TVET CERTIFICATE V in SOLAR ENERGY

SOLAR POWER PLANT MAINTENANCE

SOLSM 501

Maintain Solar Power Plant

Competence

**Credits: 12**

**Learning hours: 120**

**Sector: Energy**

**Sub-sector: Solar Energy**

**Module Note Issue date:** June, 2020

## Purpose statement

This module describes the skills, knowledge and attitude required to maintain well Solar Power plant. The learner will be able to prepare the workplace, select materials, equipment and tools. He/she will be also able to install solar power plant, clean tools and working area, manage waste materials and prepare the test protocol.

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# Learning Unit 1: Prepare preliminary activities

## Introduction to Solar power plant maintenance

This Module is about the various responsibilities and tasks related to Maintenance. Maintenance is usually carried out on-site by specialized technicians or subcontractors, in close coordination with the Operations team's analyses.

## Types of solar power plants maintenance

## Preventive Maintenance

Preventive Maintenance activities are the core element of the maintenance services to a PV plant. it comprises regular visual and physical inspections, as well as verification activities conducted with specific frequencies of all key components which are necessary to comply with the operating manuals and recommendations issued by the Original Equipment Manufacturers (OEMs). it must also maintain the equipment and component warranties in place and reduce the probability of failure or degradation. the activities should also comply with respective legal issues e.g. national standards for periodic inspection of certain electrical components.

## Corrective Maintenance

Corrective Maintenance covers the activities performed by the Maintenance team in order to restore a PV plant system, equipment or component to a status where it can perform the required function. The Corrective Maintenance takes place after a failure detection either by remote monitoring and supervision or during regular inspections and specific measurement activities

Corrective Maintenance includes three activities:

1. Fault Diagnosis also called troubleshooting to identify fault cause and localization;

2. Temporary Repair, to restore the required function of a faulty item for a limited time, until a repair is carried out;

3. Repair, to restore the required function permanently.

In cases where the PV plant or segments need to be taken offline, the execution of scheduled Corrective Maintenance during night or low irradiation hours would be considered best practice as the overall power generation is not affected.

Corrective Maintenance can be divided into three levels of intervention:

1st level: intervention to restore the functionality of a device without the need for substituting a component. in general, this kind of Corrective Maintenance includes only labor activity carried out by a specialized technician

2nd level: intervention to restore the functionality of a device that requires substitution of a component.

In general, this kind of Corrective Maintenance involves labour activity carried out by a specialised technician

3rd level: intervention to restore device functionality with a necessity to intervene on the software of the device. in general, this kind of Corrective Maintenance includes both labour activities carried out by specialized technician (that could belong to the O&M maintenance team or be subcontracted) and, often, also an intervention on behalf of the device manufacturer's maintenance team or of other external companies that have been licensed by the device manufacturer to intervene and restore device functionality.

## Predictive Maintenance

Predictive Maintenance is a special service provided by O&M Contractors who follow best practices principles.it is defined as a condition-based maintenance carried out following a forecast derived from the analysis and evaluation of the significant parameters of the degradation of the item

a prerequisite for a good Predictive Maintenance is that the devices on site can provide information about their state, in such a way that the O&M contractor can evaluate trends or events that signal deteriorations of the device. as a best practice, the device manufacturer should provide the complete list of status and error codes produced by the device together with the detailed description of their meaning and possible impact on the function of the device. additionally, a standardization of status and error codes through inverters and dataloggers within a same brand should be followed and, in the future, this standardization should be common to all manufacturers.

## Extraordinary Maintenance

Extraordinary Maintenance actions are necessary when major unpredictable events take place in the plant that require substantial activities and works to restore the previous plant conditions or any maintenance activity generally not covered or excluded from the O&M Contract.

## Advantages of solar power plants maintenance

- ✓ Increase energy yield (each cell string delivers maximum power at the best current)
- ✓ Increase ground coverage and improve land utilization (allows 10%- 20% tighter row pitch at the same energy production per panel)
- ✓ Higher reliability: Minimize power degradation over the panel and eliminate hot spots
- ✓ No additional control unit, network cabling, network configuration
- ✓ Decrease downtime (hours/year)
- ✓ Extend system lifetime (25–40 years)
- ✓ Ensure safety and reduce risk
- ✓ Enhance appearance and image

## L.O 1.1 – Plan preventive maintenance for solar power plant systems

- Content/Topic1: Recommended Practice for Maintaining solar power plant systems

Preventive Maintenance activities are the core element of the maintenance services to a PV plant. it comprises regular visual and physical inspections, as well as verification activities conducted with specific frequencies of all key components which are necessary to comply with the operating manuals and recommendations issued by the Original Equipment Manufacturers (OEMs). it must also maintain the equipment and component warranties in place and reduce the probability of failure or degradation. the activities should also comply with respective legal issues e.g. national standards for periodic inspection of certain electrical components.

an example of Preventive Maintenance is thermographic inspection aiming to identify defective panels on a PV plant. indeed, several categories of anomalies (hot spots, hot strips, moisture ingress, soling, etc.) can occur, significantly reducing the whole plant productivity. relevant inspection procedures are performed either by operators with handheld cameras or exploiting remotely Piloted aircrafts (RPAs) equipped with dedicated thermal and optical payloads. it is noteworthy that the usage of growing technology of RPAs as an innovative technology can significantly benefit power plant maintenance procedures as it can lead to time and cost savings as well as safety improvements

Preventive Maintenance also includes ad-hoc replacement of parts of inverters or sensors (Predictive Maintenance). in general, outside of the equipment warranty terms or after its expiration it is important to follow detailed Preventive Maintenance procedures, which are agreed upon in the annual Maintenance Plan. in cases where downtime is necessary to perform Preventive Maintenance, its execution during the night would be considered best practice as the overall power generation is not affected.

**Daily Activities**

Maintenance daily schedule is a means for coordination between Maintenance and Production to accomplish the required daily maintenance work.  Also, it is a means to allocate the required maintenance resources to the required work in a planned manner to cover the required maintenance work according to priority

The daily schedule is prepared by the scheduler (from the planning team) in coordination with Production and Maintenance functions during the weekly coordination meeting for next week.

The daily schedule will contain jobs/tasks for planned maintenance (e.g. Preventive Maintenance, Major Overhauls, Plant Modifications, etc.) and unplanned maintenance (such as breakdowns).

The daily schedule will include also work that was planned to be done during this week and other work that has been carried over from previous weeks (backlog). The daily schedule has to be agreed ahead by both Production and Maintenance functions to allow the planner to prepare the required materials, scheduler/maintenance to prepare the required recourses, and Production to prepare their production plans to accommodate for the required work.

The daily schedule progress will be tracked by the scheduler during the daily coordination meeting between Maintenance and Production and changes my take place in the daily schedule for next day(s) according to emerging jobs and work priorities.

Always daily checking is for critical point. For example, the temperature or pressure of a lubricant or … in a sensitive equipment or very expensive equipment or important equipment due to what it is doing.

**Weekly Activities**

Weekly maintenance activity is maintenance that is done once a week.
A weekly schedule is a way to keep track of your activities and tasks for the week. A weekly schedule includes everything you have to get done, and helps you plan out when you can get things done. It also helps you see how much time you have available.

**Monthly Activities**

Monthly maintenance activity is maintenance that is done once a month.

**Annual Activities**

Annual maintenance activity is maintenance that is done once a year.

- Content/Topic 2: Elaboration of Convenient Maintenance Plan/ Schedule

A short definition of maintenance planning and scheduling:

- ✓ Planning decides what, how and time estimate for a job.
- ✓ Scheduling decides when and who will do the job.
- ✓ Planning of a job should be done before scheduling a job.

A dated maintenance plan must include, as a minimum, the following data:

- ✓ Description of equipment tested;
- ✓ Description of test;
- ✓ Test results with All fields completed;
- ✓ Summary of project findings and recommendations, if required for additional work;
- ✓ Documentation of the conditions at which the tests were performed; and
- ✓ Name and address of the testing firm along with contact information of the individual doing the testing.

**Solar power plant maintenance Plan sample**

| COMPANY NAME | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NAME OF SOLAR POWER PLANT | | | | | | | | |
| PREVENTIVE MAINTENANCE | | | | | | | | |
| DAILY CHECKS | | | | | | | | |
| **Item** | **Checks** | **Date, Month and year** | | | | | | |
| | | **M** | **T** | **W** | **T** | **F** | **S** | **S** |
| **Solar module** | Measure the output voltage of each string | | | | | | | |
| | No dust over solar Panel | | | | | | | |
| | All Solar Module are free from shadow or debris | | | | | | | |
| | Check the tilt angle and orientation | | | | | | | |
| | Check solar module for hot spots or cracks | | | | | | | |
| **Inverter** | Measure both the input and output voltage of inverter | | | | | | | |
| | Check in fan is working | | | | | | | |
| | check for any abnormal noise | | | | | | | |
| | Any sort of dust or dirt accumulation on the inverters need to removed. | | | | | | | |
| | Check the healthiness of all indication lamps | | | | | | | |
| **Batteries (if used)** | Check for any electrolyte level, leaks, corrosion at the terminals or cracks. | | | | | | | |
| | Measure the batteries voltage | | | | | | | |
| **Balance of System (cables, junction boxes, etc.)** | Check the cables for any cracks, breaks or deterioration in the insulation | | | | | | | |
| | Check the junction boxes and make sure that there is no animal infestation there | | | | | | | |
| | Also inspect connections for corrosion | | | | | | | |
| **Names and Signature of Team in charge** | | | | | | | | |
| | | | | | | | | |
| **Note:** If any system is found to be abnormal, dive detailed descriptions in log book | | | | | | | | |

## LO 1.2 – Identification of tools, material and equipment used in solar power plant maintenance

- Content/Topic 1: Tools used in solar power plant maintenance

Electro-mechanical toolkit

Hand Electrical drilling machines

- Content/Topic 2: Instrument used in solar power plant maintenance

Thermometers


Hydrometer

Earth Resistance Meter


Multimeter

Content/Topic 3: Material and used in solar power plant maintenance

Insulator tape

Nails

Bolt

nut

Screws

Cables

- Content/Topic 4: Identification of types of equipment used in solar power plant maintenance

✓ Solar panels

✓ Charge controllers


✓ Batteries

✓ Inverters

## LO 1.3 – Identification of PPE (Personal Protective Equipment) used in solar power plant maintenance

- Content/Topic 1 : Selection of safety equipment used in solar power plant maintenance

✓ Overcoat: designed for the **purpose** of keeping the wearer clearly in view, they make abundant **use** of colors that can always be seen and glow in the dark.

