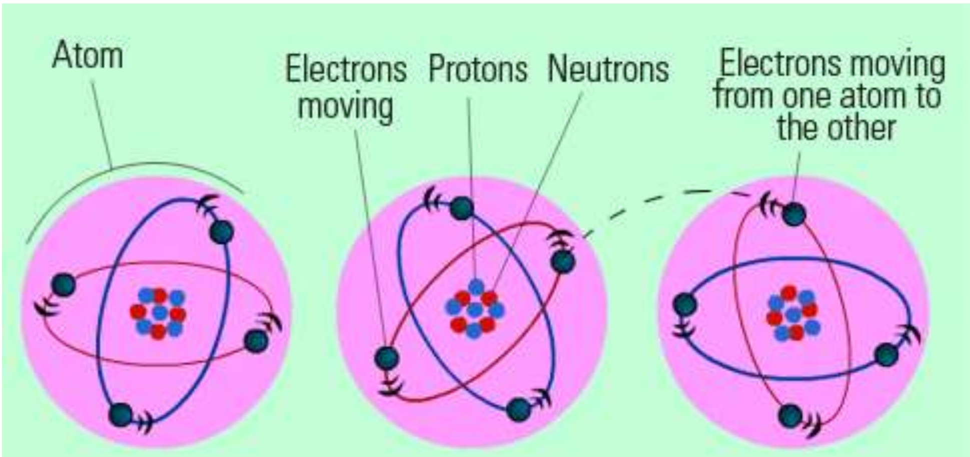

Figure 12: Once we harness electrical energy,

3.2.2.5. Solar energy

Is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic's, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.

Figure 13: Solar Energy or Solar Power

3.3. Isolate the voltage

Where these three conditions are met, live work may proceed, but minimum safe isolation procedures should be followed. These include:

3.3.1. **Identify correct isolation point or device.**
For all work on low voltage electrical equipment or circuits, it is important to ensure that the correct point of isolation is identified. When isolating the main source of energy, it is also essential to isolate any secondary source (such as standby generators, uninterruptable power supplies and micro generators).

3.3.2. **Check condition of voltage indicating device** —such as a test lamp or two-pole voltage detector.

3.3.3. **Switch off installation/circuit to be isolated.**
It should never be assumed that equipment is dead because a particular isolation device has been placed in the OFF position.

3.3.4. **Verify with voltage indicating device that no voltage is present.**
It is important to ensure that the correct point of isolation is identified before proving dead. Adequate precautions should be taken to prevent electrical equipment which has been made dead, is carried out on or near that equipment, from becoming electrically charged during that work.

3.3.5. **Re-confirm that voltage indicating device functions correctly on proving unit.**

Use proving unit to confirm that the voltage on the indicating device is functioning correctly.

3.3.6. **In Germany, Switzerland and Austria,** standards require additional steps, including:

3.3.6.1. Carry out earthling and short circuiting.

3.3.6.2. Provide protection against adjacent live parts.

3.3.7. **Lock-off device used to isolate installation circuit.**

It is preferable for an appropriate locking-off device be used on the point of isolation.

3.3.8. **Post warning notices.**

Suitable labelling of the disconnected conductors using a caution notice is vital to prevent the supply being reinstated.

3.4. Locks and danger tags

Every person working on isolated equipment should fit their own lock and/or danger tag. Alternatively, another management approved system that achieves an equivalent level of safety may be used.

When using locks or danger tags, consider the following:

- Tags should be dated and signed
- Locks should be accompanied by a corresponding tag to identify who has locked out the plant
- Tags and locks should only be removed by the person who applied them or by the supervisor after consultation with the signatory of the danger tag. In the event
  - that the person who applied the danger tag is unavailable, their tag or lock may only be removed in accordance with a management approved procedure
  - Danger Tags and/or locks should be fitted to all isolation points.

✓ **Out-of-service tags-** Out-of-service tags are used to identify equipment or machinery that has been taken out of service due to a fault, damage or malfunction (refer to Figure 14).

Figure 14: Example of an 'Out of Service' tag

The out-of-service tag is to be securely fixed to the operating control power isolator with the appropriate details completed on the tag (explaining the reason for the machine being ‘out of service)

The out-of-service tag should not be removed until the equipment is safe to be returned to service, or the reason for the out-of-service tag no longer exists.

- **The out-of-service tag may be removed by:**

- The person who attached it
- The supervisor responsible for the operation or repair of the equipment
- The maintenance person who carried out the repairs.

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer for the following questions

1. It is the energy associated with the motion and position of an object

A. Mechanical energy
B. Thermal energy
C. Electrical energy
D. Solar energy

2------------is radiant light and heat from the Sun that is harnessed using a range of ever-evolving

A. Mechanical energy
B. Thermal energy
C. Electrical energy
D. Solar energy

3. Matter is made up of atoms. In these atoms, there are some even small stuff called electrons that are constantly moving in __________.

A. Mechanical energy
B. Thermal energy
C. Electrical energy
D. Solar energy

4. All except one is isolation procedures

A. Identify correct isolation point or device
B. Check condition of voltage indicating device
C. Switch off installation/circuit to be isolated
D. None

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-4	Confirming the existing electrical supply

4.1. Introduction

A single small electrical generating unit could meet the localized demand. We call the network through which the consumers get electricity from the source as electrical supply system. An electrical supply system has three main components, the generating stations, the transmission lines and distribution systems.

4.2. Electric (supply) power system

A network of electrical components deployed to supply, transfer, and use electric power. An example of an electric power system is the grid that provides power to an extended area. An electrical grid power system can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres, and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power the standard for large-scale power transmission and distribution across the modern world. Specialised power systems that do not always rely upon three-phase AC power are found in aircraft, electric rail systems, ocean liners and automobiles.

✓ Basics of electric power

Electric power is the product of two quantities: current and voltage. These two quantities can vary with respect to time (AC power) or can be kept at constant levels (DC power).

Most refrigerators, air conditioners, pumps and industrial machinery use AC power whereas most computers and digital equipment use DC power (digital devices plugged into the mains typically have an internal or external power adapter to convert from AC to DC power). AC power has the advantage of being easy to transform between voltages and is able to be generated and utilised by brushless machinery. DC power remains the only practical choice in digital systems and can be more economical to transmit over long distances at very high voltages

Figure 15: **An external AC to DC power**

The ability to easily transform the voltage of AC power is important for two reasons: Firstly, power can be transmitted over long distances with less loss at higher voltages. So in power systems where generation is distant from the load, it is desirable to step-up (increase) the voltage of power at the generation point and then step-down (decrease) the voltage near the load. Secondly, it is often more economical to install turbines that produce higher voltages than would be used by most appliances, so the ability to easily transform voltages means this mismatch between voltages can be easily managed.

4. Balancing the grid

One of the main difficulties in power systems is that the amount of active power consumed plus losses should always equal the active power produced. If more power is produced than consumed the frequency will rise and vice versa. Even small deviations from the nominal frequency value will damage synchronous machines and other appliances. Making sure the frequency is constant is usually the task of a transmission system operator.

Figure 16: Grid Balancing

5. Components of power systems

✓ **Supplies**

All power systems have one or more sources of power. For some power systems, the source of power is external to the system but for others, it is part of the system itself it is these internal power sources that are discussed in the remainder of this section. Direct current power can be supplied by batteries, fuel cells or photovoltaic cells. Alternating current power is typically supplied by a rotor that spins in a magnetic field in a device known as a turbo generator. There have been a wide range of techniques used to spin a turbine's rotor, from steam heated using fossil fuel (including coal, gas and oil) or nuclear energy, falling water (hydroelectric power) and wind (wind power).

Figure 17: wind turbine, Hydroelectric Power, Fossil fuel use pushes carbon emissions

✓ **Loads**

Power systems deliver energy to loads that perform a function. These loads range from household appliances to industrial machinery. Most loads expect a certain voltage and, for alternating current devices, a certain frequency and number of phases. The appliances found in residential settings, for example, will typically be single-phase operating at 50 or 60 Hz with a voltage between 110 and 260 volts (depending on national standards). An exception exists for larger centralized air conditioning systems as in some countries these are now typically three-phase because this allows them to operate more efficiently. All electrical appliances also have a wattage rating, which specifies the amount of power the device consumes. At any one time, the net amount of power consumed by the loads on a power system must equal the net amount of power produced by the supplies less the power lost in transmission.

Figure 18: **A toaster is a great example of a single-phase load**

- ✓ **Conductors**

Conductors carry power from the generators to the load. In a grid, conductors may be classified as belonging to the transmission system, which carries large amounts of power at high voltages (typically more than 69 kV) from the generating centres to the load centres, or the distribution system, which feeds smaller amounts of power at lower voltages.

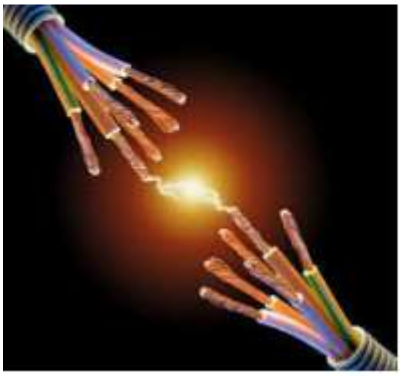

Figure 19: **Electrical Conductors**

- ✓ **Capacitors and reactors**

The majority of the load in a typical AC power system is inductive; the current lags behind the voltage. Since the voltage and current are out-of-phase, this leads to the emergence of an "imaginary" form of power known as reactive power. Reactive power does no measurable work but is transmitted back and forth between the reactive power source and load every cycle.

Figure 20: **Capacitors and Reactors**

✓ **Power electronics**

Power electronics are semiconductor based devices that are able to switch quantities of power ranging from a few hundred watts to several hundred megawatts. Despite their relatively simple function, their speed of operation (typically in the order of nanoseconds. means they are capable of a wide range of tasks that would be difficult or impossible with conventional technology.

Figure 21: Motor control & power

6. Power system in practice

Despite their common components, power systems vary widely both with respect to their design and how they operate. This section introduces some common power system types and briefly explains their operation.

✓ **Residential power systems**

Residential dwellings almost always take supply from the low voltage distribution lines or cables that run past the dwelling. These operate at voltages of between 110 and 260 volts (phase-to-earth) depending upon national standards. A few decades ago small dwellings would be fed a single phase using a dedicated two-core service cable (one core for the active phase and one core for the neutral return). The active line would then be run through a main isolating switch in the fuse box and then split into one or more circuits to feed lighting and appliances inside the house. By convention, the lighting and appliance circuits are kept separate so the failure of an appliance does not leave the dwelling's occupants in the dark. All circuits would be fused with an appropriate fuse based upon the wire size used for that circuit. Circuits would have both an active and neutral wire with both the lighting and power sockets being connected in parallel. Sockets would also be provided with a protective earth. This would be made available to appliances to connect to any metallic casing.

![logos: Federal TVET Agency, EWTI, ADRA Ethiopia]

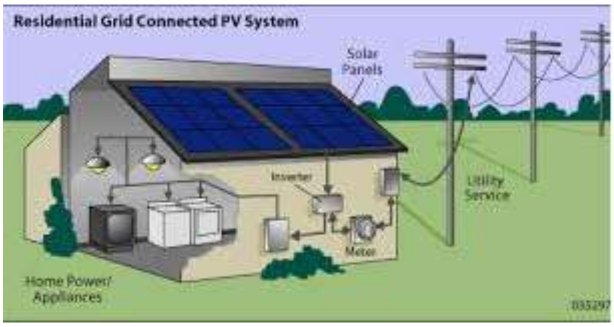

Figure 22: Solar Photovoltaic power systems

There have been a number of minor changes over the years to practice of residential wiring. Some of the most significant ways modern residential power systems in developed countries tend to vary from older ones include:

7. For convenience, miniature circuit breakers are now almost always used in the fuse box instead of fuses as these can easily be reset by occupants and, if of the thermo magnetic type, can respond more quickly to some types of fault.
8. For safety reasons, RCDs are now often installed on appliance circuits and, increasingly, even on lighting circuits.
9. Whereas residential air conditioners of the past might have been fed from a dedicated circuit attached to a single phase, larger centralised air conditioners that require three-phase power are now becoming common in some countries.
10. Protective earths are now run with lighting circuits to allow for metallic lamp holders to be earthed.
11. Increasingly residential power systems are incorporating micro generators, most notably, photovoltaic cells.

✓ **Commercial power systems**

Commercial power systems such as shopping centres or high-rise buildings are larger in scale than residential systems. Electrical designs for larger commercial systems are usually studied for load flow, short-circuit fault levels, and voltage drop for steady-state loads and during starting of large motors. The objectives of the studies are to assure proper equipment and conductor sizing, and to coordinate protective devices so that minimal disruption is caused when a fault is cleared. Large commercial installations will have an orderly system of sub-panels, separate from the main distribution board to allow for better system protection and more efficient electrical installation

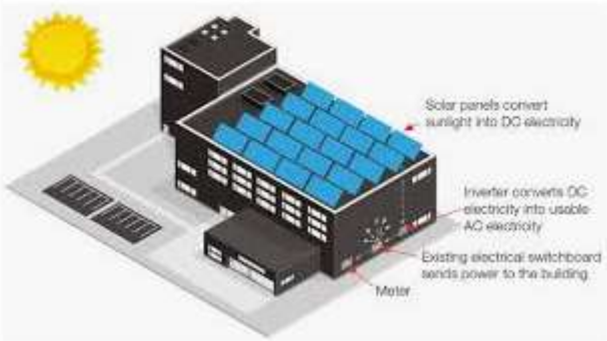

Figure 23: Commercial Solar Panel Installation

Self-Check -4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II.Say true or false for the following questions

1. Power electronics are semiconductor based devices that are able to switch quantities.
2. Power systems deliver energy to loads that perform a function.
3. Residential power systems such as shopping centres or high-rise buildings are larger in scale than residential systems.
4. Conductors carry power from the generator to the motor.
5. Direct current power can be supplied by batteries, fuel cells or photovoltaic cells.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-5	Following agreed procedures to ensure the co-ordination of site services

5.1. Introduction

This section sets forth attestation standards and provides guidance to a practitioner concerning performance and reporting in all agreed-upon procedures engagements, except as noted. A practitioner also should refer to the following sections of this Statement on Standards for Attestation Engagements (SSAE), which provide additional guidance for certain types of agreed-upon procedures engagements:

Site most often refers to:

- **Location:** n geography, location and place are used to identify a point or an area on the Earth's surface or elsewhere. The term location generally implies a higher degree of certainty than place, the latter often indicating an entity with an ambiguous boundary, relying more on human or social attributes of place identity and sense of place than on geometry
- **Website** a set of related web pages, typically with a common domain name and hosted on at least one web server. This article is about websites in general. For the Internet domain .website, see List of Internet top-level domains. Not to be confused with Website.
- **Construction site** Is the process of constructing a building or infrastructure. Construction differs from manufacturing in that manufacturing typically involves mass production of similar items without a designated purchaser, while construction typically takes place on location for a known client.

5.2. Design services

Further, safety is and should be brought to the front of the electrical design service discussion as there are many factors to consider in a design service project. Electrical systems can be designed for reliability and meet the needs of a customer or their facility but they can also be left with an unsafe system to be maintained and worked on in the future. Electric Supply's experience serves our customers well in regards to safety. We will ask the right questions up front so we can understand what it is you need, not only now but after the project is complete.

An example of some questions we might ask includes:

- Can the facility be shut down in the future for ads on or modifications?
- Will the systems allow work to be done in an energized state?
- If so, what levels of PPE are acceptable to perform that work?

It is vital that we work through these questions and more before they become an issue down the road.

The Electric Supply team specializes in providing accurate estimating, engineering and installation. Our nearly 100 years of experience uniquely equips us to tackle even the most complicated projects. Whether it's a new build, building expansion, or product expansion, we can help.

- **Control and operation of HV and LV networks**

The following definitions shall apply for the purposes of this and other related sections of the Live Working Manual. The Apparatus defined may be used individually or in combination in separate or composite tanks or enclosures.

a. **Circuit Breaker** Mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short circuit. Current may be made or broken under oil, in dielectric gas (such as SF6), or in vacuum.

Figure 24: Circuit breaker

b. **Switch Disconnected Switch** which, in the open position, satisfies the isolating requirements specified for a disconnected and may be used as an Isolating Device when open and appropriately locked. This type of device is capable of:

(i) Carrying and making current under normal and abnormal conditions.
(ii) Breaking current under normal conditions only.

Figure 25: On Off Disconnected Switch

c. **Fuse Switch** Switch disconnected in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact and may be used as an Isolating Device when the switch disconnected is open and appropriately locked. This type of device is capable of

i. Carrying and making current under normal and abnormal conditions.
ii. Breaking current under normal conditions.
iii. Breaking current under abnormal conditions only via Approved fusible links.

Figure 26: Switch Disconnected Fuse

d. **Transfer Earthling** An Approved means of earthling using withdraw able metal enclosed switchgear:

(i) Which does not require the attachment of an earthling extension? Earthling Device.

