Photovoltaic System Grounding

Course Number: EE-02-302

PDH: 2

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Module 1: Introduction

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary safety roles of grounding in long-term photovoltaic system installations.
- **Evaluate** the regulatory differences between North American grounded systems and international protective earthing standards.
- **Select** appropriately certified equipment by understanding the relationship between the NEC, NRTLs, and UL standards.

Executive Summary: Proper grounding is a life-cycle requirement for PV systems; even if a system stops producing usable power, the modules remain capable of generating hazardous voltages that must be mitigated through code-compliant grounding.

Design Fundamentals

Photovoltaic (PV) power systems are unique because they are capable of producing **hazardous voltages and currents** for decades. Unlike traditional equipment, a PV module can remain "hot" for its entire physical life, regardless of whether the system is still functional or connected to a load.

Effective grounding is not a "set and forget" task; it must be **properly maintained** to ensure safety as the system ages.

Global Grounding Philosophies

Engineering practices for grounding vary significantly based on geographic region:

- **United States and the Americas**: Generally utilize **grounded electrical systems** where one circuit conductor is intentionally connected to the earth.
- **Rest of the World (ROW)**: Frequently employ **ungrounded electrical systems**. In these configurations, no circuit conductors are connected to earth, though all non-energized metal surfaces must still be earthed for safety.

This course focuses exclusively on the **National Electrical Code (NEC)** requirements and does not cover international codes or specific manufacturing standards used outside the U.S..

Safety Standards and Equipment Certification

The NEC requires the **Authority Having Jurisdiction (AHJ)** to examine all electrical equipment for safety. Because most inspectors are not qualified to perform deep-level safety evaluations of unlisted hardware, the industry relies on a structured certification ecosystem:

- **Nationally Recognized Testing Laboratories (NRTL)**: Organizations authorized by **OSHA** to test and certify equipment to specific safety standards.

- **Underwriters Laboratories (UL)**: Coordinates the development of critical PV standards, specifically **UL 1703** (modules) and **UL 1741** (inverters and controllers).
- **American National Standards Institute (ANSI)**: The authorizing body for the development of these standards by UL and other organizations.

⚠️ **Safety Constraint**: While the NEC does not explicitly mandate that every piece of equipment be certified or listed, many AHJs will **require NRTL listing** as a condition of permit approval.

💡 **Design Tip**: Always specify equipment that carries an NRTL certification. This ensures the hardware meets standardized input/output interconnectivity and safety requirements, facilitating a smoother inspection process.

Checkpoint Quiz

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1. **Why is grounding considered a "life-cycle" requirement for PV systems?**
   a) To ensure the system reaches its 40-year efficiency rating.
   b) Because PV modules can produce dangerous voltages even after the system stops producing usable power.
   c) Only to satisfy utility interconnection agreements during the first year of operation.
   d) To prevent UV radiation from fading conductor insulation.

Answer: (b). Modules generate voltage whenever sunlight is present, regardless of system age or functionality.

2. **In the "Rest of World" (ROW) electrical philosophy, which of the following is true?**
   a) Circuit conductors are always connected to the earth.
   b) Metal surfaces of equipment are never connected to the earth.
   c) Circuit conductors are typically ungrounded, but non-energized metal surfaces must be connected to earth.
   d) There are no requirements for safety grounding.

Answer: (c). Most international systems use ungrounded circuit conductors but still require safety earthing for metal enclosures.

3. **Which organization authorizes NRTLs to test and certify electrical equipment?**
   a) NFPA
   b) OSHA
   c) IEEE
   d) ANSI

Answer: (b). OSHA provides the authorization for NRTLs to verify equipment meets safety standards.

Module 2: Definitions

Learning Objectives

By the end of this section, you will be able to:

- **Differentiate** between equipment grounding and system grounding requirements.
- **Identify** the specific components of a grounding system, including EGCs, GECs, and bonding jumpers.
- **Evaluate** the constraints of "solidly grounded" systems in the context of modern power electronics.

Executive Summary: Grounding comprises two distinct safety systems: **Equipment Grounding**, which protects personnel from energized surfaces, and **System Grounding**, which facilitates the operation of overcurrent protection by providing a return path for fault currents.

Equipment Grounding

Equipment grounding—referred to internationally as **protective earthing** or **safety grounding**—is the process of bonding all exposed, non-current-carrying metal parts of an electrical system together and connecting them to the earth.

- **The Hazard**: Insulation or mechanical failures can energize metal enclosures or PV module frames, creating severe electrical shock and fire risks.
- **The Solution**: Proper bonding reduces the potential difference between the conductive surface and the earth to near zero during a fault.
- **Equipment Grounding Conductors (EGCs)**: These are the specific conductors used to bond exposed metal surfaces together.

In conventional systems, the EGC system provides the path for ground-fault currents to return to the source. This rapid return allows **overcurrent protective devices (OCPDs)**, such as fuses or breakers, to function and clear the fault.

System Grounding

In **system grounding**, one of the current-carrying circuit conductors is intentionally bonded to the equipment grounding system and the earth. This is known internationally as **functional grounding**.

- **Grounded Conductor**: The specific circuit conductor connected to the grounding system.
- **System Bonding Jumper**: The NEC-defined connection between the grounded conductor and the equipment grounding system.

⚠️ **Safety Constraint**: Only **one system bonding jumper** is permitted in each separate electrical system where the grounded conductor is isolated from other sources.

Fault Current Path

The system bonding jumper completes the path that allows fault currents to return to the source. To ensure the OCPD trips, the equipment grounding system and the bonding jumper must maintain **low impedance** through proper conductor sizing and secure connections. Note that PV systems may exhibit different performance characteristics under fault conditions compared to standard AC systems.

Earth Connection Components

To establish a physical connection to the earth, the following components are required:

- **Grounding Electrode**: The actual metallic device (e.g., rod, plate) in direct contact with the earth.
- **Grounding Electrode Conductor (GEC)**: The conductor connecting the central grounding point to the grounding electrode.

Solidly Grounded Systems

The NEC defines a system as **solidly grounded** when it is connected to the ground without the insertion of any resistor or impedance device.

🧮 **Calculation Note**: While **fuses, circuit breakers, and mechanical relay contacts** are permitted in these circuits, **solid-state devices** (transistors, SCRs, etc.) are generally precluded because they are classified as impedance devices.

💡 **Design Tip**: Although NEC 690.41 permits equivalent grounding methods in listed equipment, be aware that most listing agencies currently only certify products in a **solidly grounded** configuration.

Checkpoint Quiz

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1. **What is the primary purpose of the Equipment Grounding Conductor (EGC)?**
   a) To carry normal load current to the PV array.
   b) To provide a path for fault currents to return to the energy source and trip the OCPD.
   c) To connect the inverter to the utility grid.
   d) To replace the need for a system bonding jumper.

Answer: (b). The EGC provides the necessary path for fault currents, allowing OCPDs to function.

2. **Which component is defined as the metallic device in direct contact with the earth?**
   a) Grounding Electrode Conductor
   b) System Bonding Jumper
   c) Grounding Electrode

d) Equipment Grounding Conductor

Answer: (c). The grounding electrode is the device used to make contact with the earth.

3. Why are solid-state devices like transistors usually excluded from "solidly grounded" circuits?

a) They are too expensive for grounding applications.
b) They are considered impedance devices by the NEC.
c) They cannot handle high DC voltages from PV modules.
d) They are only used in international "protective earthing" systems.

Answer: (b). The NEC definition of "solidly grounded" precludes the use of impedance devices, which include most solid-state electronics