✓ Overall: **Overalls** are a type of **safety** clothing made of tough cotton, denim or linen and usually used as protective clothing while working

✓ Gloves: a covering for the hand worn for protection against cold or dirt and typically having separate parts for each finger and the thumb.

✓ Safety shoes: a **shoe** with a reinforced toe cap to minimize foot injuries caused by dropped articles. With a sole of material incapable of sparking for work near combustibles or explosives.

✓ Helmet: are one of the most frequently used forms of PPE. **Safety Helmets** will protect the user's head against: impact from objects falling from above, by resisting and deflecting blows to the head

✓ Earmuff: are objects designed to cover a person's **ears** for **hearing protection** or for warmth. They consist of a thermoplastic or metal head-band, that fits over the top or back of the head, and a cushion or cup at each end, to cover the external **ears**.

✓ Goggles: are forms of *protective* eyewear that usually enclose or protect the area surrounding the *eye* in order to prevent particulates, water or chemicals from striking the eyes.

✓ Nose protection mask: are loose-fitting **masks** that cover the **nose** and mouth,
and have ear loops or ties or bands at the back of the head.

- Content/Topic 2 : Use of safety equipment used for solar power plant maintenance

The Importance of Personal Protective Equipment. ... PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels. It also includes respiratory protective equipment (RPE).

- Content/Topic 3 : Handling of safety equipment needed for solar power plant maintenance

✓ Ensure the operator is trained and qualified to operate the equipment.

✓ ensure the correct equipment is used for the job.
✓ provide personal protective equipment for employees.
✓ plan any work to minimise risks identified.
✓ use appropriate warning signs.
✓ provide appropriate training and guidelines to employees.
✓ maintain and check equipment regularly.

# Learning Unit 2 – Execute preventive maintenance

## LO 2.1 – Identify planned activities

- Content/Topic 1: Recommended maintenance activities for solar power plant systems

maintenance activities are Set of actions performed in the product development process to solve user and market problems, arising from the introduction of a new good or service.

Maintenance activities for solar power plant systems

| **COMPANY NAME** |
|---|
| **NAME OF SOLAR POWER PLANT** |
| **PREVENTIVE MAINTENANCE** |
| **DAILY CHECKS** |
| **DATE** |

| Maintenance Task | Daily | Weekly | Monthly | 3 Months |
|---|---|---|---|---|
| Visual Inspection of system wiring, Lights and Junction boxes | | ✓ | | |
| Solar Panel Maintenance | | | | ✓ |
| Battery Inspection | | ✓ | | |
| Battery Cleaning | | | ✓ | |
| Wiring Inspection | | ✓ | | |
| Inverter/Battery Charger | | ✓ | | |
| Charge Controller | | ✓ | | |
| Battery "top-up" | | | ✓ | |
| **Names and Signature of Team in charge** | | | | |

- Content/Topic 2: Interpretation of the maintenance records history

Panel Maintenance records history/ Log Sheet (every 3 months)

| **COMPANY NAME** |
|---|
| **NAME OF SOLAR POWER PLANT** |
| **PREVENTIVE MAINTENANCE** |
| **EVERY 3 MONTHS CHECKS** |
| **DATE** |

| Date | Name of Maintenance Technician | PV Module Clean | | Array Frame | | | Array Cabling | Array Output voltage |
|---|---|---|---|---|---|---|---|---|
| | | Yes | No | Good | Fair | Bad | | |
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| **Names and Signature of Team in charge** | | | | | | | | |

Weekly Battery Inspection records history for "Deep Cycle Flooded" Lead acid Battery

| **COMPANY NAME** |
|---|
| **NAME OF SOLAR POWER PLANT** |
| **PREVENTIVE MAINTENANCE** |
| **WEEKLY CHECKS** |
| **DATE** |

| Date | Battery Number | Specific Gravity | Terminals/Connection Tight | | Voltage | Water Level | | | Action Taken |
|---|---|---|---|---|---|---|---|---|---|
| | | | Yes | No | | Good | Fair | Low | |
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| **Names and Signature of Team in charge** | | | | | | | | | |

Weekly Battery Inspection Log Sheet for AGM and GEL Batteries

| **COMPANY NAME** |
|---|
| **NAME OF SOLAR POWER PLANT** |
| **PREVENTIVE MAINTENANCE** |
| **WEEKLY CHECKS** |
| **DATE** |

| Date | Battery Number | Terminals/Connection Tight | | Voltage | Action Taken |
|---|---|---|---|---|---|
| | | Yes | No | | |
| | | | | | |
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| | | | | | |
| | | | | | |
| **Names and Signature of Team in charge** | | | | | |

- Content/Topic 3: Maintenance steps of the different parts of solar power plant systems

Proper maintenance ensures that solar system life is preserved for as long as possible and the original conditions of the system are sustained, while compensating for normal wear and tear. Solar systems require little maintenance as compared to other electric systems such as diesel generators; however, they are not maintenance free

Below there are Instructions on performing preventative maintenance on major components of a solar PV system:

1. Battery
2. Solar Panels
3. Charge Controller
4. Inverter
5. Wiring and connections

**BATTERY MAINTENANCE**

A battery is a device which is used to store electrical charge. The pictures below show two common types of batteries used in solar installations.

Sealed Gel Battery

Deep Cycle Flooded -Lead Acid Battery

Batteries should be regularly and carefully maintained to extend their useful life. These activities include:

1. Inspecting and cleaning regularly
2. Checking the electrolyte level (not required for Gel Batteries)
3. Keeping in a high state of charge

1. **Battery Inspection and Cleaning**

A visual inspection should be done to assess the general condition of the system's batteries. Check for any electrolyte leak, cracks in the batteries, or corrosion at the terminals or connectors.

Effects of poor maintenance techniques are shown in the pictures below

Batteries should be clean, dry and free of electrolyte and corrosion residue. Corrosion at battery terminals is seen as a white coating around the battery terminals. Cleaning should be done once monthly

**Precautions**

To minimize hazards, the following precautions should be taken prior to carrying out battery maintenance.

- ✓ Safety goggles must be worn when performing battery maintenance
- ✓ Protective gloves and chemical-resistant rubber gloves must be worn to prevent contact with battery acid.
- ✓ If there is acid spillage, neutralize the acid with a water and bi-carbonate soda solution. Metal files should not be used to remove corrosion.
- ✓ Use tools with insulated handles to carry out any maintenance.

Do not smoke or light fire near batteries. Batteries produce hydrogen gas which is highly flammable

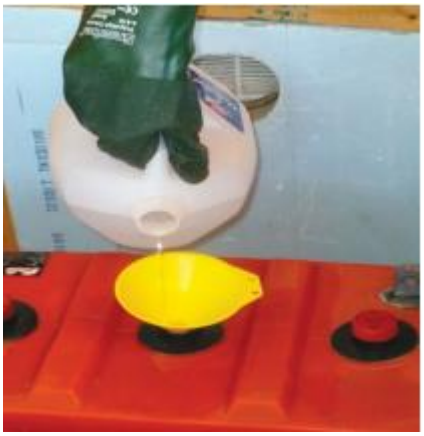
Before maintenance is carried out, each component of the system should be isolated. This would involve switching off circuit breakers to and from the battery bank and the solar panels. Battery cleaning procedures are as follows:

- ✓ Switch off/disconnect all loads on the system. Turn off or disconnect the solar charge. Then turn off the circuit breaker to and from the battery bank.

- ✓ Ensure that the caps on the batteries are sealed tight to keep any dirt from entering the battery. Wipe the top and outside of the battery with a (damp) cloth. If corrosion is present at the terminals, mix baking soda with fresh water and apply the solution to the affected area. Stubborn areas should be scrubbed with a metal brush. After cleaning, rinse the terminals with water. If available, apply petroleum jelly or grease to the connected terminal to prevent future corrosion.

- ✓ Maintenance of gel cell and AGM batteries relates only to the battery terminals and connections. The terminals and posts should be wiped until they are shiny, and if corroded, clean them properly with Bi-carbonate soda and water. If available, apply petroleum jelly or grease to the connected terminals.