(ii) (ii) Where a separate selector mechanism is used to select Bus bar Earth, Circuit Earth or Service position.

5.3. Substation construction

A part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels.

5.3.1. Types of Substation construction

a. Transmission substation

A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages.

Figure 27: Example of 115 kV to 41.6/12.47 kV 5 MVA 60 Hz substation

b. Distribution substation

A distribution substation transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution.

Figure 28: **220 kV/110 kV/20 kV station**

c. Collector substation

In distributed generation projects such as a wind farm or Photovoltaic power station, a collector substation may be required. It resembles a distribution substation although power flow is in the opposite direction, from many wind turbines or inverters up into the transmission grid. Usually for economy of construction the collector system operates around 35 kV, although some collector systems are 12 KV, and the collector substation steps up voltage to a transmission voltage for the grid.

Figure 29: **Collector HV station**

d. Converter substations

Converter substations may be associated with HVDC converter plants, traction current, or interconnected non-synchronous networks. These stations contain power electronic devices to change the frequency of current, or else convert from alternating to direct current or the reverse. Formerly rotary converters changed frequency to interconnect two systems; nowadays such substations are rare.

Figure 30: **Electrical Substation**

e. Switching station

A switching station is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector and distribution stations. Sometimes they are used for switching the current to back-up lines or for parallelizing circuits in case of failure. An example is the switching stations for the HVDC transmission line.

Figure 31: **High Tension Switching Station**

5.4. HV cable jointing and laying

Our high voltage cable laying and jointing solutions include the following services designed to assist with smooth running of site works;

- Preparation of tender drawings and documentation
- Technical assessment of tender returns
- Programming of proposed works to incorporate local network constraints and site specific limitations
- Monitoring construction progress
- Inspection of completed works
- As-built surveys of completed works

Figure 32: HV cable jointing and laying

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Self-Check -5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions

1. A distribution substation transfers power from the transmission system to the distribution system.
2. Transfer Earthling An Approved means of earthling using withdraw able metal enclosed switchgear
3. Site and place are used to identify a point or an area on the Earth's surface or elsewhere.
4. Construction site and manufacturing typically involves mass production of similar.
5. HV is a substation without transformers and operating only at a single voltage level.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-6	Identifying accurate electrical isolation prior to commencing installation in accordance with electrical regulations

6.1. Safe isolation procedures for low voltage installations

Where these three conditions are met, live work may proceed, but minimum safe isolation procedures should be followed. These include:

- Identify correct isolation point or device.
  For all work on low voltage electrical equipment or circuits, it is important to ensure that the correct point of isolation is identified. When isolating the main source of energy, it is also essential to isolate any secondary source (such as standby generators, uninterruptable power supplies and micro generators).
- Check condition of voltage indicating device —such as a test lamp or two-pole voltage detector.
- Switch off installation/circuit to be isolated.
  It should never be assumed that equipment is dead because a particular isolation device has been placed in the OFF position.
- Verify with voltage indicating device that no voltage is present.
  It is important to ensure that the correct point of isolation is identified before proving dead. Adequate precautions should be taken to prevent electrical equipment which has been made dead, is carried out on or near that equipment, from becoming electrically charged during that work.
- Re-confirm that voltage indicating device functions correctly on proving unit.
  Use proving unit to confirm that the voltage on the indicating device is functioning correctly.
- In Germany, Switzerland and Austria, standards require additional steps, including:
  - ✓ Carry out earthling and short circuiting.
  - ✓ Provide protection against adjacent live parts.
- Lock-off device used to isolate installation circuit.
  It is preferable for an appropriate locking-off device be used on the point of isolation.
- Post warning notices.
  Suitable labeling of the disconnected conductors using a caution notice is vital to prevent the supply being reinstated.

6.2. Analysis of the loads

The loads supplied by the electrical installation can be of various types depending on the business: motive power, variable control units, lighting, IT, heating, etc.

Depending on the individual case, the electrical operating parameters (phase shift, efficiency, inrush transients, harmonics, etc.) will be different. The power to be considered is not limited to the simple reading of a value in watts.

6.3. Safe isolation procedure

All electrical installations must be isolated and proven dead before work can commence. Securely “disconnecting” (isolating) one or all parts of the installation from the live supply is called `Safe Isolation`. There can be several ways of isolating an installation. Most common is by means of a Main Switch. If there is a need to isolate only one circuit at the time, then an MCB provides isolation. In domestic environment it is usually the main fuse that gets removed.

There are industry-wide recommendations on correct procedures in order to achieve safe isolation. The steps described bellow form the Safe Isolation procedure.

Before starting the Safe Isolation Procedure, remember to seek permission from a relevant responsible person, because there might be certain vital services that must not be interrupted at any time. There might be a permit to work system in place to which you will need to comply.

Three Phase installations test to confirm that there is no voltage between:

- L1 and L2
- L1 and L3
- L1 and Neutral
- L1 and Earth
- L2 and L3
- L2 and Neutral
- L2 and Earth
- L3 and Neutral
- L3 and Earth
- Neutral and Earth

Safe Isolation workflow diagram

The following workflow diagram on safe isolation is an excellent resource that should be part of every electrician's tool bag. It is designed to be downloaded and printed out to be of use to anyone:

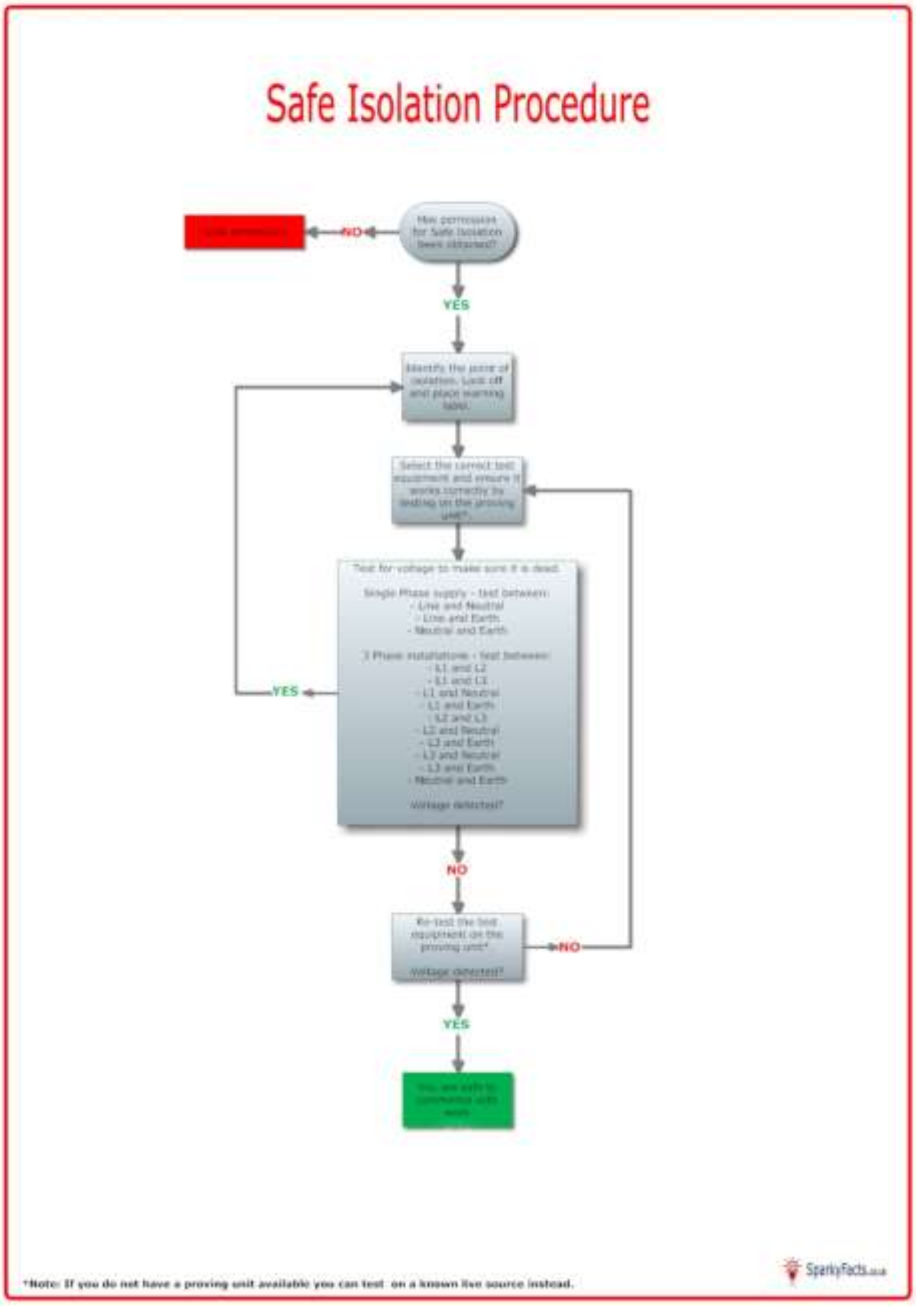


Figure 33: Diagram of Safe Isolation

6. The Safe Isolation kit

There are several different kits available on the market. You could go for a kit with the test instrument and the probing unit included or you could choose to get a basic one. As long as you have a reliable test meter with a probing unit, it does not matter which make it is.

Figure 34: Safe Isolation kit

When it comes to the actual locks itself, it can be a difficult task to prepare yourself for every possible type of MCB`s and Main Switches out there. Â A solution would be in the standardisation of circuit breakers, but until that happens, we must try to use what we can get on the market.

6.1. Quality and safety of an electrical isolation installation

A. Initial testing of an installation

Before a utility will connect an installation to its supply network, strict pre-commissioning electrical tests and visual inspections by the authority, or by its appointed agent, must be satisfied.

These tests are made according to local (governmental and/or institutional) regulations, which may differ slightly from one country to another. The principles of all such regulations however, are common, and are based on the observance of rigorous safety rules in the design and realization of the installation

The pre-commissioning electrical tests and visual-inspection checks for installations in buildings include, typically, all of the following:

- Electrical continuity and conductivity tests of protective, equipotential and earth bonding conductors
- Insulation resistance/impedance of floors and walls
- Protection by automatic disconnection of the supply
- Additional protection by verifying the effectiveness of the protective measure

B. Put in out of danger the existing electrical installation

This subject is in real progress cause of the statistics with origin electrical installation (number of old and recognised dangerous electrical installations, existing installations not in ad equation with the future needs etc.)

C. Periodic check-testing of an installation

In many countries, all industrial and commercial-building installations, together with installations in buildings used for public gatherings, must be re-tested periodically by authorized agents.

The following tests should be performed

- Verification of RCD effectiveness and adjustments
- Appropriate measurements for providing safety of persons against effects of electric shock and protection against damage to property against fire and heat
- Confirmation that the installation is not damaged
- Identification of installation defects

Self-Check – 6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions

1. The pre-commissioning electrical tests and visual-inspection checks for installations
2. Initial testing verification of RCD effectiveness and adjustments.
3. There is no voltage Single Phase installations test to confirm that.
4. There are industry-wide recommendations on correct procedures in order to achieve safe isolation.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-7	Carrying out electrical Isolation procedures to ensure a safe installation in accordance with electrical regulations

7.1. Introduction

Safe isolation has long been a procedure carried out by a competent person in order to safely isolate electrical circuits or equipment before electrical work is undertaken. Despite this, every year people within the construction industry suffer electrical shock and serious burns of which some are sadly fatal.

Below is an excerpt from the Electrical Safety First's Best Practice 'Guidance on the management of electrical safety and safe isolation procedures for low voltage installations'*:*

An electrician working on a new-build construction project installed the three-phase and neutral distribution board shown in the photograph. He energised the supply to the distribution board before the circuits connected to it were complete, to provide a supply to a socket-outlet. He was connecting the supply cables to a wall-mounted timer unit, with the line conductor connected to the circuit-breaker at the top left hand side of the bus bar assembly. The circuit-breaker had not been securely isolated and was ON as he stripped the insulation from the end of the cable. He touched the live copper conductor of the cable and was electrocuted. The distribution board was manufactured to a high standard of safety. However, if he needed to energise the board before it was complete, he should first have replaced the cover and switched off and locked the circuit-breakers supplying unfinished or incomplete circuits. He should also have ensured that circuits were not connected into circuit breakers until they were complete and had been tested.

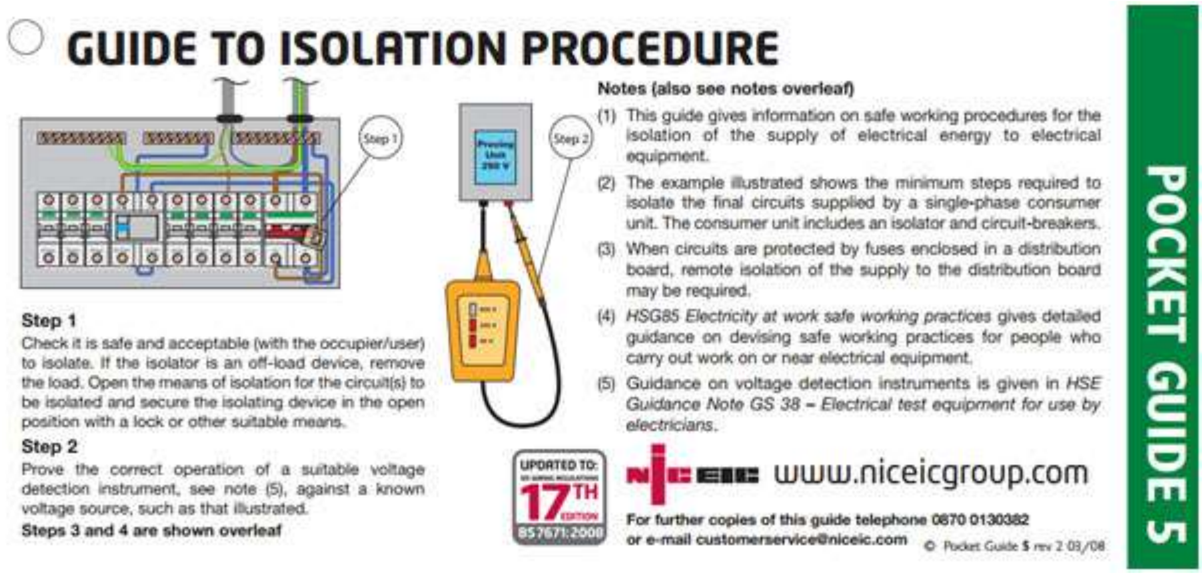


Figure 35: Guide to isolation procedure

7.2. Equipment used to safely isolate

In order to comply to HSE guidelines and to carry out safe isolation correctly, a lock and unique key, warning sign(s), an approved 2 pole voltage detector and proving unit must be used to carry out the procedures detailed in the NICEIC's 'Pocket Guide 5'. The following guidelines have been extracted from the HSE *'Electricity at work – Safe working practices HSG (Third Edition) Published 2013'*.

Switches, including circuit -breakers, should be locked in the OFF position preferably using a 'safety' lock, i.e., a lock or padlock having a unique key or combination. Lockout devices that can be attached to the actuators of circuit breakers are available and should be used where appropriate. All keys should be retained in a secure place.

You should put a notice or label at the place of disconnection so everyone else knows that work is being done. For example, a 'caution' notice can be used to indicate that someone is working on the apparatus and may be injured if it is re-energised, and 'danger' notices attached to live equipment adjacent to the place of work will indicate that the apparatus is still energised.

The instrument to do this should be properly constructed to protect against electric shock and designed to prevent short circuits occurring during use. For low voltages, proprietary voltage detectors such as two-pole voltage detectors, test lamps, or voltmeters with insulated probes and fused leads can be used (see HSE Guidance Note GS38). The use of multimeters, which can be set to the wrong function, is not recommended for proving dead on low-voltage systems, neither is the use of non-contact devices such as 'volt sticks' (note: in coal mines the use of appropriately certified non-contact devices is permitted).

It will be necessary to test the instrument before and after use. This may be done by means of a proving unit with a low power output. If live circuits are used to prove instruments, adequate precautions against electric shock and short circuits should be taken (see paragraphs 25–32). Training in the correct use of voltage detectors is essential to avoid risk in the event of unexpected use on a live conductor. All instruments used for checking circuits should be maintained and inspected frequently (note: in coal mines appropriately certified non-contact devices must be tested daily before they are taken underground)

Three types of isolation precautions

(i) **Contact Precautions-** Contact isolation precautions—used for infections, diseases, or germs that are spread by touching the patient or items in the room Methicillin-resistant Staphylococcus aurous) (examples: MRSA, vancomycin-resistant Enterococc VRE, diarrheal illnesses, open wounds, RSV). Healthcare workers should: Wear a gown and gloves while in the patient's room.

(ii) **Droplet Precautions**.

