

Module Outline

PV SYSTEM ELECTRICAL COMPONENTS





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Relevance and Background

PV modules, or panels as these are often called, are the most important component of any solar PV system, on-grid or off-grid. These not only are the costliest component, but also affect the system performance in the most substantial way. Presently, in the common on-grid systems the solar module has a cost share of about 55% to 65%; whereas in off-grid systems, where the battery also comes in, the cost share is about 45% to 55%. Also, the system's life is normally defined based on the life of the solar module. Therefore, it is essential for an officer, planner, designer, engineer or technician to understand this component fully and completely.

Many a times the term PV technology actually means the technology of the solar module. The latter are the end usable product of a long production process from silica to polysilicon to wafer to cell to module. There have been tremendous developments in the materials used in solar cells and modules, their design, and chemistry in making cells from wafers or construction of modules from cells. Cost trends of modules and their raw material have substantial impact on the solar system costs and therefore also on the levelized cost of generation or the tariff at which the systems can generate electrical units.

Well-thought of procurement of a good module and its proper care in the field promises the success of the solar system over its lifetime. Therefore, it is imperative that this topic be given utmost importance in any training program, with one or more sessions devoted to it.

Theme – Technical

Competency – Electrical

Code of the Module – To2Co3Mo7

Learning Outcomes

By the end of this module, participants will be able to:

- Explain the functions, importance and types of cables, connectors, and distribution boxes in solar PV systems.
- Understand the selection criteria for cables, connectors, and distribution boxes based on system requirements, and the related safety practices and regulations.
- Design and install cable and connector systems according to best practices.
- Perform cable dressing and utilize cable accessories effectively.
- Differentiate between solar-grade cables and common house wires.
- Comprehend the differences in requirements for AC, DC, control and communication, earthing, and battery cables in solar PV systems.

Method of Delivery

Duration	Resource Code	Resource Delivery
60 min.	M07 L01	Lecture on PV System Electrical Components

M04 L01: Lecture Presentation

The lecture presentation will cover the following aspects of cables, connectors, and distribution boxes in solar PV systems:

- Functions and importance of cables, connectors, and distribution boxes.
- Different types of cables used in solar PV systems, including AC, DC, control and communication, earthing, and battery cables, and their characteristics.
- Different types of connectors used for solar PV system interconnections, including MC4 connectors and other relevant connector types.
- Distribution boxes and their role in system wiring, protection, and distribution of power.
- Cable dressing techniques and utilization of cable accessories for proper organization and management.
- Understanding the differences between solar-grade cables and common house wires in terms of construction, insulation, and suitability for solar PV systems.
- Importance of proper cable selection, sizing, and installation based on system requirements and safety standards.
- Discussion on the requirements and considerations for AC, DC, control and communication, earthing, and battery cables in solar PV systems.
- Compliance with safety practices and regulations related to cables, connectors, and distribution boxes.

Key Topics Covered

1. Types and Characteristics of Cables
2. Connectors for Solar PV System Interconnections
3. Distribution Boxes In Solar PV Systems
4. Circuit Breakers Used In PV Systems
5. Cable Dressing Techniques and Accessories
6. Safety Practices and Regulations
7. Standards in Cables, Connectors, and Distribution Boxes



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1 Introduction

Solar cables, DCDBs (DC Distribution Boxes), ACDBs (AC Distribution Boxes), connectors, and associated components are integral parts of solar PV systems. They play a crucial role in the safe and efficient transmission of electrical power generated by solar panels. This technical content provides an overview of these components, their types, characteristics, installation considerations, and adherence to relevant standards.

2 Types and Characteristics of Cables

Solar cables used in PV systems include AC cables, DC cables, earthing cables, control cables, communication cables, and battery cables. Each type of cable possesses specific characteristics to meet the requirements of the system. Key considerations include insulation material [such as cross-linked polyethylene (XLPE) or ethylene propylene rubber (EPR)], voltage rating, conductor size, temperature rating, and flexibility. These cables are designed to withstand harsh environmental conditions and ensure optimal power transmission.

3 Connectors for Solar PV System Interconnections

Connectors are used to interconnect various components within a solar PV system, including solar panels, inverters, batteries, and other equipment. Common connector types include MC4 connectors and others specifically designed for solar applications. Compatibility, installation techniques, and proper connection practices are vital to establish reliable and safe connections. These connectors are well designed to fit firmly with male-female types connected together thereby avoiding any possibility of loose contact, stressed connection or arcs in DC current, which are dangerous to the cables and the system. Hence these connectors and the crimping tool for preparing cables for connections are both very important for healthy and safe system. Adhering to industry standards and guidelines for connectors ensures system integrity and performance.