**2. Checking the Electrolyte level**



Battery maintenance involves checking the cell electrolyte level for correct acid volume once a month. The cells should be watered back to the original acid level which is ¼ - ½" below the bottom of the vent well (the tube inside the battery cell with slots on each side).

Use only distilled water to top up the batteries.

Testing for the specific gravity of electrolyte in the battery is an accurate way to measure and compare the state of charge of each individual cell.

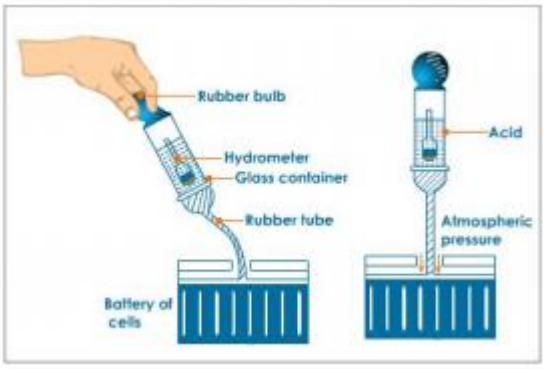
The process of checking the electrolyte specific gravity for a "Deep Cycle Flooded" Lead Acid battery is given below:

- ✓ First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell

- ✓ Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube

✓ Obtain a reading by looking at the float which corresponds to a level on the tube. The acid level in the batteries should be within two centimeters of the top of the battery. A visual inspection could also be made to check the condition of the plates. Record the cell number and the results

✓ Do not replace liquid from one cell to another



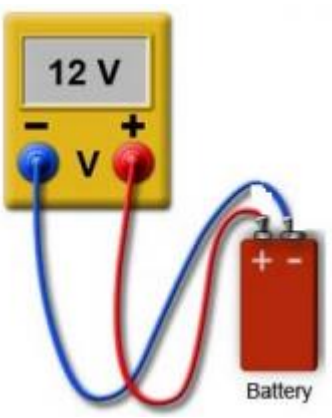

The table below shows typical battery state-of-charge at various levels of specific gravity. The voltages mentioned below are for 12V and 6V batteries.

| State of charge | Specific gravity | Voltage - 12V | Voltage – 6V |
|---|---|---|---|
| 100% | 1.265 | 12.7 | 6.3 |
| 75% | 1.225 | 12.4 | 6.2 |
| 50% | 1.190 | 12.2 | 6.1 |
| 25% | 1.155 | 12.0 | 6.0 |
| Discharged | 1.120 | 11.9 | 6.0 |

Note that the table above gives only indicative values; specific gravity will vary somewhat depending on the battery type and brand, and on the battery's temperature.

The specific gravity readings of each cell should be recorded and maintained in a log sheet.

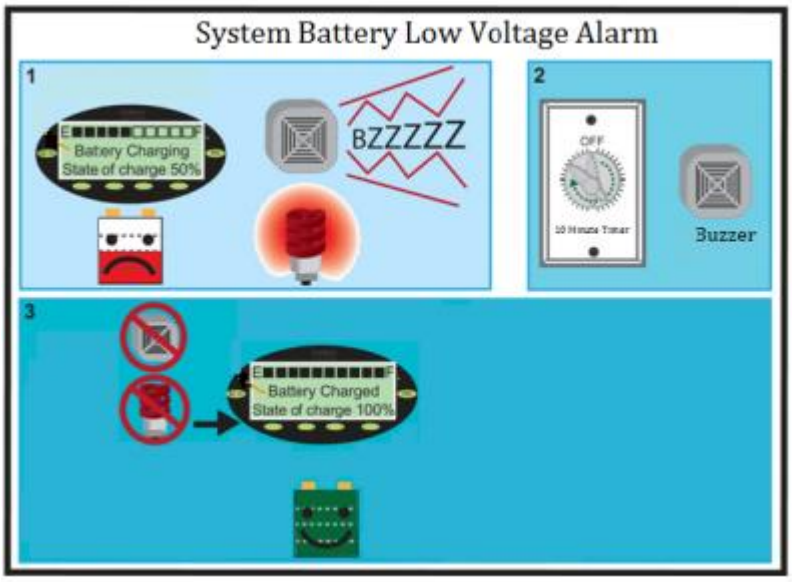
**3. Checking Battery Voltage**



Another important measure in determining the battery state of charge is the battery voltage. A volt meter is used to measure this quantity. The positive lead of the volt meter should be connected to the battery's positive terminal and the negative lead of the volt meter should be connected to the negative terminal of the battery. The table above shows the corresponding battery voltages and the corresponding state of charge of the battery. After measuring each battery's voltage, it should be recorded and maintained in a log sheet.

Battery Alerts

The solar system has an alarm to produce a visual and audible indication to alert a low battery state of charge. When the battery state of charge falls to 50% the alarm will trigger and buzzer will sound for 10 minutes. The buzzer will be automatically turned off, but will start again every 10 minutes. Turn off lights connected to the solar system to avoid deterioration of the battery.




**SOLAR PANEL MAINTENANCE**

The solar array (a number of solar panels connected together) is often thought to be maintenance free. However, occasional maintenance and inspection of the solar array must be performed to ensure the optimal use of the solar panels. This can be done by keeping the surface (glass) area of the module clean from any excess dirt.

- ✓ To remove a layer of dust and dirt from the modules, simply wash the panel with water. If the module has thick dirt or grime and bird droppings, which are harder to remove, wash with cold water and rub the panel surface with a sponge.

Do not use a metal brush to clean solar panel surface. Detergents should not be used.

- ✓ A visual inspection of the modules can then be done to check for defects in the modules such as cracks, chips, de-lamination, fogged glazing, water leaks and discoloration. If any obvious defects are found, note their location in the system logbook, so they can be monitored in the future in case further deterioration affects the modules' output.

- ✓ The condition of the array mounting frame should also be noted. Items to observe should include the array mounting bolts (e.g. bolt rusting) and checks to ensure that the frame and modules are firmly secured. The junction boxes should also be checked to ensure that the wires are not chewed by rodents or insects

Take adequate precautions while doing maintenance of the solar panels since these are located on rooftops and there is the risk of falling off

INVERTER/ CHARGE CONTROLLER

This component can be maintained by minimizing dust accumulation. A dry cloth should be used to wipe away any accumulated dirt/dust. A visual inspection should be done to ensure that all the indicators such as LED lights are working and that the wires leading to and from this device are not loose. Note that the charge controller should indicate that the system is charging when the sun is up. If not, contact the installer immediately.

WIRING AND CONNECTIONS

Wiring installations should be checked for any cracks, breaks or deterioration in the insulation/conduits. Inspect panel boxes to ensure that they have not become a home for rodents and insects. Also inspect connections for any corrosion and/or burning. Switches should not spark when turned on or off. The following sections of conduit and wiring should be checked for any signs of damage:

- ✓ Solar panels to the charge controller
- ✓ Charge controller to the battery bank
- ✓ Inverter/charger to the battery bank
- ✓ Generator to Inverter/charger
- ✓ Inverter/charger and Generator to the AC outlets
- ✓ Battery bank to the DC outlets/load.

If damage is found, consult with the installer as soon as possible. All ground wires should be checked to ensure they are not broken

For a system with power transformer at the site with installed capacity in megawatts, parameters such as the operating temperature, OTI (oil temperature), WTI (winding temperature), and oil level are monitored daily. If there is any internal disturbance in the transformer, it reflects in these parameters which are monitored at least three times in a day (at 11 AM, 02 PM and 04 PM as solar power is generated at its peak during these slots). The transformer has to be cleaned thoroughly once in six months.

## LO 2.2 – Test solar power plant

- Content/Topic 1: General faults that occurs in solar power plant systems

CLASSIFICATION OF FAULTS IN GCPV (GRID-CONNECTED PHOTOVOLTAIC) SYSTEM

Faults in PV system can be identified in two side of the system: DC side and AC side, the interface between this to part is DC/AC inverter that connected to grid.

A. Faults in DC side: The faults occurs in DC side of the GCPV system are classified into two major types: Fault in PV array and Fault in MPPT (Maximum power point tracking).

A.1. Faults in PV Array

Faults in PV arrays involve two main groups, PV panel fault and cabling fault. The most common types of fault in PV Panel/Module are Earth Fault, Bridge Fault, Open Circuit Fault and Mismatch Fault.

a) PV panel/Module Faults

1) Earth Fault

Earth fault occurs when the circuit develops an unintentional path to ground. Two types of grounding shall be provided for PV system such as system grounding and equipment grounding.

In system grounding, the negative conductor is grounded through the ground/ Earth fault protection device (GFPD) in the PV inverter.
The exposed non-current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures should be grounded in equipment grounding.

Two types of Earth faults namely Lower Earth fault and Upper Earth fault can occur.
In Lower Earth fault, the potential fault point is upper than half of the maximum voltage power point.
And the Upper Earth fault will create large backed current and very high Earth-fault current. Without any sensor, these faults are identified, when the sign of the monitored primary current of the solar inverter is changed. When the primary current becomes negative, the solar inverters initiate a controlled internal short circuit

2) Bridging fault

When low- resistance connection recognized between two points of different potential in string of module or cabling, the bridging fault will occur. Insulation failure of cables such as an animal chewing through cable insulation, mechanical damage, water ingress or corrosion cause these faults.

3) Open Circuit Fault

An open circuit fault occurs, when one of the current-carrying paths in series with the load is broken or opened. The poor connections between cells, plugging and unplugging connectors at junction boxes, or breaks in wires cause this fault.