✓ And always follow these standard precautions Standard Precautions

- Perform hand hygiene before and after every patient contact
- Use PPE when risk of body fluid exposure
- Use and dispose of sharps safely
- Perform routine environmental cleaning
- Clean and reprocess shared patient equipment
- Follow respiratory hygiene and cough etiquette
- Use aseptic technique
- Handle and dispose of waste and used linen safely

Figure 36: **Droplet Precautions**

(iii). Airborne Precautions- Airborne precautions are required to protect against airborne transmission of infectious agents. Diseases requiring airborne precautions include, but are not limited to: Measles, Severe Acute Respiratory Syndrome (SARS), Vercelli (chickenpox), and Mycobacterium tuberculosis.

Self-Check – 7	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II. Say true or false for the following questions

1. Droplet Precautions Clean and reprocess shared patient equipment
2. Airborne Precautions are spread by touching the patient or items in the room
3. Contact Precautions are required to protect against airborne transmission of infectious agents.
4. Electrical safety and safe isolation procedures for low voltage installations

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

8.1. Measuring wiring systems

In commerce, the sizes of wire are estimated by devices, also called gauges, which consist of plates of circular or oblong form having notches of different widths around their edges to receive wire and sheet metals of different thicknesses. Each notch is stamped with a number, and the wire or sheet, which just fits a given notch

In some applications wire sizes are specified as the cross sectional area of the wire, usually in mm^2. Advantages of this system include the ability to readily calculate the physical dimensions or weight of wire, ability to take account of non-circular wire, and ease of calculation of electrical properties

8.2. Identify Electrical Cable Sizes

Different sizes of electrical cable can carry different amounts of current. Cable is measured in American Wire Gauge (AWG). A larger AWG number indicates a smaller cable. Attempting to run too much current through too small of a cable can cause permanent damage to wiring. It can also start an electrical fire. Fortunately, there are a number of ways to identify the size of an electrical cable. These methods only require minimal equipment and are effective for virtually all cables.

8.3. Wire Marking Systems

The best way to prevent switched cables and related accidents is to mark each cable individually. In a good marking system, each cable can be identified at a glance; you should be able to tell immediately what type of connection that cable is for, and where it leads. One of the best ways to reach this goal is to combine colour coding and written details.

Figure 37: Wires and cables marking

8.3.1. Colour Coding for Wire Marking

Wire colour coding systems offer immediate recognition, but several different standards apply to similar wiring in different situations. The colour code that you know may not match the one in use in a different facility — or even on a different piece of equipment. If your wire marking system uses colour codes, you should keep a description of the system posted near the wires that are affected.

8.3.2. Types of Wire Markings

To combine the two methods, use colour coding to identify the type of cable or connection, and use written details to identify exactly which connection the cable serves, or where it leads. You can mark cables and wires with flag labels, wire wraps, or shrink tubes.

- **Flag Labels**

Flag labels are so called because they fold around the wire, with the ends of the label stuck together to make a "flag" that stands out. This provides an adequate area for written information, which is helpful for very small wires. The eye-catching flag can make one important wire stand out among dozens of others. However, flag labels can get caught on other wires or enclosures, and they can be torn, worn, or lost easily.

Figure 38: American Flag Sticker

- **Wire Wraps**

Wire wraps are a better approach for permanent cable marking. Instead of folding over the wire just once, the transparent "tail" of a wire wrap goes around the wire completely, and then overlaps on top of the printed material. By covering those printed details, the transparent part of the label acts as a protective shield, keeping it from being worn away; by sticking to itself, and even winding around again, a wire wrap can become the most securely-fastened label type for cables. Sometimes, a wire wrap will even outlast the wire it's attached to!

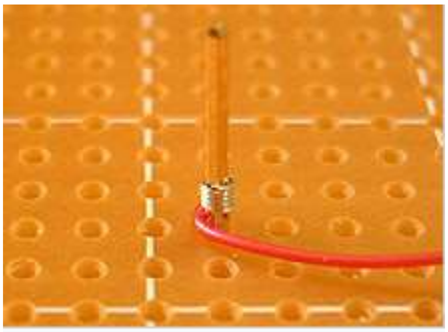


Figure 39: Wire-wrap connection

- **Shrink Tubes for Wire Marking**

Shrink tubes are composed of a special polyolefin material that shrinks when heated, you can create a complete tube-shaped label, slip it over the end of a cable, and tighten the label down with a heat gun. Shrink tubes are more flexible than wire wraps, and leave no residue behind if you need to remove them for later re-labelling. They look very clean and professional, and are perfect for cables that will be visible in a finished system. The down side of a shrink tube is that you need access to the end of a cable in order to mark it this way; a wire wrap can be applied in the middle of a long wire without disconnecting either end, but a shrink tube cannot.

Figure 40: Printed Heat Shrink Sleeves & Markers...

- **Size of Text for Wire Marking**

The next question is how large to make your printed information. That text needs to be large enough to be read easily, but small enough to be entirely visible from one side of the cable — if half the letter is on the other side of the cable, it won't be easy to read! The height of those letters should be based on the diameter of your cable. As a rule of thumb, don't make the letters taller than the diameter of the cable, and don't make them smaller than half that size. Bigger text, within that range, is easier to read, and capital letters are clearer than lowercase.

For instance, if you are marking a 16 gauge (AWG) wire, the diameter of the wire will be about 0.05 inches; the text on your label could range from 0.05 inches high to 0.025 inches, and should be in all capital letters. Most documents that you print from a computer will have text at least twice that size; anything that will fit on 16 gauge wire will have to be very fine print!

If you are using Shrink Tube, remember that your text will shrink along with the tube; most shrink tubes will reach from one-half to one-third of their original size when in use. Continuing to use that rule of thumb, if you will be labeling a 0.25-inch cable with shrink tube, your initial text should have letters around 0.5 inches tall.

Since most design programs on computers, use “points” to measure text size, it may be helpful to remember another shortcut. As a rough estimate, you can multiply the intended height (in inches) of your capital letters by 100 to get the size for that text (in points). Capital letters that are 0.12 inches tall will be about 12-point, in most typefaces.

8.4. wiring enclosures

An electrical enclosure is a cabinet for electrical or electronic equipment to mount switches, knobs and displays and to prevent electrical shock to equipment users and protect the contents from the environment. The enclosure is the only part of the equipment which is seen by users. It may be designed not only for its utilitarian requirements, but also to be pleasing to the eye. Regulations may dictate the features and performance of enclosures for electrical equipment in hazardous areas, such as petrochemical plants or coal mines. Electronic packaging may place many demands on an enclosure for heat dissipation, radio frequency interference and electrostatic discharge protection, as well as functional, esthetical and commercial constraints.

Figure 41: A municipal electrical enclosure

9. Materials

Electrical enclosures are usually made from rigid plastics, or metals such as steel, stainless steel, or aluminium. Steel cabinets may be painted or galvanized. Mass-produced equipment will generally have a customized enclosure, but standardized enclosures are made for custom-built or small production runs of equipment

a. Stainless steel and carbon steel

Carbon steel and stainless steel are both used for enclosure construction due to their high durability and corrosion resistance. These materials are also moisture resistant and chemical resistant. They are the strongest of the construction options.

Stainless steel enclosures are suited for medical, pharm, and food industry applications since they are bacterial and fungal resistant due to their non-porous quality.[1] Stainless steel enclosures may be specified to permit wash-down cleaning in, for example, food manufacturing areas.

Figure 42: Stainless steel and carbon steel

b. Aluminium

Aluminium is chosen because of its light weight, relative strength, low cost, and corrosion resistance. It performs well in harsh environments and it is sturdy, capable of withstanding high impact with a high malleable strength. Aluminium also acts as a shield against electromagnetic interference.

Figure 43: Welded aluminium alloy bicycle frame

c. Polycarbonate

Polycarbonate used for electrical enclosures is strong but light, non-conductive and non-magnetic. It is also resistant to corrosion and some acidic environments; however, it is sensitive to abrasive cleaners. Polycarbonate is the easiest material to modify

Figure 44: Cell phone frame made from Polycarbonate

a. Fiberglas

Fiberglas enclosures resist chemicals in corrosive applications. The material can be used over all indoor and outdoor temperature ranges. Fiberglas can be installed in environments that are constantly wet

Figure 45: Fiberglas – Types

9.1. Tools and equipment

Tools and equipment are two words that are often used synonymously, mainly due to the similarities of their meanings. A tool can be any item that is used to achieve a goal. Equipment usually denotes a set of tools that are used to achieve a specific objective. A tool can be non-mechanical as well

Table 2 Tools

Type of screwdriver	Tools	Description and uses
Flat-blade		Older screws tend to have a slotted head. Flat-blade screwdrivers are designed to fit into this type of screw head. Available in all sizes from the small terminal driver type to large heavy duty versions.
Phillips		Most fixing screws now have Phillips-type heads. Phillips screwdrivers tend to be available in two sizes: smaller for terminal screws and larger for fixing screws.
Posidrive		Similar to Phillips, posidrive screws are often used as terminal screws. The posidrive's star shape makes for a firmer grip between the screwdriver and the screw itself.

9.2. Hammers

The hammer is probably the most basic item in the electrician's toolbox and is used for a wide variety of jobs, such as knocking in nails and driving a chisel through masonry or wood. Hammers are generally graded according to the weight of their head.

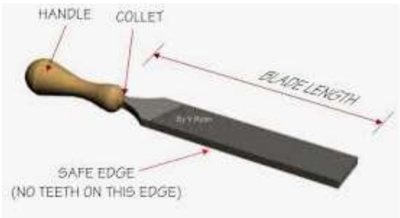
Table 3: Type of hammer

Type of hammer	Use
Claw hammer 	The claw hammer is two tools in one. The hammer face is used for general work and the claw is used for removing unwanted nails and other levering tasks. To remove a nail, the head is gripped between the two blades of the claw and the top of the hammer used as the fulcrum of a lever action.
Ball pein hammer 	Like the claw hammer, the ball pein is a combination tool with a standard striking face and a rounded second face. The ball pein was originally designed for driving in rivets.
Lump hammer 	Lump hammers are a heavy, block-headed tool usually used in combination with a cold chisel. This is a heavy tool so make sure you select a weight that is comfortable. A large two-handed version of the lump hammer is the sledge hammer, used for breaking up concrete and for general demolition type work.
Scotching hammer 	Used by electricians for cutting chases, the scotching hammer has replaceable blades or teeth that t into each end of its head.
Mallet 	The mallet can be either wood or a nylon type head. Mallets are used mainly in combination with wood chisels. The softer versions are also used for dressing cables, particularly mineral insulated, although they must be used with care when carrying out this type of job because striking the cable too hard could damage or misshape its outer sheath.

9.3. Files

Available in different sizes and levels of coarseness, les are generally used by the electrician for smoothing metal after cutting or drilling. Table shows the main types of file.

Table 4 Type of file

Type of file	Use
Flat files 	Used for - at surfaces, tapers in thickness and width at the front. A thinner version is known as a warding le and is used for ling narrow slots.
Hand files 	Has a safe edge with no teeth that can be used up to a shoulder without marking it.
Round files 	Sometimes called a rat-tail le for opening up holes or ling internal radii.
Square files 	Used for opening up square holes.
Three square files 	Used for ling square corners, sometimes called a triangular le
Knife files 	Used for tapered narrow slots and for very precise work.

Half round files 	Used to le the inside of curved surfaces.

Self-Check – 8	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Match the components in column A to their respective power plants in column B

Column A	Column B
5. Safe edge with no teeth	A. Round files
6. Sometimes called a rat-tail	B. Knife files
7. Used for opening up square holes	C. Three square files
8. sometimes called a triangular files	D. Square files
9. Used for tapered narrow slots and for very precise work.	E. Hand files

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer question

9.1. Definition about sensitivity

Sensitivity analysis is a process of varying input parameters of a model within allowed area and observing the resulting changes in the model solution. It explores how changes in the model output can be qualitatively and quantitatively attributed to different change sources.

Sensitivity analysis is a method for predicting the outcome of a decision if a situation turns out to be different compared to the key predictions. It helps in assessing the riskiness of a strategy. Helps in identifying how dependent the output is on a particular input value.

Strengthen "weak spots" As sensitivity analysis studies each variable independently, it can identify critical variables that may act as a weakness. For example In this analysis, we find out that the bond prices are extremely volatile to changes in inflation; we can take measures to reduce the impact, say by hedging.

Financial Sensitivity Analysis is done within defined boundaries that are determined by the set of independent (input) variables. For example, Sensitivity Analysis can be used to study the effect of a change in interest rates on bond prices if the interest rates increased by 1%.

9.2. Sensitivity Analysis (SA)

Investigates how the variation in the output of a numerical model can be attributed to variations of its input factors. SA is increasingly being used in environmental modelling for a variety of purposes, including uncertainty assessment, model calibration and diagnostic evaluation, dominant control analysis and robust decision-making. In this paper we review the SA literature with the goal of providing:

(i) P comprehensive view of SA approaches also in relation to other methodologies for model identification and application;

(ii) A systematic classification of the most commonly used SA methods;

(iii) Practical guidelines for the application of SA. The paper aims at delivering an introduction to SA for non-specialist readers, as well as practical advice with best practice examples from the literature; and at stimulating the discussion within the community of SA developers and users regarding the setting of good practices and on defining priorities for future research.

9.3. Purposes (settings) of SA

- ✓ Ranking (or Factor Priorization) aims at generating the ranking of the input factors x_1, x_2,…x_M according to their relative contribution to the output variability.
- ✓ Screening (or Factor Fixing) aims at identifying the input factors, if any, which have a negligible influence on the output variability.

Mapping aims at determining the region of the input variability space that produces significant, e.g. extreme, output values. The purpose of SA defines the ultimate goal of the analysis. It therefore guides the choice of the appropriate SA method since different methods are better suited to address different questions. Although SA is most commonly used for the three purposes above, our list is not exhaustive and other SA settings have been proposed.

9.4. SA and model calibration

Sensitivity Analysis is also closely connected to the process of model calibration. By 'model calibration' we mean here the process of estimating the model parameters by maximizing the model fit to (or at least consistency with) observations. SA can be used to support and complement a model calibration exercise by providing insights on how variations in the uncertain parameters (the input factors **x**) map onto variations of the performance metric (the output *y*) that measures the model fit. When an 'optimal' parameter estimate

- **Sensitivity analysis** is the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be divided and allocated to different sources of uncertainty in its inputs. A related practice is uncertainty analysis, which has a greater focus on uncertainty quantification and propagation of uncertainty; ideally, uncertainty and sensitivity analysis should be run in tandem.

The process of recalculating outcomes under alternative assumptions to determine the impact of a variable under sensitivity analysis can be useful for a range of purposes including:

- ✓ Testing the robustness of the results of a model or system in the presence of uncertainty.
- ✓ Increased understanding of the relationships between input and output variables in a system or model.
- ✓ Uncertainty reduction, through the identification of model inputs that cause significant uncertainty in the output and should therefore be the focus of attention in order to increase robustness (perhaps by further research).

- ✓ Searching for errors in the model (by encountering unexpected relationships between inputs and outputs).
- ✓ Model simplification – fixing model inputs that have no effect on the output, or identifying and removing redundant parts of the model structure.
- ✓ Enhancing communication from modeless to decision makers (e.g. by making recommendations more credible, understandable, compelling or persuasive).
- ✓ Finding regions in the space of input factors for which the model output is either maximum or minimum or meets some optimum criterion (see optimization and Monte Carlo filtering).
- ✓ In case of calibrating models with large number of parameters, a primary sensitivity test can ease the calibration stage by focusing on the sensitive parameters. Not knowing the sensitivity of parameters can result in time being uselessly spent on non-sensitive ones.[4]
- ✓ To seek to identify important connections between observations, model inputs, and predictions or forecasts, leading to the development of better model.

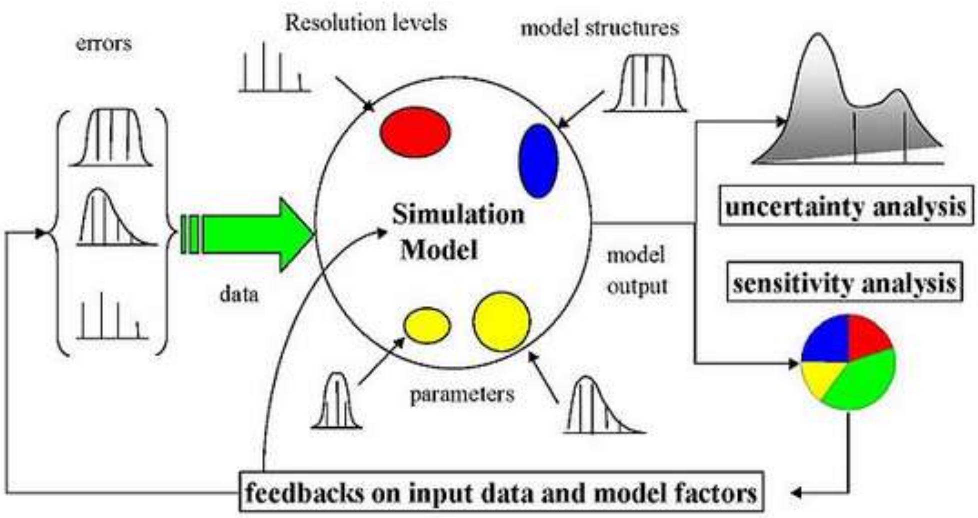


Figure 46: Sensitivity Analysis

9.5. Sensitivity auditing

It may happen that a sensitivity analysis of a model-based study is meant to underpin an inference, and to certify its robustness, in a context where the inference feeds into a policy or decision making process. In these cases the framing of the analysis itself, its institutional context, and the motivations of its author may become a matter of great importance, and a pure sensitivity analysis – with its emphasis on parametric uncertainty – may be seen as insufficient. The emphasis on the framing may derive inter-alia from the relevance of the policy study to different constituencies that are characterized by different norms and values, and hence by a different story about 'what the problem is' and foremost about 'who is telling the story'. Most often the framing includes more or less implicit assumptions, which could be political (e.g. which group needs to be protected) all the way to technical (e.g. which variable can be treated as a constant).