4 Distribution Boxes In Solar PV Systems

Distribution boxes play a crucial role in the electrical distribution within a solar PV system. ACDBs and DCDBs are two key types of distribution boxes. ACDBs receive and distribute AC power, while DCDBs handle the distribution of DC power. These boxes house various components such as circuit breakers, surge protection devices, busbars, and monitoring devices. Proper selection, installation, wiring, and adherence to relevant standards are crucial for the safe and efficient operation of distribution boxes, and effective power distribution.

ACDBs receive AC power generated by the solar PV system and distribute it to various AC loads or the grid. They are equipped with AC circuit breakers, surge protection devices, busbars, and metering devices. ACDBs ensure proper electrical isolation, protection, and monitoring of the AC side of the system.

DCDBs receive DC power from the solar panels and distribute it to various DC loads or the inverter. They include DC circuit breakers, fuses, surge protection devices, busbars, and monitoring devices. DCDBs play a crucial role in controlling and protecting the DC side of the system.

5 Circuit Breakers Used In PV Systems

Circuit breakers (CB), as the name suggests, break the electrical circuit open to safeguard the circuit and any equipment in it. The faults can occur mainly due to overloading and a short circuit. Either a load draws unnaturally higher current than its rating, or the two exposed ends of cables touch each other to induce the fault which will automatically trigger the circuit breakers. The PV system is at low voltage levels and so most common CBs used in such systems are Miniature Circuit Breaker (MCB), Molded Case Circuit Breaker (MCCB), Earth Leakage Circuit Breaker (ELCB) and Residual Current Circuit Breaker (RCCB).

The applicable international standards mandate that the CBs must be used on DC side as well as AC side on all individual strings, inverters, junction boxes and LT panels.

Higher voltage systems like MW scale power plants have Vacuum Circuit Breakers (VCB) in the switchgear and evacuation infrastructure.

MCCB can also be operated manually in cases of maintenance or emergency.




6 Cable Dressing Techniques and Accessories

Understanding the following cable accessories and dressing techniques is crucial to ensure system functionality and safety:

- Earthing (grounding) is crucial for electrical safety in solar PV systems. Earthing wires provide a path for fault currents and protect against electrical hazards. Proper selection, sizing, installation, and compliance with electrical codes and standards are essential for establishing effective earthing systems in solar PV installations.
- Control wires facilitate the transmission of signals and commands for system control, monitoring, and communication. They enable the integration and operation of various components within the solar PV system. Proper selection, installation, termination, and compliance with relevant standards ensure reliable and accurate control system functionality.



- Proper termination of cables ensures secure and reliable connections. Cable termination involves the use of cable lugs, connectors, heat shrink tubing, and insulation materials. Termination kits provide the necessary components for effective cable termination. Adherence to proper termination techniques, selection of appropriate termination kits, and compliance with relevant standards ensure optimal connection performance and longevity.
- Cable management in solar PV systems involves organizing, routing, and protecting cables to ensure safety, efficiency, and ease of maintenance. Techniques such as cable trays, conduits, cable ties and clamps help in maintaining neat and orderly cable installations. Proper cable



routing, protection, and labeling practices enhance system reliability and accessibility for troubleshooting and maintenance purposes.

7 Safety Practices and Regulations

Safety practices and regulations specific to cables, connectors, ACDBs, and DCDBs are crucial for the safe operation of solar PV systems. Compliance with relevant standards, codes, and regulations ensures electrical safety, system reliability, and protection against potential hazards. Adhering to safety guidelines during installation, operation and maintenance of these components is essential.

8 Standards in Cables, Connectors, and Distribution Boxes

Cables, connectors, ACDBs, and DCDBs should comply with specific standards and regulations to ensure their quality, performance, and safety. Key standards include the National Electrical Code (NEC), International Electrotechnical Commission (IEC) standards, and other relevant regional or local codes. Adherence to these standards helps in selecting, installing, and using components that meet the required specifications, ensuring reliable and compliant solar PV systems.

Reading Material

1. *Utility Scale Solar Power Plants – A Guide for Project Developers and Investors by International Finance Corporation*
<https://documents1.worldbank.org/curated/en/868031468161086726/pdf/667620WP00PUBL005BoSOLARoGUIDEoBOOK.pdf>
2. *Handbook for Rooftop Solar Development in Asia by Asian Development Bank*
<https://www.adb.org/sites/default/files/publication/153201/rooftop-solar-development-handbook.pdf>
3. *Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems; 3rd Edition by National Renewable Energy Laboratory*
<https://www.nrel.gov/docs/fy18osti/68469.pdf>