4) Mismatch Fault

When the electrical parameters of one or group of cells are changed from other, the mismatches in PV modules will occur.

These fault results in irreversible damage on PV modules and large power loss. These faults can be classified into permanent and temporary mismatches.

Temporary mismatches occur when a part of the panels array is shaded by shade from the building itself, light posts, chimneys, trees, clouds, dirt, snow and other light- blocking obstacles.

Non- uniform temperature can be identified due to snow covering. Permanent mismatch occurs due to faults in hotspot, soldering and degradation. Hot spot heating happens when the operating current exceeds the reduced short circuit current of a shadowed or faulty cell or group of cells within the module.

Soldering fault can be identified in resistive solder bond between cell and contacted ribbons. Discoloration, delamination and transparent layer crack result in degradation fault.

b) Fault in cables

Bridging Fault, Open-Circuit fault and Earth Fault occur in power line carrier and cabling system.
An aged connection box at the back side of a solar panel or in the corner and bend aria of cable cause bridging fault.

Upper earth and lower earth faults occur between panels and ground; result in dropped output voltage and power, and can be dangerous if the leakage currents are running through a person.

A.2. MPPT fault

MPPT increases the power fed to the inverter from PV array. The performance of MPPT degrades when the failure occurs in the charge regulators. The output voltage and the output power reduce when fault occur in MPPT.

B. Faults in AC side

In AC side two types of faults can be identified:

- ✓ Total black out which measured as exterior fault for system, lighting and unbalanced voltage
- ✓ Grid outage for AC part defect such as weaker switch, over current or over voltage and etc.

Meanwhile most PV inverters having transformers that could give good galvanic isolation between PV arrays and utility grids and perfect electrical protections.

The AC output power will become low and DC output power remains the same, when there is a fault in the inverter. This detail confirms that there is no possibility that a wire between modules/strings and inverter was broken or a breakdown occurs in strings and/or modules. So, fault in the inverter is the reason for power loss

Common inverter faults

**Overheating**

Inverters are made up of electronic components, and therefore sensitive to temperatures. High temperatures will lead to a significant reduction in production, and can even result in a production stop if the maximum operating temperature is reached.

**An assessment must therefore be made as early as the design stage to determine whether the proposed cooling technology is adequate and whether it has sufficient capacity.**

For example, it is very important that the switch cabinet and the building housing the inverter(s) are well ventilated.
Alongside an assessment of the initial design, **it is highly advisable to regularly check the cooling during the operational period and to establish that the cooling or ventilation system is actually operating correctly.**

In addition to this, a number of steps can be taken in order to prevent excessively high temperatures, such as installing and cleaning dust filters, removing undergrowth that impedes airflow, etc.

**Isolation Fault**

Another common problem is the “isolation fault”. This fault occurs as a result of a short-circuit between various parts of the circuit, and the inverter will then report an “isolation alarm”.

The short-circuit is usually the result of a combination of moisture and damage to the sleeve on the cabling, faulty installation, poor connection of the DC cables to the panel, or moisture in the connection part of the PV module. This will be more common in areas with high humidity and/or close to the sea.

In the event of an isolation fault, the inverter will stop working completely or continue to work at the minimum “required” isolation level. In the meantime, the inverter is not performing at its maximum capacity. In both cases, production is lost. It is therefore important to ensure that the DC cables are of high quality and correctly installed, i.e. that the cable bushing is watertight. To prevent this problem,
it is also important that the correct level of protection is selected for the inverter cabinet and the inverter building.

**Warning! An isolation fault can cause potentially fatal voltages in the conducting parts of the system! Ensure that maintenance is always carried out in accordance with the applicable safety standards.**

**Inverter does not restart after a grid fault**

An inverter must be able to restart itself after a grid fault (if there are no other faults).

For example, voltage peaks which occur during sudden deactivation could trigger cut-outs in the system. If the inverter does not restart itself, a service team will then have to come on site in order to restart the system. This will lead to unnecessary production loss.

**It is therefore not just the brand of the inverter that is important, but also the quality of the components used as well as the use of a good 24/7 monitoring system in order to detect faults as quickly as possible.**
If this is not organized properly, all PV modules connected to the inverter will be unable to deliver power until the fault has been discovered and an engineer has rectified the fault. This is a problem that particularly occurs in areas where the grid connection is not always stable.

## LO 2.3 – Clean/ replace required devices

- Content/Topic 1 : Main parts of solar power plant systems

✓ Solar modules: Also called **solar panels**, a **solar module** is a single **photovoltaic panel** that is an assembly of connected **solar cells**. The **solar cells** absorb sunlight as a source of energy to generate electricity. An **array** of **modules** are used to supply power to buildings

✓ Batteries: is a device that produces electrons through electrochemical reactions, and contains positive (+) and negative (-) terminals. A **battery** consists of one or more electrochemical cells, which transform stored chemical energy directly into electrical energy

✓ Inverters: is a device which converts a DC (direct current) voltage source into an AC (alternating current) voltage source. It is useful when you want to run an appliance designed to be operated from AC mains from DC supply.

✓ Charge controllers: *charge* regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk.

- Content/Topic 2: Cleaning techniques of different parts of solar power plant systems

**Solar Panel Cleaning**

Solar panels are generally pretty much self-cleaning as natural rainfall will usually wash away the accumulated dust and grime. However, if your solar panels are only tilted minimally, or you live in a high-traffic, dry or dusty area, or even by the sea, then you're going to need to clean your solar panels in order for them to continue generating maximum output of power. Dust, bird dropping, grime, leaves and sea-salt residue can all reduce the amount of power your solar panels produce, as well as reduce the lifespan of your solar panels. Solar panels are a relatively new feature of residential homes, and as such not many people know how to correctly clean their solar panels.

To remove a layer of dust and dirt from the modules, simply wash the panel with water. If the module has thick dirt or grime and bird droppings, which are harder to remove, wash with cold water and rub the panel surface with a sponge.

Do not use a metal brush to clean solar panel surface. Detergents should not be used.

**Why should you clean your solar panels?**

Dirty solar panels reduce the amount of sunlight being absorbed by the panel, thus reducing the amount of electricity being generated by the solar panel. Further to that, solar panels are a product of electrical technology, and need to be maintained in order to keep them working and in good condition for years to come.

**How often should you clean your solar panels?**

The ZEN Energy Fact Sheets recommend that solar panels be cleaned every six months, and the best times to clean are late spring and late autumn, but homes located in areas with construction and/or regional/farming areas should clean their panels more frequently. Alternatively, if you live in a relatively clan area that experiences regular rainfall, periods between cleaning could e longer, or even unnecessary. Have your panels inspected by a reputable solar specialist before getting your panels cleaned.

**When should you clean solar panels?**

Clean your solar panels on an overcast day in the early morning or evening in cooler months. Not only will this protect you from sun damage, but it'll stop any cleaning products drying too quickly on the solar panels, leaving additional grease or residue.

**Batteries Cleaning**

Battery terminals need to be regularly cleaned with a mixture of baking soda and distilled water using a battery terminal cleaner brush. Afterward rinse the terminals with water, ensure that all connections are tight and coat the metal components with a commercial sealant or a high temperature grease.

**Inverter/ Charge controller cleaning**

These components can be maintained by minimizing dust accumulation.  A blower or dry cloth should be used to wipe away any accumulated dirt/dust.

- Content/Topic 3: Assembling and disassembling techniques of different parts of solar power plant systems

Before maintenance is carried out, each component of the system should be isolated. This would involve switching off circuit breakers to and from the supply

The following are skills, knowledge and attitude during Assembling and disassembling

**You must be able to:**

P1 work safely at all times, complying with health and safety and other relevant regulations, directives and guidelines

P2 follow the relevant instructions, assembly drawings and any other specifications

P3 ensure that the specified components are available and that they are in a usable condition

P4 use the appropriate methods and techniques to assemble and secure the components in their correct positions

P5 check the finished assembly is complete and ready for tests to be carried out

P6 dismantle the tested assembly to agreed level using appropriate tools and techniques

P7 deal promptly and effectively with problems within your control and report those that cannot be solved

**You need to know and understand:**

K1 the specific safety precautions to be taken whilst carrying out the assembly and disassembly of electrical/electronic equipment (such as any specific legislation, regulations or codes of practice relating to the activities, equipment or materials)

K2 the health and safety requirements of the work area in which you are carrying out the assembly and disassembly of electrical/electronic equipment, and the responsibility they place on you

K3 the personal protective equipment and clothing (PPE) to be worn whilst carrying out the assembly of electrical/electronic equipment

K4 the hazards associated with assembling and disassembling electrical and electronic equipment on experimental, and how to minimize them and reduce any risk

K5 the precautions to be taken to prevent electrostatic discharge (ESD) damage to circuits and sensitive components (such as use of earthed wrist straps)

K6 the procedures for obtaining the various types of circuit drawings, sketches, development sheets, job instructions and other related specifications that are used during the assembly and disassembly of electrical/electronic equipment, and how to interpret them correctly

K7 how to identify the electrical/electronic equipment/components to be used; component identification systems (such as codes and component/equipment orientation indicators)

K8 the assembly and disassembly methods and procedures to be used, and the importance of adhering to these procedures

K9 how the components/equipment is to be aligned and positioned prior to securing, and the tools and equipment that are used

K10 the various joining, fastening and connecting devices that will be used, and their method of installation and disassembly