9.6. Purpose of the Checklist for Conflict Sensitivity in Education Programs

The Checklist offers a practical framework for analysing the operational and technical aspects of education programs. This ensures the reduction of conflict and tensions, which promotes equity and social cohesion and builds peace. With this Checklist, USAID expects Missions to develop and maintain a deeper, context- specific understanding of the underlying sources of conflict and their interaction, influence on, and impact within the education domain.

9.6.1. **Conflict sensitivity is** in education and why is it important? Conflict sensitivity in education includes:

• Understanding the context in which the organization or program is operating, particularly inter-group relations

• Understanding the interactions between interventions and the context/group relations; and

• Acting upon the understanding of these interactions in order to minimize negative impacts and maximize positive impacts of a program or other intervention. When education increases social tensions or division, it can contribute to conflict. For instance, if children or youth from one ethnic group have less access to education than those of other groups, or if a history textbook favors the dominant group, then this can increase tensions that may contribute to conflict. Conflict sensitivity requires diagnosing these elements and taking actions to remedy them. Education that is conflict sensitive encompasses policies, activities, and approaches that promote equitable access to educational opportunity and curricula based on skills and values that support peace and social cohesion.

- **Conflict sensitivity as "do no harm**" A minimum requirement of being conflict sensitive is to "do no harm"—keeping in mind the impact of education assistance on conflict. This requires making all decisions with an awareness of how they could affect power relations and inter-group relations that may contribute to conflict. For example, there should be enough awareness of the context to ensure that new programs do not favour one side of a conflict through language of instruction, teacher recruitment, or location of schools.
- **Conflict sensitivity** as promoting inclusion and equitable access By collecting and analysing data, we can determine who does and does not have access to education and why. Once this is determined, we can design and monitor our programs to meet education needs of marginalized and vulnerable population groups, thereby making education more inclusive and equitable. A conflict-sensitive education program may also work to actively transform tension and support peace by teaching respect for diversity, as well as local, national, and global citizenship.

Self-Check – 9	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions

1. Sensitivity analysis is a process of varying input parameters of a model within allowed area and observing.
2. Conflict sensitivity Understanding the context in which the organization or program is operating.
3. Sensitivity Analysis is also closely disconnected to the process of model calibration.
4. Sensitivity auditing It may happen that a sensitivity analysis of a model-based study is meant to underpin an inference.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1	Identifying the means of electrical isolation is accurately prior to commencing installation

Safe isolation procedure

Step 1. Identify the point of isolation for the system or circuit. Lock off, place warning label and keep the key to the lock with yourself

Step 2. Select the correct and mains approved test equipment and ensure that it works correctly by testing on the proving unit

Step 3. Test the outgoing side of the means of isolation (Main Switch, MCB, Fuse, etc.) to make sure it is dead. Depending on the type of the supply you will need to complete the following tests:

Step 4. Re-test the test equipment on the proving unit

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task 1. Measure the current, voltage & resister isolation (Main Switch, MCB, Fuse, etc.)

List of Reference Materials

1. ^ "Godalming Power Station". Engineering Timelines. Retrieved 3 May 2009.
2. ^ Williams, Jasmin (30 November 2007). "Edison Lights The City". New York Post. Retrieved 31 March 2008.
3. ^ Grant, Casey. "The Birth of NFPA". National Fire Protection Association. Archived from the original on 28 December 2007. Retrieved 31 March 2008.
4. ^ "Bulk Electricity Grid Beginnings" (PDF) (Press release). New York Independent System Operator. Archived from the original (PDF) on 26 February 2009. Retrieved 25 May 2008.
5. Saltelli, A. (2002). "Sensitivity Analysis for Importance Assessment". Risk Analysis. 22(3): 1–12. CiteSeerX 10.1.1.194.7359. doi:10.1111/0272-4332.00040.
6. ^ Jump up to:[a] [b] [c] Saltelli, A.; Ratto, M.; Andres, T.; Campolongo, F.; Cariboni, J.; Gatelli, D.; Saisana, M.; Tarantola, S. (2008). Global Sensitivity Analysis: The Primer. John Wiley & Sons

Solar PV System Installation and Maintenance
Level-II

Learning Guide-45

Unit of competence:-	**Install Wiring Systems in Conduit and connect Equipment**
Module Title:-	**Installing Wiring Systems in Conduit and connecting Equipment**
LG Code:	EIS PIM2 M02 LO2 **LG-45**
TTLM Code:	EIS PIM2**TTLM 1019v1**

LO2:- Install wiring system.

Instruction Sheet	Learning Guide 32

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Fixing wiring systems safely using PVC and flexible conduits
- Recording test data

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:-

- Fix the wiring systems safely using PVC and flexible conduits
- Record test data in the format required

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, in pages 70, 85, respectively.
4. Accomplish the Self-check 1, Self-check 2, in pages 84, 89, respectively
5. If you earned a satisfactory evaluation from the "Self-check" proceed to Operation Sheet 1in page 90.
6. Do the "LAP test" in page 91.

Information Sheet-1	Fixing wiring systems safely using PVC and flexible conduits

1.1. Introduction

A solar PV system is made up of multiple components that collect the sun's radiated energy, convert it to electricity and transmit the electricity in a usable form.
The main component is the solar panel, which is comprised of a group of individual solar cells that convert sunlight energy to electricity. The panels are held in place by a frame which is either fastened to an existing structure or is placed atop a stand that is mounted on the ground. Panels are typically comprised of 40 individual solar cells. Several panels connected together in series are identified as a "string" and often operate as a single generating unit, meaning if one panel becomes inoperable, it shuts down the entire string. Multiple strings assembled together into one solar facility are referred to as an "array."
The electricity produced by individual panels is direct current (DC) which is brought together in a combiner box and fed as a single DC flow to an inverter. The inverter converts the electricity that is produced by the PV cells from DC to alternating current (AC), a form that can be tapped by users of the electrical grid (grid-connected systems are also referred to as a grid-tie system).2 Disconnects are located in both the DC and AC lines to allow the utility company to interrupt electrical current during repair and maintenance.3 A breaker panel is necessary for protecting the system from short circuits and voltage surges. A utility meter accounts for the amount of electricity transfer between on-site service and the utility grid.

1.2. Components for wiring solar PV systems

Basic components of grid-connected PV systems with and without batteries are:

- Solar photovoltaic modules
- Array mounting racks
- Grounding equipment
- Combiner box
- Surge protection (often part of the combiner box)
- Inverter
- Meters – system meter and kilowatt-hour meter
- Disconnects:
  - ✓ Array DC disconnect
  - ✓ Inverter DC disconnect
  - ✓ Inverter AC disconnect
  - ✓ Exterior AC disconnect

If the system includes batteries, it will also require:

- Battery bank with cabling and housing structure
- Charge controller
- Battery disconnect

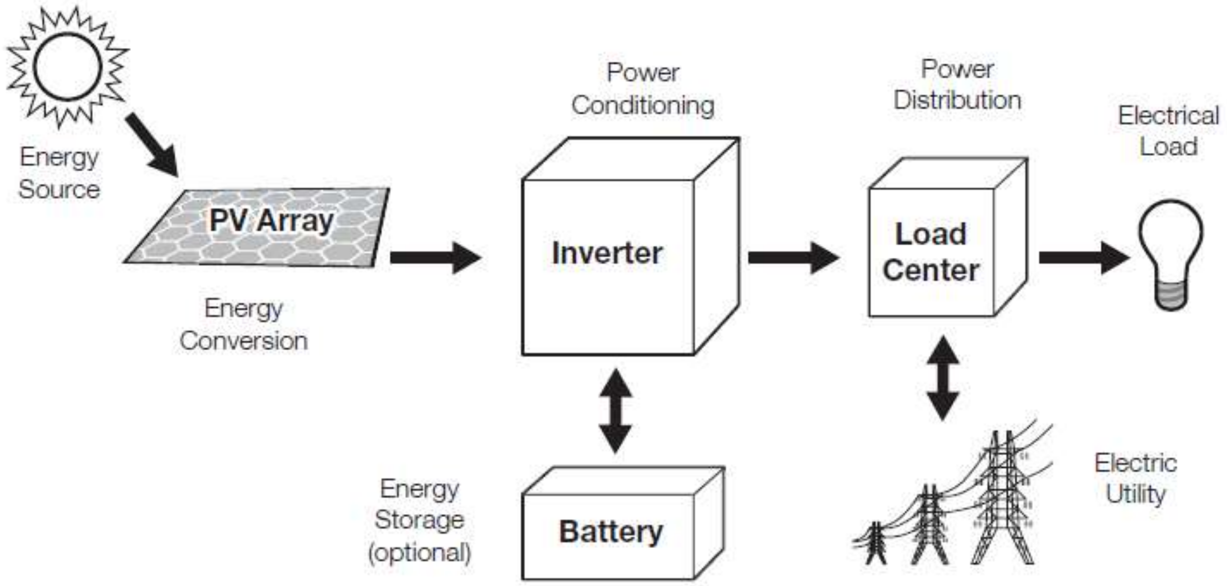


Figure 47: **PV system overview**

- **Solar Modules**

The heart of a photovoltaic system is the solar module. Many photovoltaic *cells* are wired together by the manufacturer to produce a solar *module.* When installed at a site, solar modules are wired together in series to form *strings*. Strings of modules are connected in parallel to form an *array*.

- **Array Mounting Racks**

Arrays are most commonly mounted on roofs or on steel poles set in concrete. In certain applications, they may be mounted at ground level or on building walls. Solar modules can also be mounted to serve as part or all of a shade structure such as a patio cover. On roof-mounted systems, the PV array is typically mounted on fixed racks, parallel to the roof for aesthetic reasons and stood off several inches above the roof surface to allow airflow that will keep them as cool as practical.

- **Grounding Equipment**

Grounding equipment provides a well-defined, low-resistance path from your system to the ground to protect your system from current surges from lightning strikes or equipment malfunctions. Grounding also stabilizes voltages and provides a common reference point. The grounding harness is usually located on the roof.

- **Combiner Box**

Wires from individual PV modules or strings are run to the combiner box, typically located on the roof. These wires may be single conductor pigtails with connectors that are pre-wired onto the PV modules. The output of the combiner box is one larger twowire conductor in conduit. A combiner box typically includes a safety fuse or breaker for each string and may include a surge protector.

- **Surge Protection**

Surge protectors help to protect your system from power surges that may occur if the PV system or nearby power lines are struck by lightning. A power surge is an increase in voltage significantly above the design voltage.

- **Meters and Instrumentation**

Essentially two types of meters are used in PV systems:

- ✓ **Utility Kilowatt-hour Meter**
- ✓ **System Meter**

Utility Kilowatt-Hour Meter – The utility kilowatt-hour meter measures energy delivered to or from the grid. On homes with solar electric systems, utilities typically install bidirectional meters with a digital display that keeps separate track of energy in both directions. Some utilities will allow you to use a conventional meter that can spin in reverse. In this case, the utility meter spins forward when you are drawing electricity from the grid and backwards when your system is feeding or "pushing" electricity onto the grid.

System Meter – The system meter measures and displays system performance and status. Monitored points may include power production by modules, electricity used, and battery charge. It is possible to operate a system without a system meter, though meters are strongly recommended. Modern charge controllers incorporate system monitoring functions and so a separate system meter may not be necessary.

- **Inverter**

Inverters take care of four basic tasks of power conditioning:

- Converting the DC power coming from the PV modules or battery bank to AC power
- Ensuring that the frequency of the AC cycles is 60 cycles per second
- Reducing voltage fluctuations
- Ensuring that the shape of the AC wave is appropriate for the application, i.e. a pure sine wave for grid-connected systems

- **Disconnects**

Automatic and manual safety disconnects protect the wiring and components from power surges and other equipment malfunctions. They also ensure the system can be safely shut down and system components can be removed for maintenance and repair. For grid connected systems, safety disconnects ensure that the generating equipment is isolated from the grid, which is important for the safety of utility personnel. In general, a disconnect is needed for each source of power or energy storage device in the system.

- **Battery Bank**

Batteries store direct current electrical energy for later use. This energy storage comes at a cost, however, since batteries reduce the efficiency and output of the PV system, typically by about 10 percent for lead-acid batteries. Batteries also increase the complexity and cost of the system.

Types of batteries commonly used in PV systems are:

- Lead-acid batteries
    - Flooded (a.k.a. Liquid vented)
    - Sealed (a.k.a. Valve-Regulated Lead Acid)
- Alkaline batteries
    - Nickel-cadmium
    - Nickel-iron

1.3. Charge Controller

A charge controller, sometimes referred to as a photovoltaic controller or battery Charger is only necessary in systems with battery back-up. The primary function of a charge controller is to prevent overcharging of the batteries. Most also include a low voltage disconnect that prevents over-discharging batteries. In addition, charge controllers prevent charge from draining back to solar modules at night. Some modern charge controllers incorporate maximum power point tracking, which optimizes the PV array's output, increasing the energy it produces.

I. Installation Procedures, Safety and Protection

The actual installation procedure begins with the design of installation diagram, site selection for installation of array and battery bank, preparation of bill of quantities of the required items, installation materials and list of safety measures. In this chapter, overview will be given to the various steps of installations pertaining to non-pumping applications. However many of these could also be applied to pumping applications as well.

The installation process for smaller systems consisting of one module, a CR, a battery and few DC loads may be very simple. But the larger systems require special attention to minimize probability of system failure and also to minimize overall cost of the system.

II. Line Diagram for Installation

The entire PV system should be diagrammed before final costing and installation. The diagram should include wiring of modules in the array or sub-arrays, regulators; AC and DC load centers, battery bank, inverter, grounding and circuit protection.

For a very simple system such as solar home systems, a simple wiring plan can be sketched as shown in figure.2 below.

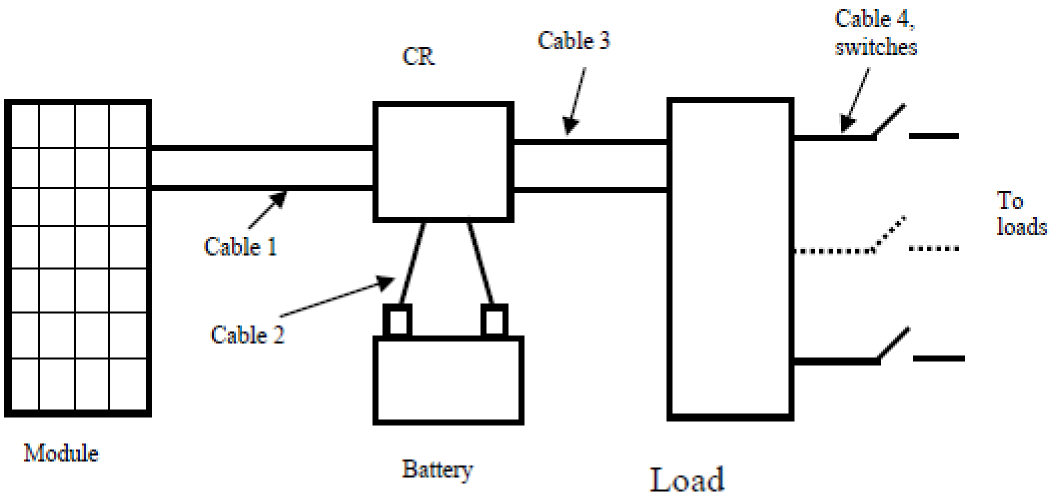


Figure 48: Installation diagram for simple PV system

The module capacity; length and size of wires; type and model of CR; type, capacity and voltage of the battery; load center details etc. are to be indicated in the diagram for easy installation process. However, actual location of the components of the system will depend upon the plan of the building where the system is to be installed. Selecting the best locations for mounting the module and installing the CR, battery and load center can minimize the required length of the cables.

