



TOPIC OF STUDY

Solar Maintenance and Operation



KEY TERMS

multimeter
volt meter
amp meter
continuity tester
pyranometer
Megger/insulation tester
infrared camera

LESSON

Tools for Evaluating Solar Equipment Performance

OBJECTIVES

Students will be able to:

- Demonstrate use of a multimeter and other basic OM tools.
- Perform basic diagnostic tests using these tools.

BIG IDEA(S)

Use of a multimeter and pyranometer (light meter) are necessary tools when evaluation solar system performance.

TASK LIST SUBCATEGORY

603 Demonstrate the use of testing and performance equipment

OVERVIEW

This session covers the common tools used in O&M use. This will be somewhat of a review of introduction to tools in other lessons, but with special attention to how the tools are used in O&M work. Use of multimeter and pyranometer (light meter) is reviewed.

INSTRUCTIONAL

MATERIALS NEEDED

Teacher preparation: Be acquainted with content, prepare practice activities demonstrating the use of multimeter and other tools.

Teacher presentation: Links to Resources / Videos

Content:

MATERIALS

- Multimeter
- Learning Lab devices to be tested:
 - modules
 - good and bad cables
 - good and bad fuses
 - inverter

Technology: Computer and monitor

IMPLEMENTATION (LESSON PLAN)

1. Review Use of multimeter with attention to O&M procedures
2. Multimeter (best O&M tool is a 600 - 1000 Volt rated meter, with clamp on current meter, capable of testing AC and DC current)
 - AC volt meter
 - Typically used in O&M to:
 - Test presence of voltage for safety reasons
 - Confirm correct AC voltage from grid to inverter / microinverters



IMPLEMENTATION (LESSON PLAN) - CONTINUED

- Line to Line = 240, Line to Neutral & Ground = 120, Neutral to Ground = 0
 - Verify phase consistency - two components that are on the same phase should have zero voltage difference
 - Note: Polarity does not matter
- DC volt meter
 - Typically used in O&M to:
 - Test presence of DC string or inverter voltage for safety
 - Verify number of working modules on a string
 - Test whether a module is defective
 - Test whether an optimizer is defective
 - Check for short-circuits or open-circuits on a string
 - Narrow the search for the location of a problem on a DC string
 - Check polarity of DC wiring
 - Note: Polarity does matter. Red probe should be on the positive line, Black probe on the negative line. Otherwise result will be reversed (negative reading)
- Continuity tester (preferably with beep feature)
 - Used in O&M to:
 - Check for short-circuits / ground-faults
 - Check for open-circuits (broken wires, bad connections)
 - Check fuses
 - Check breakers and switches
 - Check phase consistency on de-energized devices
 - Note: Polarity does not matter
 - Note: Do not check continuity on a live or energized line - especially if there is a voltage difference across the leads. You will get an erroneous reading and/or damage the meter.
 - Note: Continuity is just a Yes / No test:
 - Beep and zero resistance = continuity. The leads are connected to a closed circuit (this can be good or bad)
 - No beep and OL (open line) = discontinuity. The leads are connected to an open circuit (this can be good or bad)
 - Note: there are other more advanced procedures involving resistance testing and diode testing beyond the scope of this course.
 - PRACTICE: test fuses
 - PRACTICE: short-circuit / open-circuit tests
- AC amp meter
 - Used in O&M to:
 - Confirm that line is producing power - and verify that the power is what it should be.
 - Example: Power (Watt) = Voltage (Volt) X Current (Amp). If a line should be producing 5 kW. $5,000 \text{ W} / 240 \text{ V} = 20.8 \text{ A}$
 - Line 1 and Line 2 from a PV system should carry equal current.
 - Current should be less than the fuse or breaker protecting the line.
 - Unusually high current can indicate an isolation fault.
 - Clamp direction usually does not matter

IMPLEMENTATION (LESSON PLAN) - CONTINUED

- DC amp meter
 - Make sure meter is set to DC current - and it is often necessary to calibrate the meter by holding the zero button - to set the meter to zero before taking a reading.
 - Used in O&M to:
 - Check module or string performance
- 3. Pyranometer (light meter)
 - Measures the irradiance of the sun in watts/meter squared.
 - Used to calculate expected power output to compare with measured performance.
- 4. Thermometer
 - Used in O&M to:
 - Check temperature of back of module to adjust performance expectations
 - Check modules or wire connections or devices for hot spots - indicating bad modules / cells, or bad wiring connections that are over-heating.
- 5. Other / Advanced (mention briefly)
 - Insulation Tester 'Megger' - tests for isolation faults (voltage 'leaks') indicating partially worn or damaged wire insulation even if there is not a total short-circuit.
 - Infra-red camera - hand-held or on a drone to test an array for hotspots. Can also check equipment for overheating connections.
 - Data cable tester - tests ethernet cables.
 - IV-Tracer - advanced expensive equipment to measure current and voltage relationships on a string.
- 6. Well-stocked truck
 - A variety of basic tools are common in O&M work. Keep commonly used items in service vehicle at all times. Anticipate needs and be prepared for site visits by bringing any additional items that may be needed.
 - PPE:
 - hard hat
 - fall protection
 - reflective vest, eye protection, ear protection, electrically insulated gloves.
 - General tools:
 - Multimeter
 - Impact driver, hammer drill, (bandsaw), (sawzall)
 - Driver accessories and screw drivers (including tiny 1/8", 3/16" for inverter disconnections and small data wire connections), all kinds of sockets, torx bits, hex bits, drill bits, hole saws, masonry bits
 - Wire strippers, wire cutters, utility knife, scissor snips, tin snips, channel lock pliers, needle nosed pliers
 - Basic parts and supplies:
 - PV stickers, string marking stickers, colored tape
 - Electrical tape - rubber and normal, Noalox, PVC glue, Geocell / silicon caulk
 - Fuses, Circuit Breakers, Breaker Blanks
 - Wire nuts, line tap connectors, ground lugs, romex connectors
 - PV wire, commonly used wires and cables
 - Screws, anchors, nuts & bolts, racking and mounting hardware
 - Squirrel guard (a few pieces for repairs / replacing small sections if cut for access...)
 - MC4 and Enphase connectors, crimping tools, splice crimping tool
 - Spare optimizers, microinverters, communication devices, CTs