K11 the function of the various items of electrical/electronic equipment or components

K12 the use of torque wrenches, and the importance of ensuring fasteners are adjusted to the required settings

K13 the types and rating of wires/cables and fuses; their function and application

K14 the principles, conventions and wiring regulations associated with electrical measurement and assembly

K15 the consumables, tools and equipment that are used for constructing and fitting wiring looms to vehicles

K16 the importance of using the specified fasteners for the assembly and why you must not use substitutes

K17 dealing with components or fastening devices that are incorrectly assembled, damaged or have other faults

K18 the quality control procedures to be followed during the assembly and disassembly operations

K19 the types of tests which the assemblies will be subjected to

K20 how to adjust and make minor alterations to assembled units and their alignment, where appropriate, to meet specifications

K21 the procedure to check that the developed units meet the specification and quality control requirements

K22 how to conduct any necessary checks to ensure the accuracy and quality of the assembly produced

K23 the principles, conventions and wiring regulations associated with electrical measurement and assembly

K24 the use of meters and computer-aided fault diagnostic equipment

K25 recognizing defects (such as incorrect assembly, ineffective fasteners, foreign object damage)

K26 the importance of ensuring that the completed assembly is free from leftover items and foreign objects

K27 preparations to be undertaken on the components and fixing points prior to fitting the components into the vehicle

K28 how to check that the tools and equipment to be used are correctly calibrated and are in a safe, tested and serviceable condition

K29 the importance of ensuring that all tools are used correctly and within their permitted operating range

K30 the problems that can occur with the development activities on experimental vehicles, and how these can be overcome

K31 the extent of your own responsibility and to whom you should report if you have problems that you cannot resolve

**You must be able to:**

1 Carry out all of the following during the assembly and dismantling activities:

1.1 obtain and use the appropriate documentation (such as job instructions, drawings, specifications, planning and quality control documentation)

1.2 adhere to procedures or systems in place for risk assessment, personal protective equipment and other relevant safety regulations and procedures to realize a safe system of work

1.3 use safe and approved techniques to dismantle and re-assemble sub-assemblies and components to the vehicles

1.4 check that all tools and measuring equipment to be used are within current calibration/certification dates

1.5 ensure that sub-assemblies and components used are free from damage, foreign objects, dirt or other contamination before assembling them

1.6 return all tools and equipment to the correct location on completion of the fitting activities

1.7 leave the work area and machine in a safe and appropriate condition on completion of the activities

- Content/Topic 4: Replacement of defective parts

  The primary method for fixing a defect or fault is repair. If repairing is impossible or would cause unreasonable costs, the item can be replaced with a faultless one.

The liable company has the right to repair the defect or fault if it offers to do so immediately after receiving notice of the problem from the buyer and the repairs are done within a reasonable time, without causing a decrease in the value of the item and without undue inconvenience for the buyer.

The consumer has the right to refuse the offer of repairing the item if it would cause significant inconvenience or a decrease in the value of the item, or if there is the risk that the costs incurred by the consumer will not be compensated.

**Replacement**

A defective item can be replaced with a faultless one if repairing is impossible or would cause unreasonable costs. If the warranty is still valid, the warranty period is not extended due to the replacement: the original warranty will remain in place. The replacement item must correspond to the defective one in value and quality, and it must fulfil the criteria according to which the consumer purchased the original one.

## LO 2.4 – Complete maintenance report

- Content/Topic 1: Preparation of the maintenance report

**A maintenance report** shows **maintenance** details of each event in the time range, including the Setup/Takedown Time, Instructions, Event Time, Facility, Event, ID (Rental, Contract or Event), Service, and Customer.

- Content/Topic 2: Maintenance report format

Maintenance report format sample

| **COMPANY NAME** |
|---|
| **NAME OF SOLAR POWER PLANT** |
| **PREVENTIVE MAINTENANCE** |
| **DAILY CHECKS** |
| **DATE** |

| EQUIPMENT TYPE | NO. OF FACILITIES | MAINTENANCE TASK | PLANNED | ACTUAL | EXCEPTION FROM PLANNED | NOTES |
|---|---|---|---|---|---|---|
| **Solar module** | | output voltage of each string | | | | |
| | | Inspection | | | | |
| **Inverter** | | Inspection | | | | |
| | | input voltage of inverter | | | | |
| | | output voltage of inverter | | | | |
| | | healthiness of all indication lamps | | | | |
| **Batteries (if used)** | | electrolyte level | | | | |
| | | batteries voltage | | | | |
| **Names and Signature of Team in charge** | | | | | | |

REPORT DEFINITIONS

| Column Heading | Definition | Sample Input |
|---|---|---|
| Equipment Type | Asset name and/or Maintenance description. | Solar module |
| No. of Facilities | Number of equipment in the population. Annotate when number includes non-ISO facilities. | 1000 Inverter |
| Maintenance Task | Description of task | Voltage measure |
| Planned | Annual number of tasks planned for the year. NA when planning is not applicable to the Maintenance task. | A number or “NA” |
| Exception from Planned | Text describing exceptions or differences between planned and actual | Winter storm disturb the tilt angle |
| Notes | Text to provide information NOT related to exceptions | Tilt angle inspections |

- Content/Topic 3 : Keeping records of maintenance activities

Maintenance records are written notes that provide documentation about the upkeep of a certain piece of equipment. Most of the time when people talk about these sorts of records in an industrial setting, they’re referring to the formalized reports and files kept by fleet owners, industrial plant operators, or other business people engaged in some sort of work with machines. Keeping an adequate log of mechanical service and repairs in these scenarios is usually considered good business practice, and may also be required by law. Records are particularly useful in maintenance management because they help businesses ensure that their equipment is kept in good condition, and they also offer a way to manage and track repair and preventative upkeep expenses

Here we list the benefits of keeping a maintenance record.

- ✓ Prevent expensive repair works from happening
- ✓ Helps you create specialized maintenance programs
- ✓ Prevent problems regarding warranty claims
- ✓ It increases the safety of operators
- ✓ Helps you track who is accountable for a piece of equipment
- ✓ It increases the resale value of the equipment

4 Ways to Keep a Maintenance record

Start a Paper Trail

Whether you use a pen to jot down on paper the dates and details of every Equipment maintenance service that your Equipment undergoes, or you type the information in your computer, print it, and put it in a file folder, having an easily-accessible *paper* trail is still a very common and practical way to keep a car maintenance log. This option is particularly convenient if you want to sell your Equipment at a dealership or privately; having an easy-to-read, tangible folder of documents detailing how you've maintained your Equipment can help to increase its market value.

Download an App

A great way to keep track of all thing's equipment related, equipment is an all-in-one, easy-to-use, highly-customizable FREE app for Android 2.1+ equipment. Once you've entered your equipment's make, model, and year in the app, it can provide tons of helpful statistics, graphical charts, and interesting reports about your Equipment. (Yes, you can use if for more than one equipment).

Use Microsoft Excel

Use equipment maintenance log template to keep track of your auto repairs and maintenance upkeep. Vertex42 offers spreadsheet templates for Microsoft® Excel®, OpenOffice.org, and Google Docs. With their template of columns, you'll be able to keep track of the dates you have your equipment serviced, what was done, and how much it was. In addition to providing a detailed equipment maintenance log, you can also use the template to create a vehicle maintenance *schedule* so that you know exactly what your equipment (really) routinely needs and when it needs it.

- Content/Topic 4 : Analysis of the maintenance report

Report analysis is the process of exploring data and reports in order to extract meaningful insights, which can be used to better understand and improve business performance.

How do you Analyze a report?

Draw out the findings that are most important and directly align with your **analysis** goals. Summarize your findings in a memo, **report** or email. Start with an executive summary that describes your **analysis** and highlights the key findings. Include the appropriate level of detail and your recommendations for next steps

# Learning Unit 3 – Rectify faults in solar power plant systems

## LO 3.1 – Identify faults

- Content/Topic 1 : Solar power plant systems troubleshoot procedures

Troubleshooting is a method of finding the cause of a problem and correcting it. The ultimate goal of troubleshooting is to get the equipment back into operation. This is a very important job because the entire production operation may depend on the troubleshooter's ability to solve the problem quickly and economically, thus returning the equipment to service. Although the actual steps the troubleshooter uses to achieve the ultimate goal may vary, there are a few general guidelines that should be followed.

**General Troubleshooting Guidelines**

The general guidelines for a good troubleshooter to follow are:

Use a clear and logical approach

- Work quickly
- Work efficiently
- Work economically
- Work safely and exercise safety precautions

Solar Power plant Safety: Lockout / Tagout For Solar Power Systems

As in all electrical systems, shock and electrocution pose serious risks in solar energy power systems. Likewise, solar installers and solar PV maintenance technicians must follow lockout / tagout (LOTO) procedure, wear personal protection equipment (PPE) and follow fall protection guidelines.

✓ **Visual inspection**

Visual Inspection, used in maintenance of facilities, mean inspection of equipment and structures using either or all of raw human senses such as vision, hearing, touch and smell and/or any non-specialized inspection equipment.