III. Special Considerations in Wiring PV Systems

In wiring solar PV systems, there are at least two concerns that an electrical contractor or electrician may not have previous experience with. First, the system on the array side of the inverter must be designed for DC power, which requires larger wire sizes than for AC power at the same voltage. Second, array wiring must be sized and selected to withstand elevated temperatures. The *ampacity*, which is the current-carrying ability of a wire, must be adjusted to account for temperature conditions that occur in PV systems.

Exterior Wiring – For PV systems in general, wiring in exterior locations must be suitable for the outdoor, wet environment; suitable for exposure to sunlight; and able to operate in temperatures in the range of 65-80oC (149-176° F). Wiring will be subjected to the highest temperatures in the junction boxes of solar modules; these conductors should have insulation rated for 90oC (194° F).

Module Pigtails – In contrast to other NEC articles, NEC 690 allows exposed, single conductor cables for interconnecting PV modules. This allows PV modules to be manufactured with permanently attached pigtail conductors with multi-contact (MC) connectors on the ends. Such module pigtails are becoming standard and significantly reduce the labor required for installing the array.

Roofing Penetrations for Conduit – Particular attention should be paid to sealing around roof penetrations for conduit. As with sealing around the array mounting brackets, this is best handled by the roofing contractor to ensure the roof warranty is not voided.

IV. Preparing Shingle Roof for Installation

1. Locate roof rafters or trusses.

Here are 3 options to finding the locations:

A. Locate and measure the locations of the rafters in the attic or at the outside eave and transfer measurements to the roof.
B. Use a hammer or rubber mallet to tap the roof and locate the rafters. This will work with a cap sheet or composition roof.
C. . Scan the roof with a high sensitivity stud finder.

2. Once the rafters have been located, snap a vertical chalk line on every rafter to identify the location.
3. Measure up from the eave 16" (400 mm) in at least 3 locations. Snap a chalk line. This marks the location of the bottom edge of the slider feet.

   Note: This line needs to be 0.22" (5.5 mm) away from the nearest front edge of shingles.
4. Measure up from chalk line 0.8" (20 mm) and snap a new chalk line. This marks the location of the bottom edges of the modules.
5. Measure up from the module chalk line to the desired module height to form the array. Snap horizontal lines at the measured locations for each row of rail.
6. Mark and layout solar module vertical lines.

   Note: modules should not fall in shaded areas.

V. Seven Steps How to Install Solar Panels

Let us talk about how to install solar panels. You can use the services of an EPC installer or can do-it-yourself. Given below is the solar installation guide for an off grid solar system which is simple and easy. A prospective solar buyer can read this blog and understand how to install solar panels on his own at his home.

Step – 1: Solar Panel Installation Made Easy

Which direction should be the solar panel face?

The mounting structure provides the base for the entire solar system so make sure it is sturdy and properly fastened to the rooftops of your house or commercial establishment. A typical mounting structure is made up of aluminum. The performance of the solar panels depends upon the direction in which these panels are placed. The best direction to face solar panels is south, since here they receive the maximum sunlight. East and West directions also work well. North is the only direction that we should not want to put our panels on. Since India lies in Northern Hemisphere, south direction works best here.

Figure 49 :**Roof top Solar Mounting Structure**

Rooftop Solar Mounting Structure is used to fix solar panel with it. You can fix both mono crystalline and polycrystalline panel with it. This is ready to use structure of 1 kw, offered by loomsolar.com. You can connect 4 panel of 270 watt.

In Which angle should you install solar panels?

The Solar panel tilt angle (the angle between the horizontal ground and the solar module) should be decided according to the latitude of your location anywhere in the world. It is generally believed that the modules placed at a tilt angle equivalent to the latitude of the place, would generate the maximum energy output. You can also use a solar tracker to increase the conversion efficiency.

Step – 2: Assemble Solar Panels

Once the solar structure is fixed accurately, we will connect it with solar modules. We should ensure that all nuts and bolts of solar modules are fixed with solar structure so that it is properly secured and lasts long.

Figure 50: Assembled Solar Panels

Step-3: Electrical Wiring

MC4 connectors are used to connect solar panels. These are universal connectors and can be connected with any type of solar panels. The solar array wiring becomes simpler and faster using MC4 connectors.

Figure 51: MC4 connectors

Few modern solar modules come with wire leads that have MC4 connectors on the ends, else they have a built-in junction box at the back with wires jotting out. In a series connection you will have to connect the positive wire from one module to the negative wire of another module. In a parallel connection, you connect the positive to positive and negative to negative leads. A parallel connection maintains the voltage of each panel while a series connection increases the voltage in order to match it with the battery bank.

Step-4: Connection between Solar Panel and Solar Inverter

In the picture given below, the backside of an inverter is shown where solar panel wire is connected. Connect the positive wire from the solar panel with the positive inverter terminal and the negative wire with negative terminal of the inverter.

Figure 52: Solar Panel and Solar Inverter connection

There are other connections too like battery wire connection and output wire connection with the inverter. In all, Solar panel, Solar Battery and Grid input are connected with the solar inverter to produce electricity. The output of a series string of solar modules is connected to the input of the inverter. Make sure the inverter is turned off while the connections are being done.

Step-5: Connection between Solar Inverter and Solar Battery

In an off grid solar system, Battery is mandatory where it is used to store power backup. This battery is connected with solar inverter to recharge it with solar panel and grid. The positive terminal of the battery is connected with the positive of the inverter and vice versa.

Figure 53: Solar Inverter and Solar Battery Connection

Step-6: Connection between Solar Inverter and Grid

In order to connect the inverter to the grid simply plugs it in in the main power switch board, so that it gets power from the grid. The output wire is also connected with board that is supplying electricity in home.

Figure 54: Connection between Solar Inverter and Grid

In order to calculate the excess energy generated from the solar system we need to install a metering device. We need to connect the positive wire from the metering device with the line terminal and the negative wire to the neutral terminal of the inverter.

Step-7: Start Solar Inverter through Solar Panel & Grid

After all the connections are done, we switch on the mains. There is a digital display which shows the total solar unit generated during the day, what is supply volt and current (amp) from solar panel etc. In the picture below is shown the front side of Microtek solar inverter.

Figure 55: Front side of Microtek solar inverter

VI. Installing Conduit

Before you learn how to install conduit, let's first learn exactly what conduit is.

Conduit is hard**,** durable protective tubing that completely covers and protects wires or cables used in electrical applications that typically need protection from exposure to sunlight and other elements.

When installing conduit, wire is pulled through the conduit tubing and then typically passed through walls, under driveways, secured to the exterior and even to the interior of a house. Basically conduit installation protects the wires running through your walls, underground, on your roof, or down the side of your house.

- Types of Conduit

Some of the more popular types of conduit that are used in electrical work include: rigid-steel, electrical metallic tubing (EMT), rigid non-metallic (poly vinyl chloride - PVC), and flexible metallic and non metallic conduit.

✓ **Rigid Non metallic (PVC) Conduit**

Rigid Non metallic Conduit (also known as PVC conduit) is made of a rugged plastic and thus is ideal for underground conduit installations including direct burial and concrete encasement installation. Installing conduit that is made out of plastic is cheaper, plus it's strong, waterproof and has a low absorption rate.

To cut it, you'll need a hacksaw or tubing cutter and possibly a clamp or vise to keep it from moving. Cut at a 90° angle. After cutting, you'll need to file the sharps edges down.

PVC conduit is available in sizes from 1/2 inch to 5 inches in diameter and up to 20 feet in length.

✓ **Flexible Metallic Conduit**

Flexible metallic conduit is made of either steel or aluminium and typically used for conduit installation in areas where there may be movement or vibration. You can also get it for use in wet conditions.

To cut it, you'll need a hacksaw and possibly a clamp or vies to keep it from moving. Cut at a 90° angle.

Flexible metallic conduit is available in sizes from 3/8 inches to 4 inches in diameter and you can basically get any length you want.

- **Conduit Installation**

Installing conduit consists of measuring out the length of the conduit, cutting, threading and bending it to fit the requirements of your project, installing the fittings and supports, securing the conduit into place and installing the couplings/connectors, connecting to the outlet boxes, pulling the conductor (wire) through the conduit tubing and making / securing / testing the connections.

When installing conduit make your runs of conduit as straight and direct as possible and avoid any unnecessary bends.

- **Fish Tapes & Conduit Tools**

Pulling wire and working with conduit is very challenging without the proper tools. Klein Tools' complete line of conduit tools allows you to get the job done while saving time, effort and materials.

a) Fish Tape Pulling & conduit Pliers **b)** Fish Tapes c) PVC Cutters

Figure 56: Fish Tapes & Conduit Tools

- **Pulling Wire with a Fish Tape**

The most commonly used tool for pulling wire through conduit is fish tape, an electrician's tool with a long, flat metal wire wound inside a wheel-shaped spool. Fish tapes are widely available in a range of lengths starting at 25 feet. There are also nylon tapes that don't include a spool; these may be the most economical option for when you need a fish tape only for small jobs.

1. Feed the end of the tape, which has a hook on it, into the same end of the conduit that you will pull from.
2. Push the tape through the conduit, unwinding from the spool as you go. Stop feeding when the hook end emerges from the opposite end of the conduit.
3. Strip insulation from the end of each wire, using wire strippers. Strip each wire a different amount. For example, if there are three wires, strip one about six inches, one about four inches, and one about two inches.
4. Hold the three wires together so their insulation is aligned. Grab all three with linesman's pliers and twist their bare ends together.
5. Bend the longest wire into a hook and loop it through the hook of the fish tape, then wrap the loop closed.
6. Wrap the fish tape hook and the bare wire ends with electrical tape.
7. Apply lubricant to the tape, if desired. Feed the wires into the conduit while your partner pulls them through from the other end by pulling on the fish tape.

VII. Safety during the Installation

Solar systems require that engineers and electricians work on the roof. It’s the builder’s responsibility to provide the safe practices during the installation. Improper safety equipment can result in fines to the builder while installation of solar plant. A main problem is occurring in solar systems is that solar modules generate DC electricity when exposed to sunlight. As well, solar systems may be of multiple electrical modules, the utility grid and batteries. Manufacturers of modules and other electrical components will provide safety precautions by manual of safety precaution carefully followed. While installing the modules on the roof, at least one safety eye must be installed. Work should be done under some experts and experienced person to supervising the installation of solar plant.

Power arrays, when exposed to the sun, can produce several hundred volts of dc power. Any contact with an exposed or uninstalled component of the PV array can produce serious burns and fatal electric shock. The electrical wiring design and installation methodology are subject to rigorous guidelines. Some important safety precautions to be necessary as follow:

- ✓ Do not attempt to service any portion of the PV system unless you understand the electrical operation and are fully qualified to do so.
- ✓ Use modules for their intended purpose only. Follow all the module manufacturer's instructions. Do not disassemble modules installed by the manufacturer.
- ✓ Do not open the diode housing and junction box placed on any factory-wired modules on back side.
- ✓ Do not use modules in systems that can exceed 600 V open circuit.
- ✓ Do not connect or disconnect a module unless the array string is opening circuited. All the modules in the series string are covered with non transparent material.
- ✓ Do not install in stormy and rainy season.
- ✓ Take care from falling any object on solar module.
- ✓ Do not stand or step on modules.
- ✓ Do not work on PV modules when they are wet. Keep in mind that wet modules when cracked or broken can expose maintenance personnel to very high voltages.
- ✓ Do not attempt to remove snow or ice from modules.
- ✓ Do not direct artificially concentrated sunlight on modules.
- ✓ Do not wear jewellery when working on modules.
- ✓ Avoid working alone while performing field inspection or repair.
- ✓ Wear suitable eye protection glasses and rubber gloves while working on panel.
- ✓ Do not touch terminals contacts (conducting parts) while modules are exposed to light without wearing electrically insulated rubber gloves.
- ✓ Keep the fire extinguisher always ready, a first-aid box while performing work on a solar plant.
- ✓ Do not install modules where flammable gases or vapors are present.

Self-Check -1	Written Test

Directions: - For the following statements, write TRUE if it is correct or write FALSE if it is incorrect on another answer sheet.

1. Solar panel is the main component In PV system.
2. An inverter converts the electricity that is produced by the PV cells from AC to DC.
3. Arrays are always mounted on roofs or on steel poles set in concrete.
4. Grounding equipment provides a well-defined, low-resistance path for current flow.
5. In PV system, batteries store direct current electrical energy for later use.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-2	Recording test data

1. **Introduction to Solar Panel Testing**

Solar PV panels are subjected to a variety of tests. Via the solar panel tests, safety and compliance with the minimum quality standards are checked, of which passing is a precondition to getting approval for the solar modules.

2. **Solar panel test criteria and procedures**

There are two types of solar panel tests,-

- the tests, which check the minimum requirements for the approval and
- the advanced testing procedures, which assess the quality of solar PV panels of solar PV panels.

The first tests check the solar PV panels in accordance with given norms and standards.

The latter examines the quality of solar PV panels and evaluates these using advanced test criteria. These quality tests enable users to compare different solar panel types on the basis of quality or test seals.

The different testing procedures are used for the assessment and appraisal of solar PV panels. They vary in terms of their test and measurement criteria and the use of measurement methods.

- **Test procedures for the approval of solar PV panels**

Certain minimum requirements must be fulfilled to get approval for a solar module. These ensure the safe operation, the suitability of the components and the functionality of solar PV panels.

One of the most important solar panel testing procedures is the IEC certification. It indicates that the solar PV modules **comply** with individual safety, quality and durability requirements.

In these tests, the solar PV panels are subject to various loads, which are defined by the so-called ICE standards. The standards were established by the International Electro technical Commission (IEC) in Geneva.

During the tests, solar PV panels are subject to various loads. This includes, for example, the impact of external influences, which are generated artificially on the solar panel degradation, what effect mechanical loads have as well as different climatic conditions (heat, cold, humidity, climate change or the UV solar radiation) on the solar PV panels.

A successful passing of the tests is a precondition for the approval for solar PV modules. The solar PV panels have successfully passed the tests if no serious changes occur in their behaviour or no significant loss of performance at different climatic conditions is reported.

- **Standard Test Conditions (STC) tests**

Another central solar panel test procedure is the standard test conditions-tests (STC-tests**),** which are run for all solar PV panels.

They enable the evaluation and **comparison** of different solar panel types, by determining current, voltage and power of solar PV panels under comparable test conditions.

The solar PV modules are **subjected** to a solar radiation of 1000 W/m², a module temperature of 25°C and an air mass coefficient of 1.5. The determined power is given in Watt peak.

In addition to laboratory tests, the solar PV panels are also **exposed** to **real** conditions. In these tests, the investigations **occur** at the place, where the solar PV panels will be installed, either on the roof of a building or a large open area.

In addition, other criteria become relevant to the performance examination of solar PV panels and are considered in the calculations. These include a minimal solar radiation of 800 W/m², a temperature determination and its consideration by value calculations and the angle of incidence, which is determined with the aid of inclinometer.

- **NOCT-Test**

Another solar panel test procedure is the NOCT-Test. NOCT stands for Normal Operating Cell Temperature.

With the help of NOCT-Tests, loads of the materials of the solar modules are properly evaluated, and the heat radiation to the environment is determined**.**

NOCT is therefore considered as a standard measure for the assessment of the PV systems components.

The NOCT average values are:

- Wind speed 1m/s (is the lower section of the wind strength 1 (3,6 km/h)
- An irradiance of 800 W/ m²
- Air Mass of 1,5
- Air Temperature of 20°C
- Electrical voltage at no load and in an open-circuit

  ✓ The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light-generated current.

  A solar panel which is rated at 17 volts will put out less than its rated power when used in a battery system. That's because the working voltage will be between 12 and 15 volts. Because wattage (or power) is the product of volts multiplied by the amps, the module output will be reduced.

NOCT is measured in the approval test of solar PV panels.

3. Documents to be furnished during PV Installation

1. Computer print/ Blue print of electrical drawings showing**:** Single line diagram of the installation, indicating rating, size and details of protection, details of loading, net metering system (Bidirectional).
2. Site plan locating the proposed roof top solar equipment's.
3. Plan and elevation of the solar unit, inverter unit and control panel showing all round clearances etc.
4. Details of earthling provided for the proposed installation.
5. Requisite fees paid receipt for drawing approval
6. Structural stability certificate obtained from the certified structural engineer for the roof of factory shed / poultry farm / ware house where proposed solar PV modules are be erected.
7. Clear title deeds/ sale deed proof for owning the factory shed / poultry farm / ware house / land.
8. NOC / approval from competent authority for factory shed / poultry farm / ware house

4. Inspection and Issue of Safety Approvals

After completion of solar roof top installation work, the following documents shall be submitted by the consumer for pre-commissioning inspection.