**Visual inspection Checklist**

| | | | Defect Present? | | | |
|---|---|---|---|---|---|---|
| **COMPONENT** | **DEFECT** | | **No** | **Yes** | **If Yes, Score** | **Safety issue?** |
| **1. Label** | See New Module Checklist | | | | | |
| **2. Backsheet** | 2.2 | Burn marks | | | | |
| | 2.3 | Discolouration | | | | |
| **3. Junction Box** | See New Module Checklist | | | | | |
| **4. Wiring** | 4.3 | Cracks or exposed metal | | | | |
| **5. Frame** | See New Module Checklist | | | | | |
| **6. Front Glass** | See New Module Checklist | | | | | |
| **7. Encapsulation** | 7.2 | Discolouration | | | | |
| **8. Cells** | 8.9 | "Snail trails" | | | | |
| | 8.10 | Shiny locally/inconsistent colour | | | | |
| **9. Cell Metallization** | See New Module Checklist | | | | | |
| **10. Cell Interconnection** | See New Module Checklist | | | | | |
| **SUMMARY** Indicate if any defects and safety issues are present and sum score | | | | | | |

The need to de-energize the system applies when installing, inspecting or performing maintenance on photovoltaic (PV) systems, but de-energizing those systems can be a bit trickier than standard electrical systems. The energy from PV modules is “wild” meaning it varies with the sunlight and is not controlled by electronics. Even under cloudy conditions and at night there is the potential for shock hazard with a PV system.

Although PV modules can never be completely de-energized, the ac output of the inverter can be de-energized, and the dc voltage reduced to acceptable levels. The modules in a string can be manually disconnected to reduce the voltage to individual modules. Or you can use module-level power electronics, such as power optimizers and microinverters, which automatically reduce module voltage when the ac breaker is switched off.

To safeguard first responders, the National Electrical Code (NEC) Article 690.12 “Rapid Shutdown” requires modules and exposed conductive parts within the PV array boundary to be reduced to 80 V within 30 seconds, and conductors outside the array boundary to be limited to 30 V within 30 seconds.

**How to LOTO a PV system**

While site specific, general shutdown procedures are the same for PV systems as for standard electrical systems:

- ✓ **Testing**

Announce the shutdown and state the magnitude of the energy (i.e. voltage and current levels).

Use a clamp meter, such as the Fluke 376 FC True-RMS Clamp Meter to test Current, voltage and continuity.

Open circuit breakers, fuses, and leads between modules.

Once you have verified there is no voltage in each component, apply the lock and tag to each component with the worker’s name, date, energy sources, isolating devices, magnitude of stored energy, and work being performed.

For PV systems you need to control both the dc (before the inverter), and the ac (after the inverter) sides of the circuit. The steps below describe the process of LOTO procedures for systems that are grid-tied, in which the inverter senses the grid and shuts off when there is no grid voltage present. You should always follow all your organization’s safety and maintenance procedures, as well as NEC regulations when working on PV systems.

DC-side LOTO

PV modules will always have voltage, so you need to LOTO the PV source circuit conductors, which run from the modules to the combiner box, to prevent the dc power from energizing the dc side of the inverter.

Disconnect fuses in the dc combiner box to remove parallel connections and isolate individual strings.

LOTO the output circuit from the combiner to the dc recombiner, which is found in large-scale PV systems between string combiner boxes and a central inverter.

LOTO source circuit leads, also known as home run wires, that run from the modules or battery bank to the combiner box. The leads are the positive and negative ends of a PV string, which is a group of modules connected in series. Use a plug lock or apply a tag without a lock if a lock on the leads is not feasible.

AC-side LOTO

On the ac side, incoming power from the grid will be present and precautions must be taken to isolate and deenergize the PV system.

Remove the fuses in the ac combiner, which connects multiple string inverters in large scale systems.

LOTO the ac recombiner output circuit between the ac combiner and the grid connection to ensure there is no voltage from the grid.

LOTO the low voltage (LV) side of the transformer. If the LV side is not de-energized, ac power may be present on the ac recombiner or central inverter.

Important details

PV systems have both dc and ac conductors. Be sure to test for the presence of voltage on each, using the correct setting on your clamp meter. This is especially important because many conductors are the same color regardless of the type of electricity they carry. For instance, PV wire is often black, while the NEC requires three-phase power to have black, red, and blue wires.

LOTO not only the PV circuit breaker in the main electrical panel but also all disconnects at the module, inverter, charge controller, and batteries. Note a battery bank with more than 24 two-volt cells in series must have a disconnection mechanism.

PV modules can never be fully de-energized, so a disconnection mechanism is required for emergency responders to isolate a PV array from the rest of the building.

Module-level power electronics, such as microinverters, are becoming increasingly popular. DC voltages are often limited to 50 Vdc or less with microinverters, compared to the 600 Vdc limit in string inverters. As a result, the NEC permits certain connectors that comply with Section 690.33 of the NEC to be used as dc disconnects for microinverter dc circuits. Per Section 690.33(E)(1) states that connectors shall either “be rated for interrupting current without hazard to the operator” or “be a type that requires a tool to open and marked ‘do not disconnect under load’ or ‘not for current interrupting’”.

In PV systems, inverters store energy in capacitors. It is important to discharge that energy before beginning work, because there still could be capacitance on the dc side. It can take a few minutes to ensure inverters are at a zero state of energy.

Some tests, such as determining PV string current or insulation resistance with a megohmmeter, require the system to be energized. In other instances, it is necessary to isolate and de-energize a specific component—such as an inverter or transformer—while leaving the rest of the system on.

Many new PV systems with battery storage are ac-coupled, meaning the battery bank has its own multimode inverter with one ac circuit connected to stand-alone loads. This increases resiliency but also complexity in maintenance and LOTO. To fully deenergize the system, both the PV interactive inverter and battery multimode inverter need to be off.

The processes described in this article are intended to be used as an example of LOTO procedures for PV. Be sure to follow all or your organization’s safety and maintenance procedures as well as NEC regulations

when working on PV systems

- ✓ **Assumption (Possible cause)**

Examples of failing PV module components due to a lack of quality assurance in the production process include:

1. Failed insulation test - modules with failed or skipped insulation test can cause dispersive and dangerous leakage currents, leading to safety risks

2. Incorrect cell soldering – imperfections in cell soldering can lead to corrosion, undesired electrical resistances, and bad current transmission, to list but a few

3. Undersized bypass diode – increases the chance of hotspots (overheating of cells) or the damage of the bypass diode itself

4. Junction box adhesion - incorrect adhesion of the junction box to the module can cause poor connections interrupting module current, humidity ingress with subsequent corrosion leading to performance losses and increasing risk of electrical arcing leading to fire, to list but a few

5. Delamination at the module edges - water can ingress causing humidity, oxidation and corrosion in cells leading to performance losses

6. Arcing in a PV module - caused by a damaged cell interconnect ribbon - can cause fire during operation of the module

7. Visually detectable hotspots - cells are overheating, which has a negative impact on the energy production of the module (module degradation)

8. Power rating (flash test) is not correctly performed, the sorting of the modules by performance will be incorrect and because of the resulting PV module mismatch losses, the simulation used for the financial model will not be matched. A high uncertainty of the nominal power of total PV plant will lead to uncertainties of the specific energy yield and performance ratio (PR) in the same order of magnitude

- Content/Topic 2: Recognition of faulty parts in solar power plant systems

Based on knowledge of how a PV system produces energy and the underlying dependencies, it is possible to reason about faults. Faults in PV systems can be characterized as permanent power losses but a more fine-grained analysis might be suitable if there are failure-specific patterns that can be utilized. This chapter gives an overview of possible failure conditions and describes the different kinds of methods that have been established by previous studies.

A study conducted in Spain discusses the following failures in solar modules:

- ✓ Yellowing and browning
- ✓ Delamination
- ✓ Bubbles in the solar module
- ✓ Cracks in cells
- ✓ Defects in anti-reflective coating
- ✓ Hot spots caused by the panel acting as a load
- ✓ Edge-seal delamination
- ✓ Newly cracked cells
- ✓ Delamination over cells and interconnections
- ✓ Split encapsulation over cells and interconnections
- ✓ Protruding interconnections
- ✓ Potential Induced Degradation (PID)

## LO 3.2 – Rectify detected faults

- Content/Topic 1: procedures for fault rectification

To diagnose and find faults in electrical installations and equipment is probably one of the most difficult tasks undertaken by an electrician. The knowledge of fault finding and the diagnosis of faults can never be completely learned because no two fault situations are exactly the same. As the systems we install become more complex, then the faults developed on these systems become more complicated to solve. To be successful the individual must have a thorough knowledge of the installation or piece of equipment and have a broad range of the skills and competences associated with the electrotechnical industries.

The ideal person will tackle the problem using a reasoned and logical approach, recognize his own limitations and seek help and guidance where necessary.

The tests recommended by the IEE Regulations can be used as a diagnostic tool but the safe working practices described by the Electricity at Work Act and elsewhere must always be observed during the fault-finding procedures.

If possible, fault finding should be planned ahead to avoid inconvenience to other workers and to avoid disruption of the normal working routine. However, a faulty piece of equipment or a fault in the installation is not normally a planned event and usually occurs at the most inconvenient time. The diagnosis and rectification of a fault is therefore often carried out in very stressful circumstances.

- Content/Topic 2: Rectification of faults in different parts of solar power plant systems

**Troubleshooting PV panels**

First check the output of the entire system at the metering system or inverter. Before you get on the roof, check and record the inverter's input voltage and current level from the array. You will likely encounter one of two scenarios:

- ✓ The entire PV system is down/does not produce power; this may be related to a problem with the inverter.
- ✓ The PV system output is less than expected; this may be related to a problem with one of the arrays or modules.

Trace out the individual branch wiring backward from the concentrator. On the roof, visually check the entire system for any obvious damage. (Wiring may have been accidentally disconnected during a previous service on another device.) Once you find the failed module or array, check all wires, switches, fuses and circuit breakers. Replace blown fuses; reset the breakers and switches. (Since the PV system is on the roof, a lightning strike or power surge may have affected it.) Check for broken wires and loose or dirty connections. Replace and clean as needed. Be on the lookout for wire nuts that are connecting modules together. They may have worked loose and caused lack of contact.

The concentrators can be a great place to troubleshoot the system because the individual wires from the modules are brought back there. Each module may have a fuse that should be checked with your Fluke 376 FC.

Wiring problems and loose connections may also cause a module to produce too low a voltage. All wiring connections should be checked. If a module output is low, it may mean that an individual section of cells is bad. These may be traced out using the Fluke 376 FC at the junction boxes until the culprit is found.

Any dirt on the modules, or modules in the shade, can cause a reduced output. Although the modules are usually designed to be maintenance free for years, they may need to be cleaned. Pollen can be a problem in some areas of the country.

**Troubleshooting PV load**

The PV system is used to operate building electrical loads and any problems with the loads will affect the system as well. The first step is to check the load switches, fuses and breakers with the Fluke 376 FC — check to see if the proper voltage is present at the load's connection. Next, use the Fluke 376 FC to check the fuses and circuit breakers. If there are blown fuses or tripped breakers, locate the cause and fix or replace the faulty component. If the load is a motor, an internal thermal breaker might be tripped or there might be an open winding in the motor. For testing purposes, plug in another load and see if it operates properly.

As with any electrical system, check for broken wires and any loose connections. Clean all dirty connections and replace all bad wiring. With the power off, check for and repair any ground faults. If any fuses or breakers blow or trip again, there is a short that must be located and repaired.

If the load still does not operate properly, use the Fluke 376 FC to check the system's voltage at the load's connection. The wire size may be too small and need to be increased. It may also be possible that that the wires running to the loads are too long. This will show up as a low voltage at the load. In this case you can reduce the load on the circuit or run a larger wire.

**Troubleshooting PV inverters**

You likely work with variable speed drives every day, so are used to checking ac and dc power. The inverter in a PV system can also fail and cause problems. The inverter converts dc from the PV system into ac power for building use. If the inverter is not producing the correct output, first use check and record the inverter's operating dc input voltage and current level. On the ac side, use the Fluke 376 FC to check the inverter's output voltage and current levels. Many of these systems have a display that indicates current inverter and system performance. Because the Fluke 376 FC produces a true-RMS reading, you can use the voltage and current to measure and record the kilowatt (kW) output. If possible, use the inverter display to show the

current total kilowatt hours (kWh). You can then write down this value and compare it to the one recorded during the last inspection.

If the inverter does not produce the right amount of power, there may be several problems—all of which can be easily checked with the Fluke 376 FC:

- blown fuse
- tripped breaker
- broken wires

Use the Fluke 376 FC to measure the output ac side of the inverter because the load on the inverter might have a current demand that is too high. You can either reduce the loads or install a larger converter. With the power off, check for and repair any ground faults before starting the inverter again.

The inverter may be tied into the local utility. The ac current output from the inverter fluctuates with the level of solar input on the array. The inverter maintains the correct output voltage and phase to the utility. Any voltage problems from the utility may cause the inverter to shut down. In this event, contact the utility for repairs.

- Content/Topic 3: After-repair Testing of different parts of solar power plant systems

The following summarizes common types of testing conducted on PV systems what information it provides:

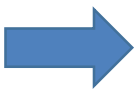
✓ **Continuity and resistance testing:** verify the integrity of grounding and bonding systems, conductors, connections and other terminations.

✓ **Polarity testing:** verifies the correct polarity for PV dc circuits, and proper terminations for dc utilization equipment.

✓ **Voltage and current testing:** verify that PV array and system operating parameters are within specifications.

✓ **Insulation resistance testing:** verifies the integrity of wiring and equipment, and used to detect degradation and faults to wiring insulation.

✓ **Performance testing:** verifies the system power and energy output are consistent with expectations. These tests also require measurements of array temperature and solar irradiance.



For stand-alone or hybrid PV systems incorporating energy storage and additional energy sources, the following additional tests may be conducted:

- ✓ Measurements of battery voltage, capacity and specific gravity.
- ✓ Verification of charge controller set points and temperature compensation.
- ✓ Verification of charging current and load control functions.
- ✓ Verification of performance and wiring integrity for other sources, such as generators.

## LO 3.3 – Complete maintenance report

- Content/Topic 1 : Preparation of the repair report

Repair report format sample

<table>
<tr><td colspan="6">COMPANY NAME</td></tr>
<tr><td colspan="6">NAME OF SOLAR POWER PLANT</td></tr>
<tr><td colspan="6">PREVENTIVE MAINTENANCE</td></tr>
<tr><td colspan="6">DAILY CHECKS</td></tr>
<tr><td colspan="6">DATE</td></tr>
<tr><td colspan="2">Format No.</td><td colspan="2">Rev. No.</td><td colspan="2">Rev. date</td></tr>
<tr><td>Request No.</td><td>Request date</td><td>Requested by</td><td>Req. department</td><td>Received by</td><td>Work order No. & date</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">System failure registered</td><td colspan="3">System ID and Name</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="6">Report Checklist</td></tr>
<tr><td>Sr. No.</td><td colspan="2">Description</td><td>Status</td><td colspan="2">Comment/ suggestion</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
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<tr><td></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="6">Remarks</td></tr>
<tr><td colspan="3">Installed/ repaired spare parts</td><td colspan="3">Required action</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Checked by<br><br>Reviewed by</td><td colspan="3">Date<br><br>Date</td></tr>
</table>

- Content/Topic 2: Keeping records of repair activities

This remainder of the report will be organized as follows:

- ✓ Presents a comprehensive review of the state-of-the-art and state-of-the-practice literature on
- ✓ Equipment replacement and equipment retention decision making.
- ✓ Investigates future uncertain purchase costs.
- ✓ Explores the costs of delaying replacing equipment.
- ✓ Presents a methodology for improving downtime, operations and maintenance (O&M) costs, and mileage forecasting.

**4 Ways to Keep Maintenance report**

Start a Paper Trail

Whether you use a pen to jot down on paper the dates and details of every Equipment maintenance service that your Equipment undergoes, or you type the information in your computer, print it, and put it in a file folder, having an easily-accessible *paper* trail is still a very common and practical way to keep a car maintenance log. This option is particularly convenient if you want to sell your Equipment at a dealership or privately; having an easy-to-read, tangible folder of documents detailing how you've maintained your Equipment can help to increase its market value.

Download an App

A great way to keep track of all thing's equipment related, equipment is an all-in-one, easy-to-use, highly-customizable FREE app for Android 2.1+ equipment. Once you've entered your equipment's make, model, and year in the app, it can provide tons of helpful statistics, graphical charts, and interesting reports about your Equipment. (Yes, you can use if for more than one equipment).

Use Microsoft Excel

Use equipment maintenance log template to keep track of your auto repairs and maintenance upkeep. Vertex42 offers spreadsheet templates for Microsoft® Excel®, OpenOffice.org, and Google Docs. With their template of columns, you'll be able to keep track of the dates you have your equipment serviced, what was done, and how much it was. In addition to providing a detailed equipment maintenance log, you can also use the template to create a vehicle maintenance *schedule* so that you know exactly what your equipment (really) routinely needs and when it needs it.

- Content/Topic 3: Analysis of the repair report

**Level of Repair Analysis (LORA)**

Level of Repair Analysis (LORA) is an analytical methodology used to determine when an item will be replaced, repaired, or discarded based on cost considerations and operational readiness requirements. For a complex engineering system containing thousands of assemblies, sub-assemblies, components, organized into several levels of indenture and with a number of possible repair decisions, LORA seeks to determine an optimal provision of repair and maintenance facilities to minimize overall life-cycle costs. Logistics personnel examine not only the cost of the part to be replaced or repaired but all of the elements required to make sure the job is done correctly. This includes the skill level of personnel, tools required to perform the task, test equipment required to test the repaired product, and the facilities required to house the entire operation

- Content/Topic 4: Billing of repair work

Repair Bill is aimed at self-employed and small auto shops, looking for easy to use invoicing and bookings software. Also, for those who wish to accept card payments from their clients.

# Learning Unit 4 – Clean the workplace

**Why is Cleanliness Important in the Workplace?**

Maintaining **cleanliness** in the **workplace** not only creates a healthier environment for employees but also tends to help companies become more efficient and productive.

## LO 2.1 – Collect tools and equipment

- Content/Topic 1: Identification of different tools/equipment used for cleaning

**Brushes** for cleaning sharp edges

**Lubricants** is a substance, usually organic, introduced to reduce friction between surfaces in mutual contact, which ultimately reduces the heat generated when the surfaces move.

**Blower machines**: is equipment or a device which increases the velocity of air or gas when it is passed through equipped impellers.
They are mainly used for flow of air/gas required for exhausting, aspirating, cooling, ventilating, conveying etc. **Blower** is also commonly known as Centrifugal Fans in industry.

**Sponge** is a tool or cleaning aid made of soft, porous material. Typically used for cleaning impervious surfaces, sponges are especially good at absorbing water and water-based solutions.