1. Requisition letter of the owner/tenant of the installation.
2. Work completion report in the prescribed format which is duly signed by Licensed Electrical Contractor, Concerned Supervisor and the prospective consumer.
3. Requisite inspection fees paid receipt /Chillan as per fees notification.
4. Manufacturers test report of the solar roof top installation & Calibration report of Energy meter and connected current transformers and protective relays if any.
5. List of authorized persons who will operate at the said installation.
6. At the time of inspection a responsible representative of the Consumer / Electrical supervisor should be present along with testing instruments.
7. The defects pointed out during the inspection should be rectified in order to bring the installation in general conformity with the CEA (Measures Relating to Safety and Electric Supply) Regulations, 2010 and a rectification report signed by the consumer, and contractor should be sent to the jurisdictional officer of the Electrical Inspectorate.
8. After verification of the compliance report by the inspecting officer safety approval will be granted under Regulation 32 of CEA (Measures Relating to Safety and Electric Supply) Regulations, 2010

Self-Check 2	Written Test

Directions: - Match the following questions from column "B" to column "A"

Column "A"	**Column "B"**
…….1. Advanced testing procedures	A. Loads are evaluated properly
……..2. Check the minimum requirements	B. Approving with given norms &standards
……..3. NOCT-Tests	C. examines the quality of solar PV panels
……..4. STC tests	D. establish standards
..…….5. IEC	E. **evaluate** & **compare** different solar panels

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Operation Sheet 1	Fixing wiring systems safely using PVC and flexible conduits

Operation Title: Installing a PV System.

1. Wear your related PEES (safely clothes)
2. Ensure the roof area is capable of handling the desired system size.
3. Select hand tools, instruments & materials related to the project..
4. Have a line diagram of PV installation
5. Take all measurement data on the roof
6. Finally check quality of your project
7. clean, check and return tools, equipment and any surplus resources and materials to storage

.

LAP Test 1	Fixing wiring systems safely using PVC and flexible conduits

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: By using approved diagram, tools equipment and materials you are required to perform the following tasks within 2 hour.

.

Task- 1. Properly seal any roof penetrations with roofing industry approved sealing methods

Task- 2. Install equipment according to manufacturer's specifications, using installation requirements and procedures from the manufacturers' specifications

Task- 3. Properly ground the system parts to reduce the threat of shock hazards and induced surges

Task- 4 do open -circuit, short-circuit and ground tests properly

Task- 5. Check for proper PV system operation by following the checkout procedures on the PV System Installation Checklist.

Instructions: By using approved diagram, tools equipment and materials you are required to perform the following tasks within 2 hour.

List of Reference Materials

Honsburg, C. & Bowden, S. (2016). Short-circuit current. PVEducation.Org. Available at: www.pveducation.org PV-Cables, Inc. (2016). Available at: http://www.pv-cables.com

Schwartz, J. (February – March, 2005). Tools of the solar electric trade. Home Power Magazine 105, 22-26. Available at: www. homepower.com

Solar PV System Installation and

Maintenance

Level-II

Learning Guide -46

Unit of Competence	Install Wiring Systems in Conduit and connect Equipment
Module Title	Installing Wiring Systems in Conduit and connecting Equipment
LG Code	**EIS PIM2 M07 LO3 LG-46**
TTLM Code	**EIS PIM2 TTLM 0819v1**

LO3:- Connect wiring system and equipment

Instruction Sheet	Learning Guide:-33

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- Complying with IEE wiring regulations
- Checking electrically and mechanically sound connections
- Identifying appropriate safe and sensible defective parts

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:-**

- Comply with IEE wiring regulations
- Check electrically and mechanically sound connections
- Identify appropriate safe and sensible defective parts

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, in pages 95, 105, and 113, respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, in pages 104, 112, and 123, respectively
5. If you earned a satisfactory evaluation from the "Self-check" proceed to Operation Sheet----

Information Sheet-1	Making connections complying with IEE wiring regulations

Wiring and Fittings

Harvested electricity is distributed between different parts using electric cables and fittings. To make efficient use of the energy collected by the modules and stored in batteries, you must choose the right size and type of cables and fittings. Wiring procedures are broadly similar in extra-low-voltage DC systems and in higher-voltage AC systems, but there are important differences, as explained below.

This module describes extra-low-voltage DC cables and fittings for small solar electric systems. Topics covered include: choosing cable size and type, choosing fittings (switches, fuses, connector strips, etc.) and methods of earthing (grounding) the system.

Figure 7.1 Common types of wiring cable

Wiring Cable

Make sure to choose the proper cable size and type when planning your system (note that the terms 'wire' and 'cable' are used interchangeably in this chapter). Copper cable is available in various sizes: 1.0mm^2, 1.5mm^2, 2.5mm^2, 4.0mm^2, 6.0mm^2, and 10.0mm^2. (See Figure 7.1). This size refers to the cross-sectional area of the wire; in the US and Canada, the American Wire Gauge, AWG, is used to indicate cable sizes.) Table 7.1 lists common international and North American sizes of cables and their resistance values (see below).

While AC systems normally distribute power using smaller sized cables (i.e. 1.0 or 1.5mm^2), 12V DC systems ordinarily use cable of at least 2.5mm^2 or

Larger. Flexible/stranded two-core cable of 2.5mm^2 size is ideal for many 12V

Table 7.1a Copper cable size and resistance(metric sizes)

Cable Size	Resistance in ohms per meter (□/m)
2.5mm2	0.0074
4.0mm2	0.0046
6.0mm2	0.0031
10.0mm2	0.0018
16.0mm2	0.0012
25.0mm2	0.00073
35.0mm2	0.00049

Table 7.1b Copper cable size and resistance
(American sizes)

American Wire Gauge (AWG)	Size in mm2	Resistance in ohms per foot (□/ft)
14	(2mm2)	0.002525
12	(3.31mm2)	0.001588
10	(6.68mm2)	0.000999
8	(8.37mm2)	0.000628
6	(13.3mm2)	0.000395
4	(21.15mm2)	0.000249
2	(33.62mm2)	0.000157
1	(42.41mm2)	0.000127
0	(53.5mm2)	0.000099

Note: These measurements are for a one-way run, meaning they must be doubled when making resistance calculations

Distribution circuits and larger sizes are also available. Stranded wires, being considerably more flexible, are easier to work with and fix to walls, and are used a lot in smaller solar home systems. Choosing the right cable is important from a safety and ease-of-work point of view. If in doubt get advice.

Three-core cables – wires that have a separate ground or 'earth' wire – are used in larger DC and AC systems (i.e. for circuits that serve DC and AC equipment receptacles respectively). Again, note that use of earth/ground cables requires qualifications and knowledge of local codes and standards.

Be careful when using colour codes to indicate DC polarities in cables. Different countries use different colour codes for polarities. The two most common colour combinations used are: brown (+) and grey or blue (–); or red (+) and black (–). Earth wires are mainly green/yellow. When selecting cable Colours always keep to local standards. In the case of appliance cables (which may not match local standards), check the instructions for information.

Table7.2 below shows the current IEE (Institute of Electrical Engineers) DC cable marking and colour codes.

Table 7.2 IEE DC cable marking and colour code

Function	Marking	Colour	Note
Two-wire unearthed DC power circuit			
Positive of two wire	L+	Brown	Previously red, still used in places
Negative of two wire	L–	Grey	Previously black, still used in places
Two-wire earthed DC power circuit			
Positive (of negative earthed) circuit	L+	Brown	Previously red, still used in places
Negative (of negative earthed) circuit	M	Blue	Previously black, still used in places
Positive (of positive earthed) circuit (rare)	M	Blue	
Negative (of positive earthed) circuit (rare)	L–	Grey	

In reality, installers use cables that are locally available. If these are not the right colour, mark the colour code or label cables (+ and –) using insulating tape. Remember, the point of colour codes is to make sure that anyone modifying or repairing the system afterwards knows which cables are positive and negative. AC cables are also colour-coded. Just because cables are carrying 12V DC or 24V DC does not mean that installation standards can be lower than they are in 230/110V AC house mains wiring! A short circuit in a 12V DC system can cause a fire as easily as in an AC circuit. The larger the system the larger the risk. Large DC distribution systems are often installed in hospitals and schools. These circuits need to be installed and tested as specified in electrical codes using the correct instruments.

Some important points to remember:

- Cables laid where they will be exposed to the sun should either be specially selected sunlight-resistant cable (IEC 60811) or they should be encased in the right type of sun-resistant conduit, which is a special type of plastic pipe used for enclosing electric wire.
- When DC cables pass underground or up outside walls, they should be run through a conduit (or they should be armored).
- Always refer to and comply with local codes.

Switches, Sockets and Fuses

Switches

Switches are used to turn appliances and other loads on and off. They also serve the important purpose of disconnecting modules, batteries and loads during servicing and emergencies. Always select the right type and size of switch for the purpose.

Switches and disconnects need to be properly rated for the circuit in which they are being installed – in terms of current and voltage. A switch or disconnect in a 12V DC circuit needs to be rated for 12V DC and the maximum current expected in that circuit, while a switch or disconnect in a 220V AC circuit needs to be rated for 220V AC and the maximum current expected in that circuit.

Many switches and disconnects are rated for both DC and AC current/voltage, though the values for AC and DC may be different. When 220V AC switches must be used to turn lights or small appliances on and off (e.g. because suitable 12V DC switches are not available, which is often the case) always make sure that their nominal current rating is twice the maximum expected DC current. Only use the proper DC-type switches of the correct voltage and current rating on main switches that control high current DC appliances, PV array or battery circuits. Improperly used AC switches may burn up or arc, and may cause dangerous short circuits or fires! (See Figure 7.2.)

Figure 7.2 Common AC switches for lighting circuits

Sockets

Sockets (or power outlets) are receptacles into which the plug is inserted to access power for appliances. In DC circuits ‘DC sockets’ must be used. Mixing up AC and DC sockets and plugs can be extremely dangerous. DC sockets are a different shape to AC sockets to prevent AC appliances from being plugged into them (see Figure 7.3).

Firstly, there is the possibility that the wrong appliances might get plugged in, damaging the appliance. Secondly, AC sockets are designed for low currents and may not be able to handle the high current of DC circuits. Also, it is extremely dangerous if a 12V DC appliance which has been fitted with a 110/220V AC plug is plugged into an AC socket.

Figure 7.3 DC sockets and plug

Fuses and miniature circuit breakers (MCBs)

Fuses are devices placed in circuits to prevent accidental damage to appliances, modules and charge-controller circuitry from high current normally associated with short circuits. The very high current that batteries will deliver under short circuit conditions can cause fires, extensive damage or even explosions! Ideally, in a system, there should be a fuse on each of the battery, solar array and load circuits.

When a short circuit occurs, or there is an overload, the fuse 'blows' (i.e. a strip of wire inside melts) and opens the circuit so that current cannot flow. Once a fuse has blown, the cause of the high current should always be investigated and repaired before replacing the fuse with a new one of the same rating. Miniature circuit breakers (MCBs) are small switches that automatically break the circuit when there is a short circuit or overload. Unlike fuses, they can be switched back on once the wiring problem has been corrected. DC-rated fuses and circuit breakers should be used in DC circuits, and AC-rated fuses and circuit breakers should be used in AC circuits. They also need to be correctly rated for the circuit voltage.

As a minimum safety precaution, all small systems (less than 100Wp) require at least one fuse: the main battery fuse. Larger systems should have a fuse to protect each major circuit, the battery and the module/array. If there are loads that need to be protected independently, then fuses should be included in the circuit of that load.

Some charge controllers contain in-built electronic load and circuit protection. Look for these charge controllers that have circuitry to protect loads and PV arrays. Such charge controllers not only avoid the problem of including multiple fuses, they also avoid the common (and very dangerous!) practice of consumers replacing blown fuses with the wrong-sized fuse wire.

In all cases, when planning fuse protection, choose the main battery fuse first and follow these suggestions:

- The fuse should be DC rated.
- It should be on the positive cable(s) from the battery, as near as possible to the battery's positive terminal in unearthed and in negative earthed-systems which most systems are. Its rating in amperes (A) should be less than the thermal rating (current rating) of the battery cables. A 30A fuse protecting a cable designed to take 20A means that if 29A flows in the cable the fuse will not blow – but the cable, which is

designed to take a maximum of 20A, will overheat and become a fire hazard. However, a 15A fuse would provide full protection.

- Its 'breaking capacity' (in kA) should be greater than the battery short circuit current. This means that the fuse needs to be able to blow (i.e. not arc) if there is a short circuit – short-circuit currents can be very high.

  Other fuses (often located in the charge controller) are important but do not protect against battery short circuit from faults in cables between the battery and the charge controller. When placing fuses on inverter circuits refer to the inverter manual, which should specify fuse size and type (as well as recommended cable size from battery to inverter).

Sizing fuses

Sizing fuses is not straightforward but national electrical codes and inverter/ battery/charge-controller manuals will give specifications. The instructions below are only for: battery fuses in single battery systems below 100Wp; and fuses in 12V DC distribution circuits. However, they will give a introduction to the process. To calculate the required fuse size for each major 12V DC circuit, follow the steps below

Consult an electrician when selecting AC fuses:

.

1. List the circuits that need to be protected

2. Divide the power by system voltage to get current in amps. This is the maximum rated current in the circuit

3. Increase this figure by 20 per cent of its value (i.e. multiply this figure by 1.2,). This is the size of the fuse required. Remember fuses also protect cables from heating up (a fire hazard), so the 'current rating' or 'cable thermal rating' of all cables protected by this fuse need to be greater than the current rating of the fuse.

If there is only one fuse in the system, then cables serving the lights and the appliances and connected to the modules are also protected by it – but only if the current rating or cable thermal rating of all cables protected by this fuse are greater than the current rating of the fuse. It is often necessary to place a fuse in each major load circuit.

Selecting fuses

Fuses are rated in amps. They are sized to 'blow' very quickly when the current is about 20 per cent greater than the maximum expected current in the circuit. If, for example, there is a short circuit in one of the appliances, the circuit draws much more than the rated current (i.e. more than 20 per cent higher), so the fuse rapidly heats up, 'blows' very quickly and opens the circuit.

PV suppliers and electronic equipment shops stock fuses of various sizes, ranging from 0.25 amps to 30 amps or larger (see Figure 7.4). Make sure you select the right fuse and keep enough spares to replace the blown fuses. Ask your PV dealer to provide you with the right type of fuse. For extra-low-voltage DC circuits of 5 amps and above, cartridge-type fuses are commonly used. Below 5 amps, glass 'automotive' type fuses are often used. Avoid 'wire-type' fuses as they are easily bypassed and not appropriate for solar PV systems.

Automotive fuses are designed for use with SLI or sealed 'leisure' types of batteries. Although not specifically made for solar PV systems, they are integrated into some types of charge controllers for small SHS (i.e. less than 100Wp) and even small caravan lighting systems. Use of automotive-type fuses should be limited to systems that contain only one 12V battery.

If more than one battery is to be used then a 'proper' cartridge-type fuse is needed. Be careful when choosing 'AC-type' fuses for DC applications. They may also be rated for DC, but at a lower current. The DC rating is commonly given in catalogues and datasheets, but is often not on the fuse itself. DC-rated MCBs are also available.

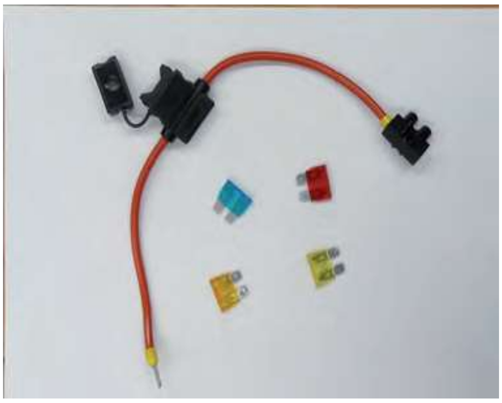


Figure 7.4 Battery DC-rated fuses: the blade type fuses (top-left) are only suitable for a single 12V battery of up to about 100Ah capacity; larger battery banks need the types of fuses shown in the rest of two pictures

Self-Check -1	Written Test

Matching:

Match the following DC cable function and colour codes based on current IEE (Institute of Electrical Engineers) codes.

7. Mache column A and column

A	B
----1. Two-wire unearthed DC power circuit,	
Positive of two wire	A. Brown
----2. Two-wire unearthed DC power circuit ,	
Negative of two wire	B. BLUE
----3. Two-wire earthed DC power circuit,	C. GREY
Negative (of negative earthed) circuit	

Note: Satisfactory rating –2 points and above Unsatisfactory - below 2 points

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _____________

Information Sheet-2	Checking electrically and mechanically sound connections

Making Connections

Wires in solar electric systems should be connected securely, safely and carefully. The extra-low DC voltage of solar PV systems is not an excuse to take shortcuts with regards to safety. More system problems are caused by bad connections than by failures of the equipment itself. The following tips are given to help make sure that the initial connections last a long time. But remember, good wiring is a skill, and needs to be learned.

Use connector strips and/or junction boxes

Connector strips are insulated screw-down wire clamps used to connect wires together (see Figure 7.5). Connector strips are available in various sizes to fit $2.5mm^2$ or larger wire. Junction boxes are plastic or metal containers inside which electrical connections are made. They are normally mounted inside walls. Buy the right size junction box for your installation and make connections properly. Never connect wires by twisting and always enclose connector strips in boxes.