**Broom** A domestic utensil with fibers bound together at the end of a long handle, used for sweeping

**Water Hoses** Hollow tubes designed to carry fluids from one location to another

- Content/Topic 2: Method of collecting tools and equipment used in solar power plant system

In addition to training and education, applying general safety principles—such as proper work practices, equipment, and controls—can help reduce workplace accidents involving the moving, handling, and storing of materials. Whether moving materials manually or mechanically, your employees should know and understand the potential hazards associated with the task at hand and how to control their workplaces to minimize the danger.

**What precautions should workers take when moving materials manually?**

When moving materials manually, workers should attach handles or holders to loads. In addition, workers should always wear appropriate personal protective equipment and use proper lifting techniques. To prevent injury from oversize loads, workers should seek help in the following:

- ✓ When a load is so bulky that employees cannot properly grasp or lift it,
- ✓ When employees cannot see around or over a load, or
- ✓ When employees cannot safely handle a load.

- Content/Topic 3:  Arrangement of tools/equipment according to their use

Pointers to follow in **storing tools and equipment**:

✓ Have a designated place for each kind of **tools**.
✓ Label the **storage** cabinet or place correctly for immediate finding

## LO 4.2 – Arrange non-used materials(consumables)

- Content/Topic 1:  Selection of area for storing non-consumable and non-used materials

ake **unused materials** back to storage areas rather than leaving them lying around.
segregate any **materials** which could contaminate each other or be dangerous if stored close together, eg avoid **storing** paint or bleach next to food in a shop stock room. consider how you'll ensure the security of high-value goods.

- Content/Topic 2:  Discard unused tools and equipment

  Electrical and electronic equipment is made up of a wide variety of materials, many of which can be reused (for example, there's enough steel in an iron to produce 13 steel cans).

  By recycling your old and unwanted electrical items, you're doing your bit to help the environment by preventing potentially hazardous waste from entering landfill and causing soil and water contamination.

- Content/Topic 3:  Disposal of waste materials

✓ Throw away all needles, syringes, lancets, and other sharp objects in a hard-plastic or metal container. It should have a lid that screws on or fits tightly. The white hard-plastic bottle with a screw-on lid from Central Sterile Supply (CSS) is perfect for sharp objects.
✓ When the container is ½ to ¾ full, put on the lid tightly. You can now put the sealed container in your trash can.

✓ You can also use a coffee can to dispose of sharp objects. Before throwing the can away, you must cover the plastic lid with heavy-duty tape, such as duct tape. This makes it stronger. It will stop

sharp objects from sticking through the plastic lid.

✓ Do not put sharp objects in glass or clear-plastic containers.
✓ Do not put sharp objects in any container that will be recycled or returned to a store.
✓ Keep containers with sharp objects out of the reach of young children.

## LO 4.3 – Clean tools and working area

- Content/Topic 1 : Different methods of cleaning tools and equipment used in solar power plant system

To ensure tools have a longer utility and lifespan, they must be properly cared for. Cleaning your tools should be approached in the same manner that you clean any other equipment or surface in your facility.

The cleaning principles are:

1. **Dry clean.** Remove visible and gross soils and debris.
2. **Pre-rinse.** Rinse all areas and surfaces until they are visibly free of soil.
3. **Wash (soap and scrub).** Use the right detergent in the right concentration with the right level of mechanical action in the right water temperature for the right contact time.
4. **Post-rinse.** Rinse away all visible detergents and remaining soil.
5. **Inspect.** Look again at crevices and other contamination traps to ensure they're free of soils and detergents. Determine whether steps 1-4 should be performed again.
6. **Sanitize.** Foam, wipe or spray sanitizing chemicals onto surfaces as per the appropriate instructions.
7. **Dry.** Ensure adequate time is allotted for equipment to thoroughly dry.
8. **Verification.** Gather proof that the cleaning performed achieved the expected level by following facility verification protocols.

- Content/Topic 2: Different methods of cleaning the working area in solar power plant system

Why is it important to keep your work area clean and tidy?

That's easy; it's because you care about your job and the people around you and you want them working in a clean and safe environment. Yes, **maintaining a clean workplac**e is crucial to creating a healthy, safe and pleasing environment.

Different cleaning methods Cleaning is usually done in several ways:

- ✓ Mechanical - by machine or human action or both
- ✓ Chemical
- ✓ Combination of both mechanical and chemical
- ✓ Heat and Steam (sterilization).

Examples of cleaning methods

| Mechanical action (Machine) | Mechanical action by man | Mechanical + Chemical | Notes |
|---|---|---|---|
| Vacuuming | Vacuuming | None | - |
| Polishing | Hand Polishing | Polishing | - |
| Washing | Hand Washing | Washing | - |
| Scrubbing | Hand Scrubbing | Scrubbing | - |
| Dry Cleaning | Dry Cleaning | Dry Cleaning | - |
| Hot Water Extraction | Hot Water Extraction | Hot Water Extraction | - |
| Stripping and Sealing | Stripping and Sealing | Stripping and Sealing | - |
| Sweeping | Sweeping | Sweeping | May need sweeping compounds |
| - | Wet mopping | Wet mopping | - |
| Spot cleaning | Spot cleaning | Spot cleaning | - |
| Pressure washing | Pressure washing | Pressure washing | Does not always need chemicals |

## LO 4.4 – Manage waste materials

- Content/Topic 1: Arrangement of waste materials according to their nature

There may be different types of waste such as Domestic waste, Factory waste, Waste from oil factory, E-waste, Construction waste, Agricultural waste, Food processing waste, Bio-medical waste, Nuclear waste, Slaughter house waste etc.

We can arrange waste as follows:

- ✓ Solid waste- vegetable waste, kitchen waste, household waste etc.
- ✓ E-waste- discarded electronic devices such as computer, TV, music systems etc.
- ✓ Liquid waste- water used for different industries, tanneries, distilleries, thermal power plants
- ✓ Plastic waste- plastic bags, bottles, bucket, etc.
- ✓ Metal waste- unused metal sheet, metal scraps etc.
- ✓ Nuclear waste- unused materials from nuclear power plants Further we can group all these types of waste into wet waste

- Content/Topic 2: Disposal of waste materials

**Methods of Waste Disposal**

1. **Composting and Vermicomposting**

This method is useful for the disposal of biodegradable waste. The part of the garbage which can rot in nature to form harmless substances is called biodegradable (plants and animal waste). Different biodegradable waste can be dumped in a pit. Here, it can be allowed to decompose after which the garbage will convert into useful manure. This is known as composting.

The process of decomposition may take around 2 to 3 months. To make the process fast, red worms may be used for composting. This method is called vermicomposting. Vermicompost is the high-quality manure.

**Advantages of Composting**

- ✓ The useful component of the garbage can be converted into manures which can enrich the soil.
- ✓ Degradable waste is easily disposed of.

2. **Landfilling**

A low-lying open area out of the city where garbage is collected and dumped is known as a landfill. The garbage is loaded into the truck and dumped in the landfill. When that area is fully covered with the garbage, it is covered with layers of soil. Now it can be converted into a park or a playground.

**Advantages of Land-filling**

- ✓ It is an easy method of waste disposal.

**Disadvantages of Land-filling**

- ✓ Garbage remains open for a long period of time. This can attract flies and cause various diseases.

### 3. Incineration

This method is mainly used to dispose of the medical waste. In this method, garbage is burnt at a high temperature in a special furnace called *Incinerator*. This reduces large amounts of garbage into a small amount of ash which can be disposed of in the landfill site.

**Advantages of Incineration**

- ✓ It is the most suitable waste disposal method to dispose of the medical and contaminated waste.

**Disadvantages of Incineration**

- ✓ Energy is used for burning which makes the method costly.
- ✓ It may lead to air pollution.

## Reference(s):


https://www.solarpowereurope.org/wp-content/uploads/2018/12/OM-Best-Practices-Guidelines-V3.0.pdf / August 2020

https://www.cleanmax.com/solar-update/smooth-operation-and-maintenance-as-easy-as-1-2-3.php / August 2020

https://www.energy.gov/sites/prod/files/2015/09/f26/7a%20-Step5-Operations-Maintenance.pdf / August 2020

http://www.poweringhealth.org/Pubs/Guyana_Solar_PV_Systems_Maintenance_Guide.pdf / August 2020

https://www.bhg.com.au/how-to-clean-solar-panels-from-the-ground / August 2020

https://www.fluke.com/en-us/learn/blog/renewable-energy/solar-panel-safety-lockout-tagout / August 2020

https://www.caiso.com/Documents/Procedure3-StandardMaintenanceReportingSystem_SMRS_.pdf / August 2020

http://160592857366.free.fr/joe/ebooks/Electronics%20and%20Electrical%20Engineering%20Collection/BIRD,%20J.%20(2001).%20Electrical%20Circuit%20Theory%20and%20Technology%20(2nd%20ed.)/Electrical_Circuit_Theory_and_Technology_2E.pdf / August 2020

https://iea-pvps.org/wp-content/uploads/2020/01/Report_IEA-PVPS_T13-08_2017_Technical_Assumptions_Used_in_PV_Financial_Models.pdf / August 2020

https://books.google.rw/books/about/Electrical_Installation_Calculations.html?id=0K4hsfg9eqsC&redir_esc=y / August 2020

http://directory.umm.ac.id/Networking%20Manual/Advanced%20Electrical%20Installation%20Work%20-%205th%20Edition.pdf / August 2020