Prepare wire ends carefully Strip 0.5 to 1cm (about 0.25 to 0.5 inches) of insulation from the end of the wire.

Make sure the wire is clean. Then, before fixing the wire to a terminal or connector, twist the end. If possible use 'shoelace crimp terminals' (see Figure 7.6).Use weather-proof boxes and conduits when connecting wires outdoors

If connected outdoors, wires should be enclosed in junction boxes. Make sure there is extra wire for entry and exit from junction boxes.

Figure 7.5 Connector strips and junction boxes

Figure 7.6 Shoelace crimp terminals

Do not twist wires around terminal connections in the battery, module or charge controller Use a crimping tool , if one is available, to fix ring-type or spade-type ends to the wire. These are less likely to be pulled off or to be affected by corrosion. If the installation site is near the ocean, solder terminal connections so that they do not corrode.

Inspect all connections carefully after installing. Make sure no wires are loose. Check for places where bare wire might overlap and cause a short circuit.

Be neat in wiring

Neat wiring not only looks better, it is easier to service and less likely to get tangled, or crossed and shorted. Align wires coming from terminal strips so that they are straight.

Seal all fittings and switches

This should be done with a silicon paste (non-flammable – ask your electrical supplier for advice). This is to stop insects from getting into junction boxes, light-fittings and other items of electrical equipment.

Wire Size, Voltage Drop and Maximum Wire Runs

Solar PV system designers must choose whether to use 12/24V DC circuits, 110/220V AC circuits or some combination of the two. This book is primarily concerned with systems up to 500Wp that use 12/24V DC circuits and the wiring practice of lower voltage DC systems. Larger AC and combination AC/ DC systems are also briefly discussed, but require assistance from qualified electricians .

In extra-low-voltage DC systems, selecting the correct cable size is extremely important. As with water pipes, the cross-sectional area of a cable determines how much current can pass through it. Larger diameter cables allow more current to flow than cables with small diameters (see Figure 7.7). Because lower voltage systems require a higher current to carry the same power as higher voltage systems, they generally require larger sized cables.

Box 7.4 shows the difference in current flow between wires in a 24W lamp connected to a 12V DC battery and a 24W lamp in a 220V AC grid system.

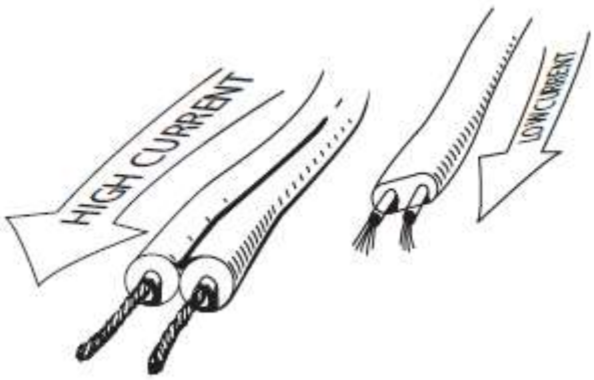


Figure 7.7 Larger-diameter cables are needed to carry larger currents

What is Voltage Drop?

Voltage drop is the loss of voltage (and hence power) due to resistance in long cable runs. If the wire's cross-section area is too small for a given current, an unacceptable voltage drop will occur over its length. Resistance in the cable converts electrical energy to heat and causes a consequent voltage drop.

When the voltage drop is too large in, for example, the cables from the PV module or array, the battery or battery bank will not be charged properly; in distribution circuits it will affect performance of lamps and appliances, and may damage them. The voltage drop also wastes expensive energy from the PV array and battery.

Voltage drop occurs in all wire runs. However, voltage drops of more than 5 per cent are always unacceptable. Correctly selected cable sizes will avoid unacceptable voltage drops. Review every circuit in an extra-low-voltage system for voltage drop.

Suppose, for example, that a 24W lamp is powered from a battery located in a kitchen 50m (165 feet) from the battery (see Figure 7.9). How much voltage drop will there be if a 1.5mm2 cable carries the power to the lamp? Will the voltage drop affect the performance of the lamp? If so, what is the correct wire size to be used?

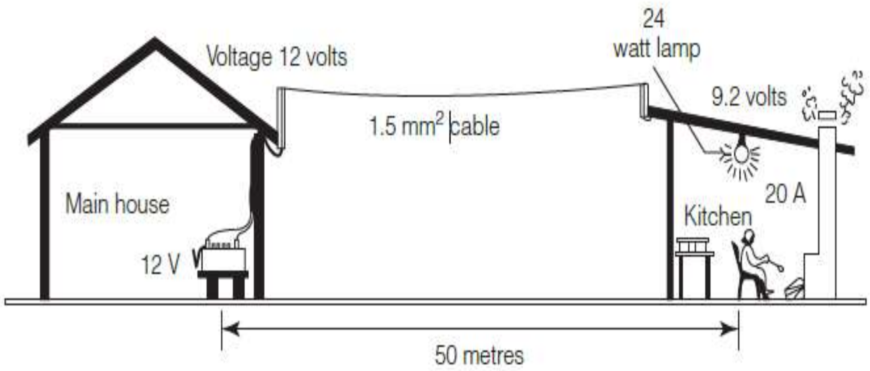


Figure 7.9 Voltage drop in a 12V DC system: the cable between the buildings is too small.

Earthing and Lightning Protection

'Earthing' (or 'grounding' for North Americans) refers to a variety of measures taken to avoid shock hazards, to protect against lightning and to ensure that sensitive electrical equipment operates properly. Unless a site is extremely susceptible to lightning strikes, 12V DC solar PV systems below 100Wp require minimal earthing protection. Solar PV systems that include an inverter or generator have increased electrical safety and fault risks, and should follow national AC system regulations and manufacturer installation instructions. National standards and codes vary considerably with respect to grounding/ earthing of PV systems. For example, in some countries (e.g. South Africa) all PV systems are required to be grounded. When installing your system, be sure you understand the need for and principle of earthing/grounding – as well as the regulations in Ethiopia (yellow/green) and what exactly they require.

As elaborated in the sections below, earthing serves several fundamental protective and functional purposes:

- It ensures that fuses will blow (or circuit breakers will trip) quickly when there is an electrical fault.
- It ensures that all parts of the electrical system that could become 'live' under fault conditions have the same 'electrical potential' with respect to the earth and cannot cause a shock to consumers. It reduces the risk of damage from lightning strikes.
- It provides functional earthling to enable correct operation of sensitive electronic equipment that must be earthed to work properly.

The sections below discuss each of the above points and the final section provides advice on setting up earthling circuits.

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System earthling and electric shocks

Small 12 or 24V DC solar PV systems without inverters do not normally pose a risk of electric shock. Therefore, provided they have adequate fuse protection, there is little need to worry about earthing unless national regulations specifically require it.

When any component of a solar PV system operates at 110 or 220V AC, the system must be designed to limit the risk of electric shock across the system and to ensure that a ground fault will trigger a circuit disconnection. Ungrounded inverters or appliances can potentially cause shocks when used improperly or in wet or damp conditions.

Note that there is a big difference between small inverters for powering one or two socket outlets and larger inverters (or inverter-chargers) that power entire electric circuits. Larger inverters normally have dedicated terminals for earth connections – and clear instructions about connecting the earth circuit in the manual.

Appliance and accessory earthling

Metalwork associated with the electrical system and appliances can potentially become 'live' under fault conditions. Such metalwork is normally earthed to keep it at the same 'electrical potential' as the general mass of the earth. Earthling ensures that such metalwork never has a voltage above 50V. Ordinarily, this is achieved by connecting all the earth terminals of metal casings and appliances back to a main earthling terminal via an earth wire. The main earthling terminal is connected to the body of the earth via an earth electrode. Note that the earthling of other metalwork in a building (such as water pipes, gas pipes and metal frames) may also be required; this is known as equipotential bonding. The details of how electrical systems are to be earthed (earth-wire sizes, testing requirements, etc.) can be found in national electrical codes and in installation instructions/manuals. Systems which require earthling need to be designed and installed by appropriately qualified persons.

Earthling circuits

In a typical small PV system, all casings of appliances, inverters or arrays and the negative terminal of the battery are connected to a main earth terminal. This, in turn, is connected to an earthed electrode (see Figure 7.11).

Note that:

- Earthling for systems with voltages less than 24V is often not required but national electrical codes need to be consulted.

- Modules and arrays would normally be earthed by connecting the array to the main earth terminal. Where there is a high likelihood of a lightning strike, the array frame may be grounded separately.
- Earthling in systems with inverters and 110/230V AC circuits involves

connecting all metal casings and the negative battery terminal to a single terminal, and that terminal to an earth rod. Always read inverter manuals carefully and consult a qualified electrician for advice when planning circuits

7.11 Earth rod connection

Lightning protection in off-grid systems

In areas prone to electrical storms, protection against lightning is always necessary. Where there is little risk, systems below 100Wp do not usually require lightning protection. Although lightning protection is unlikely to offer protection from a direct hit, proper protection equipment can reduce the effects of voltage, current and magnetic field fluctuations caused by nearby hits. There are two strategies to protect against lightning strikes:

- An external lightning protection system protects the array by attracting the strike and directing it into the ground via protective conductors
- An internal system, which might be a DC isolator in the charge regulator,

reduces the risk of voltage surges damaging other components of the installation.

Functional earthling

Some appliances do not work properly if they are not earthed. This includes some communications and measurement equipment. This is unlikely to be an issue in DC SHS systems. Note that some functional earthling circuits cannot be integrated into central earthling circuits. The IEE colour for functional earth cables is cream.

Self-Check -2	Written Test

Say True or False

---1. Wires in solar electric systems should be connected securely, safely and carefully.

---2. Voltage drop is the loss of voltage (and hence power) due to resistance in long cable runs.

---3. Ungrounded inverters or appliances can potentially cause shocks when used improperly or in wet or damp conditions

Note: Satisfactory rating –2points and above Unsatisfactory - below points

Answer Sheet

Score = ___________

Rating: ___________

Name: _________________________ Date: ____________

Information Sheet-3	Taking appropriate, safe and sensible actions to defective parts

Common failures and improper practices

Given the huge varieties and modularity of PV systems, it is obvious that a significant number of mistakes can be made in case of insufficient training of installers about the availability and technical parameters of the different PV components as well as about the national requirements when it comes to administrative processes, grid connection requirements and building regulations

.

There are a number of stages in the development of a PV system in which mistakes can occur:

- Site selection
- Design and planning of the system
  - Selection of components
  - Mechanical failures
  - Electrical failures
- Physical installation of the components
  - Mechanical failures
  - Electrical failures
- Safety (personnel safety as well as safety of installation from e.g. external exposures)
- Service, including inspection & maintenance (insufficient)

Site selection

Site selection includes obvious aspects such as orientation, inclination and shading (including solar resource prediction), but also elements which are less straightforward, such as environmental impact assessments when it comes to large ground-mounted installations. Common failures in the field of initial site selection for rooftop systems are very rare.

Most installers (as well as end-customers) are aware of the importance of orientation and inclination of the PV installation. We will see almost no north-facing installations on residential roofs. Unfortunately, shading is not always taken into account and more easily overlooked by the designer/installer. Therefore, it is important to perform detailed solar resource predictions, taking into account the orientation, inclination and all potential shading by surrounding trees and/or buildings. Regarding larger ground-mounted systems, an important aspect is to analyze the potential impact of such a large PV plant on biodiversity. Therefore, it is important to perform an environmental impact assessment and the results of such assessment need to be openly discussed with the public, policy makers and all other involved players.

Design and planning of the system

The design and planning stages include all decisions taken on the appropriate size of the system as well as the selection of the different components. It is important to take into account basic structural load and wind load calculations. Moreover, emphasis should be put on the sizing, including the size and selection of an appropriate inverter, cables, power optimizer and switch devices as well as combiner boxes and transformers. This task normally ends with a modeling exercise on the future performance of the PV system and therefore also includes knowledge about software and simulation tools for yield modeling. For residential systems, it is of critical importance to respect the building and safety codes, including measures on ventilation of the building, access for fire departments, maximum load, etc. When the roof is not appropriate for the installation of a PV system, this should be simply acknowledged.

Common mistakes to be encountered in this stage are then:

- Incorrect energy yield prediction
- Different azimuths or inclinations in the same string
- Strings with modules of different power rating
- Stability: insufficient structural load calculations
- Sizing: e.g. undersized cables
- Shading problems not sufficiently taken into account
- Mismatch: e.g. inverter mismatch or generation meter not well fitted to inverter output
- Incorrect circuit protection
- No lightning protection, earthing and surge protection
- Building codes and electrical codes for grid connection not taken into account
- Missing documentation at late stages of design (not compliant with IEC standard)

Physical installation of the components:

This step requires normally the combined work of a roofer and an electrician. Again, it is clear that without sufficient training on the specificities of PV, the likelihood of mistakes during this step can be significant. Common mistakes to be encountered in this stage are then:

- Installer does not follow the design of the system
- Insufficient inverter & module ventilation (the area around the inverter should be kept clear to allow good air flow for proper cooling

• Roof perforation without adequate sealing methods
• Poor wiring: tight or loose cables
• Labeling not present or incorrect
• No earthing or lightning protection
• No intervention in the case of rust
• Badly placed sensors

Safety

Safety issues include both the personnel level (worker safety) as well as the product level (safety of installation).Worker safety: Ideally, a team responsible for the installation of a PV system should consist of an electrician and a roofer. The electrician should manage the electrical DC connections as well as the connection to the grid, whereas the roofer should have sufficient experience to manage the installation of the panels mechanically on the roof and make the interconnections between the modules on the DC side. Ideally; electricians, roofers and other construction workers are to bring their knowledge together in a new kind of job description which could be called "solar installer".

Safety of installation:

An important element that is also being discussed extensively in certain EU countries is fire protection. First of all, it is crucial to understand that in case of a fire where a PV system was present, the fires were mainly caused by external fire sources and only few cases have been reported in which the PV system itself was the source of fire (improper polarity can cause severe damage to the array and system electronics and has been known to cause fires in some systems). The concerns are therefore not related to the quality of the PV systems itself, but to the safety of fire fighters when extinguishing a fire in a building with a PV system.

Therefore, 4 elements are of crucial importance: the design of the PV system, the quality of the PV components, the quality of the installation and communication towards other stakeholders (such as fire departments).

It should also be pointed out that multiple solutions are available in all stages of design and installation, such as selecting and designing the site in order not to block the access for fire departments, foresee sufficient labeling and applying it correctly, designing the electrical plan (for cables and other electrical equipment) in accordance with safety requirements, etc…

Image 1: Owners should stay away from the PV system during and after a fire and inform the fire brigade about the particular hazards from the PV system.

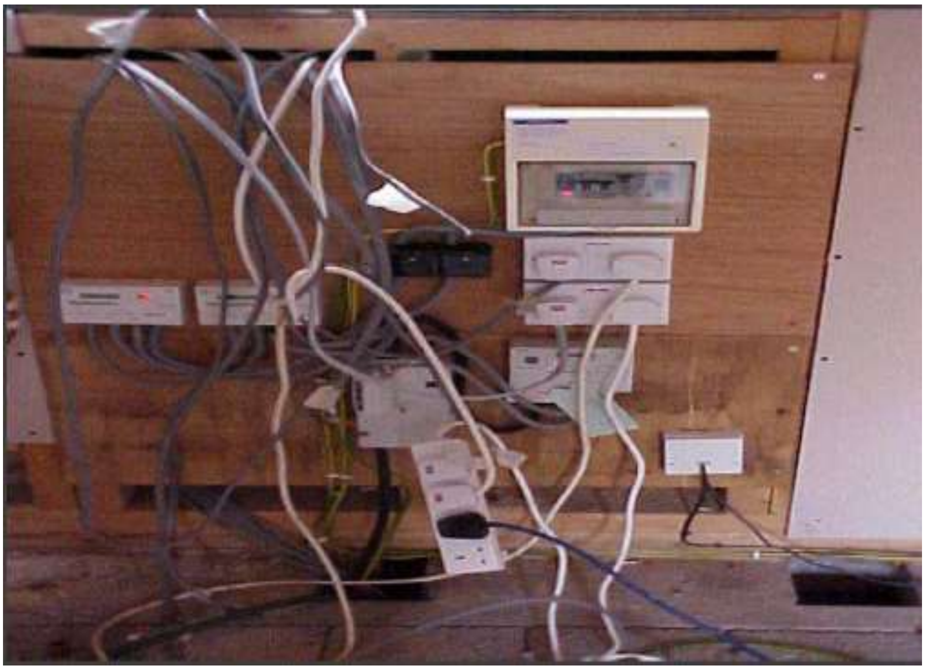

Image 2: Improper wiring method

Image 3: Short circuit and overvoltage converter

Image 4: Crack damage – fixing system

Image 5: Storm damaged modules

Service, including inspection and maintenance

An installer is of course not only a technician but also a salesperson. Basic marketing skills are therefore a must. Good knowledge about the environmental, financial and other economic benefits of PV is indispensible.

Common mistakes to in this area are:

- Manuals, warranties, test certificates, grid connection docs not supplied to owner/operator
- Not being able to deliver information on the latest innovations and specialized applications(BIPV)
- Not being able to deliver information on administrative requirements, grid connection procedures, support schemes and other related benefits
- Too aggressive sales attitude
- Failure to deliver quick and adequate inspection and maintenance service

PV system maintenance includes maintaining all parts of the system and requires little maintenance, except for batteries in case of autonomous systems. Batteries maintenance depends on the type and the charge/discharge cycles. Maintenance should be performed at least once a year, but the installer should additionally inform the system owner to monitor the system performance. The most common maintenance issue is the cleaning of the glass area to remove dirt and dust which can be done by washing the module with water. Cleaning is necessary during long dry periods when rain cannot provide natural cleaning. The modules should be cleaned when they are not excessively hot.

List of common failures and improper practices

1. PARAMETER	Failure/Improper practice
Site Selection	
Orientation	north / west facing installations
Inclination	- different azimuths or inclinations in the same string - array not tilted at an angle of latitude (for throughout the year best performance
Shading	- place the system in area surrounded by trees and/or buildings - seasonal shading is not taken into account
Corrosion	- modules are located in areas exposed to salt water
Biodiversity (for large ground mounted systems)	- potential impact to wildlife is neglected because of inadequate EIA
2. Design and planning of the system	
Structural load	- age and condition of the roof is not considered - not use of specified hardware leading to stability problems - no respect to the building codes
Wind load	- inadequate mounting - system not mounted on concrete bases
Location	- no respect to the building and safety codes (eg overload the roof, no access for fire departments) - BOS are not sited in weather resistant or rain-tight enclosures
Equipment	- inappropriate inverter, undersized cables, power optimizer and switch devices as well as combiner boxes and transformers
Lightning/grounding	- no lightning protection, earthing and surge protection - PV system installed in an exposed location - allow copper (equipment grounding conductor) to come in contact with the aluminum rails and module frames
Electrical connections	- improper polarity - incorrect circuit protection - mismatch: e.g. inverter mismatch or generation meter not well

	fitted to inverter output - lengths of electrical wiring are not minimized - electrical codes for grid connection not taken into account

PARAMETER	Failure/ Improper practice
Physical installation of components	
Shading	- distances between the module rows are not kept
Roof Damage	- perforation without adequate sealing methods
Corrosion	- materials used outdoors are not sunlight/UV resistant
Array Modules and Configurations	- modules are subjected to excessive forces due to thermal expansion of the support structure - put too few modules in series for proper operation of the inverter during high summer array temperatures - insufficient module ventilation - modules of different configurations and different nominal power ratings are used in the same PV array
Inverter	- placed in a position where it is directly exposed to the sunlight - insufficient ventilation - placed in a long distance from the PV array combiner/junction box - installed on or near a combustible surface
Wiring	- tight or loose cables - improper cable support with exposure to physical damage - multiple cables entering a single conductor cable gland
Conductors	- not supported within 30cm of boxes or fittings - bending conductors too close to connectors
Batteries	- not installed in an enclosure separated from controls or other PV system components - installed close to radioactive and flammable materials - exposed to direct sunlight - exposed to high temperature
Labeling and warning signs	- not present or incorrect placed
Sensors	- badly placed
Boxes or conduit bodies	- cover them making nearly inaccessible for service

PARAMETER	Failure/ Improper practice
Safety	
Technician's safety	- fall protection equipment is not used even though it is needed - noncompliance with accident prevention regulations - work in adverse conditions: wet conditions, strong winds or frosted roof surfaces - the installer walks on the panels - the inverter is installed after wiring
For the event of a fire	
Organizational measures	- not labeling the PV system at the building's connection box and main distributor with an indicator sign - lack of general plans for emergency workers
Structural measures	- no fire-resistant routing of DC power - no routing of DC power cables outside of the building or - the inverter is installed inside the building
Technical measures	- lack of DC disconnect switch in the area of the building's main fuse box
Maintenance/ Inspection	
Technician	- not annually maintenance of mechanical and electrical connections (circuit currents and voltages, battery electrolyte etc) - front surface of the PV modules not covered during maintenance - bent, corroded, or otherwise damaged mounting components re not replaced - loose components or fasteners are not re-secured or tightened - fire extinguishers are not located in close proximity to the battery - owner is not informed /taught to frequently monitor the system's performance
Owner (PV installer shall advice the owners for several maintenance measures to be followed)	- kWh produced is not periodically recorded (deviation from expected values may reason for checking the system) - panels are not adequately washed, when needed - panels are scratched during the cleaning procedure (brushes, and harsh detergents are used) - trees near the system are not adequately trimmed - batteries' surfaces are not kept cleaned - the electrolyte level in the batteries is not checked

Self-Check -3	Written Test

Say True or False

---1. Building codes and electrical codes for grid connection not taken into account may cause accident.

---2. Improper polarity of Electrical connections in PV system is wrong practice.

---3. Incorrect circuit protection may cause danger in PV system connection.

---4. Poor wiring: tight or loose cables is improper practice.

---5. Using undersized cables in PV connection system may result electrical accident.

Note: Satisfactory rating –2 points and above Unsatisfactory - below 2 points

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _____________

List of Reference Materials

1. **Alone Solar Electric Systems .The Earthscan Expert Handbook for Planning, Design and Installation** ***Mark Hankins,*** **series editor: frank jacksonRTHSCANEXPERT HANDBOOK**

2.-TRAINING OF PHOTOVOLTAIC INSTALLERS, Issued by EPIA, June 11, Revised Sep 11.

Solar PV System Installation and Maintenance

Level-II

Learning Guide-47

Unit of competence:-	**Install Wiring Systems in Conduit and connect Equipment**
Module Title:-	**Installing Wiring Systems in Conduit and connecting Equipment**
LG Code:	EIS PIM2 M02 LO4 **LG-47**
TTLM Code:	EIS PIM2**TTLM 1019v1**

LO4:- Inspect and notify completion of work

Instruction Sheet	Learning Guide 34

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Confirming final work with instructions
- Notifying supervisor upon completion of work
- Inspecting tools, equipment and surplus resources and materials

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:-

- Confirm final work with instructions
- Notify supervisor upon completion of work
- Inspect tools, equipment and surplus resources and materials

Learning Instructions:

7. Read the specific objectives of this Learning Guide.
8. Follow the instructions described below 3 to 6.
9. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, in pages 127, 131, and 133, respectively.
10. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 9 in pages 130, 132, and 137, respectively
11. If you earned a satisfactory evaluation from the “Self-check” proceed to Operation Sheet----

Information Sheet-1	Confirming final work with instructions and requirements

1. Permitting and Inspection

Most local governments require a building permit prior to the installation of a PV system to ensure the system meets engineering and safety standards. After installation of a PV system is completed and prior to it being energized, a system inspection is often required to ensure code compliance. Rooftop system inspections are often performed at the local government level by building inspectors. It is worth noting that permitting and inspection have limitations.

The permitting and inspection process usually does not consider whether the system is designed and installed to maximize performance. A system located in the shade may not produce any energy, but still pass code inspection, for example.

A streamlined permitting process can be established for small rooftop PV systems or those meeting a standard set of design criteria. Establishing standard design criteria allows installers to know in advance that a PV system will be approved if it is designed to code, thereby reducing the uncertainty, time, and costs associated with additional engineering studies or re-doing an incomplete or incorrect permit application.

2. Checklist for the final work of PV installations

Once the PV system installation has been completed, the following checks will be held to know how the system is running; and the action should be taken in a maintenance operation in order to ensure a proper performance of a PV system.

A. General installation (electrical)

- Equipment compliant with standards, correctly selected & no damaged
- Equipment accessible for operation, inspection & maintenance
- Equipment and accessories correctly connected
- Particular protective measures for special location
- Equipment and protective measures appropriate to external influences
- System installed to prevent mutual detrimental influence
- Conductors connected and identified
- Conductors selected for current carrying capacity and voltage drop
- Conductors routed in safe zone or protected against mechanical damage
- Sunlight-resistant and wet-rated conductors are used in exposed locations
- Cables properly terminated with terminals listed for such conductors
- Presence of fire barriers, seals and protection against thermal effects

B. **General installation (mechanical)**

- Ventilation provided behind array to prevent over heat in / fire risk
- Array frame & material corrosion proof
- Array frame correctly fixed and stable;
- Roof penetrations secure and weather tight
- Modules attached to the mounting structure according to the manufacturer's instructions
- Cable entry weatherproof

C. **Protection against overvoltage/electric shock**

- Live parts insulated, protected by barrier/enclosure, placed out of reach.
- Over current devices in the D.C. circuits listed for dc operation? If device not marked D.C, verify D.C. listing with manufacturer
- Each module or series string of modules have an over current device protecting the module (only relevant if required)
- Array frame equipotential bonding present (only relevant if required)
- Surge protection devices present (only relevant if required)
- User-accessible fuses in "touch-safe" holders or fuses capable of being changed without touching live contacts

D. **D.C. System:**

- Physical separation of A.C. and D.C. cables
- D.C. switch disconnected fitted (to IEC60364-712.536.2.2)
- D.C. cables – protective and reinforced insulation (only relevant if required)
- All D.C. components rated for operation at max. D.C.. system voltage (Voc stc x 1,25)
- PV strings fused or blocking diodes fitted to only relevant if required)

E. **A.C. System**:

- A.C. isolator lockable in off position only
- Inverter protection settings to local regulations

F. **Charge Controller (if exists)**

- Exposed energized terminals not readily accessible
- Diversion controller has an independent backup control method
- PV system schematic displayed on site

G. **Batteries (if exist)**

- Limited access
- Installed in well ventilated areas

H. Junction boxes

- Appropriate type and size and allow the conductors within to be accessible

I. Labeling & identification

- General labeling of circuits, protective devices, switches and terminals (to IEC60364-6-61
- PV system schematic displayed on site
- Protection settings & installer details displayed on site
- Emergency shutdown procedure displayed on site
- A.C. isolator clearly labeled
- D.C.. isolator / junction boxes suitably labeled
- Signs & labels suitably affixed and durable

J. Owner's Documentation.

- warranty,
- component warranties,
- owner's manuals,
- Utility interconnection agreement,
- Instructions for operation and maintenance.

Self-Check -1	Written Test

Directions: - Match the following questions from column "B" to column "A"

Column "A"	Column "B"
.......1. General installation (electrical)	A. Limited access
........2. General installation (mechanical)	B. Array frame correctly fixed and stable
........3. D.C. System	C. Conductors connected and identified
........4. A.C. System:	D. Inverter protection settings
........5. Batteries	E. PV strings fused or blocking diodes fitted

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _________________

Information Sheet-2	Notifying supervisor upon completion of work

1. Work Completion Report

A spreadsheet or other reporting format is used for collecting data, calculating results and reporting purposes. Inputs for such a system may be downloaded from a data collection and monitoring system or combination of systems, or they may be input manually. Regardless of the method, the inputs should be standardized for consistent results.

Reports should include the following elements, at a minimum:

- System name, address/location
- System size, type (fixed, tracking), module, inverter, pitch and azimuth
- Name of person(s) performing the tests and reporting the results
- Test equipment used (monitoring/model, irradiance sensor, temperature sensor, etc.)
- Period of time for measurements
- Number of measurements taken and used
- Irradiance measured (and conversion of POA to GHI if appropriate)
- Temperature measured (and conversion of ambient to module/cell if appropriate)
- Wind Speed Measured
- AC Power or Energy Measured
- Uncertainty of the test results and acceptable tolerance
- Notes on any significant findings or observances
- Summary and narrative of the outcome (lab report).

2. Reporting Performance Results

Ultimately, an owner or O&M provider should be able to generate EPI reports within the data collection and monitoring system, without the need to download monitoring data to another reporting system. This requires incorporating a standard PV energy production model into the monitoring system. This system should also use standardized methods of collecting weather and irradiance data. The data collection and monitoring system will then be capable of producing Predicted Energy from the design model, Expected Energy from real operating conditions, and Measured Energy. If a standardized method of incorporating the model and actual weather and irradiance data is used in any monitoring system, then monitoring results will be consistent across all platforms.

Self-Check 2	Written Test

Directions: - For the following statements, write TRUE if it is correct or write FALSE if it is incorrect on another answer sheet.

1. Period of time for measurements is NOT mentioned in the work report.
2. Wind speed measured is included in the work completion report.
3. . Irradiance measured is considered in the work completion report.
4. Test equipment used in the work is not included in the work completion report.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Short answer question

Information Sheet-3	Inspecting tools, equipment and surplus resources and materials

1. Introduction

Hand tools are available to assist the solar energy system owner to measure the power output of their system, and to make adjustments in the tilt and orientation of a solar module or array to maximize the energy production of their system.

Placement of a solar module or an array to capture the sun's energy and transform it into direct current electricity, determining the suitability of a site as location for a solar module or an array, or measuring voltage and amperage are best accomplished with the right tools. These tools are easy to use and readily accessible.

2. Tools for a Successful Solar Electric Installation

'The right tool for the job makes all the difference'.

We've all heard that bit of wisdom thousands of times. And it's no different for a Solar Electric (PV) system installation than for anything else. Fortunately, most of the tools needed for a PV install are commonly used and easily found. There are very few highly specialized tools. Below are several lists that describe many of the tools needed for an installation. They are broken out into functional groups for site assessment, installation and maintenance. Most of the specialized tools fall into the site assessment and maintenance categories; the installation tools are probably already in your tool box!

2.1. Basic Tools Needed for Installation

- Angle finder
- Torpedo level
- Fish tape
- Chalk line
- Cordless drill (14.4V or greater), multiple batteries
- Hole saw
- Hole punch
- Torque wrench with deep sockets
- Nut drivers (most common PV sizes are 7/16", ½", 9/16")
- Wire strippers
- Crimpers
- Needle-nose pliers
- Lineman's pliers

- Slip-joint pliers
- Small cable cutters
- Large cable cutters
- AC/DC multimeter
- Hacksaw
- Tape measure
- Heavy duty extension cords
- Caulking gun
- Fuse Pullers

2.2. Additional Tools to Consider (especially for multiple installations)

- DC clamp-on ammeter
- Reciprocating saw / Jig saw
- Right angle drill
- Conduit bender
- Large crimpers
- Magnetic wristband for holding bits and parts
- C-clamps
- Stud finder
- Pry bar

2.3. Tools for Battery Systems

- Hydrometer or Refractometer
- Small flashlight (to view electrolyte level)
- Rubber apron
- Rubber gloves
- Safety goggles
- Baking Soda (to neutralizer any acid spills)
- Turkey Baster
- Funnel
- Distilled Water
- Voltmeter

Figure 57: Basic hand tools for installation work

Although solar systems require common household tools such as a screw driver, hammer rails and so on, there are specialized tools designed specifically for solar installations. Some tools are designed for simple applications such as disconnecting solar connections, while others are more complex such as wire crimping die sets.

Other tools that are not commonly thought of are safety equipment. Rope, harnesses, safety glasses, gloves, earplugs, boots, hard hats and protective clothing are all designed to keep you safe while working in your installation environment. Working with multiple people is another safety measure that is highly recommended, we also suggest that any equipment you use to reach your roof is checked prior to use. Faulty ladders and old rope can not only cause bodily harm, but may also be a factor for damaged system components. On those sunny days, some sun block may also be a welcome addition to your set of equipment for personal protection.

Figure 58: Appropriate wearing during work

Different rooftop applications may also require different tools. For pitched roof installations, a cordless drill and impact driver, drill bits, sockets, utility knife and caulking gun will cover most your essentials. Flat roof installations are simple due to the racking equipment typically used, in most cases a ballast system where weights instead of connectors hold the PV array in place

Grounding your racking system has become fairly integrated into racking applications. Grounding lugs, bolts and even integrated grounding into the railing system are now common place, and most installers will not need to source these grounding components from outside sources. Checking all wiring connections and utilizing the tools mentioned above will also be essential before turning your system in the on position and enjoying your new clean, renewable energy source.

Self-Check 3	Written Test

Directions: - Match the following questions from column "B" to column "A"

Column "A"	Column "B"
…….1. **Basic Tool for Installation .**	A. Hydrometer
……..2. **Basic Tool for multiple installations**	B. measures diffused sun energy
…….. .3. **Tool for Battery Systems**	C. DC clamp-on ammeter
	D. Angle finder

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

List of Reference Materials

References

1. Honsburg, C. & Bowden, S. (2016). Short-circuit current. PVEducation.Org. Available at: www.pveducation.org PV-Cables, Inc. (2016). Available at: http://www.pv-cables.com

2. Schwartz, J. (February – March, 2005). Tools of the solar electric trade. Home Power Magazine 105, 22-26. Available at: www. homepower.com