1. Fuse (String Fuse)

- **Function: Overcurrent Protection for Individual Strings.**
- **Why it's needed:** A PV string is a current source. When multiple strings are combined in parallel (on a busbar), the current adds up. If one string develops a fault—most commonly an internal **short circuit**—it can experience a reverse current flow *from* the other healthy strings. This reverse current can be many times higher than the string's normal operating current.
- **Analogy:** Imagine a multi-lane highway where one car (a faulty string) suddenly stops and goes into reverse. The fuse for that lane blows, preventing a catastrophic pile-up (damage to the faulty module and wiring) without affecting the other lanes (healthy strings).
- **In short:** It protects the faulty string *from* the power of all the other healthy strings. It is a **selective protection** device.

2. DC MCB (Miniature Circuit Breaker)

- **Function: Main Disconnect and Overcurrent Protection for the Entire Array.**
- **Why it's needed:** This breaker serves two primary purposes:
    1. **Isolation/Switch Duty:** It provides a safe and easy means to manually disconnect the entire PV array from the inverter for

maintenance, troubleshooting, or in case of an emergency. This is a crucial safety requirement.

2. **Backup Overcurrent Protection:** It protects the main cables running from the combiner box to the inverter. These cables are sized for the total current of *all* parallel strings. The MCB is calibrated to trip if the total current exceeds the cable's safe capacity, which could happen in a very rare fault condition between the box and the inverter that the string fuses wouldn't see.

- **Analogy:** This is the **main switch** for the entire highway system. It can shut down all traffic at once. It also protects the main exit ramp (the cable to the inverter) from being overloaded by the combined traffic from all lanes.

3. SPD (Surge Protective Device)

- **Function: Overvoltage Protection.**
- **Why it's needed:** PV systems, with their long outdoor cable runs across roofs and fields, are highly susceptible to transient voltage surges. These surges are primarily caused by:
    - **Lightning strikes** (direct or nearby).

- **Utility grid switching events.**

  An SPD shunts (diverts) this massive, sudden surge of energy to the earth/ground wire, preventing it from traveling to the expensive and sensitive inverter and destroying it.

- **Analogy:** A **pressure relief valve** on a pipe. Under normal conditions, it's closed. If a pressure spike (voltage surge) occurs, it opens instantly to vent the excess pressure, protecting the pipe and everything connected to it.

Why is there a DC MCB when each string is protected by a fuse?

The two devices are **not redundant**; they protect against **different faults** in **different locations** and serve **different operational purposes**.

Feature	**String Fuse**	**DC MCB (Main Breaker)**
Protected Component	The individual PV string and its wiring.	The main output cable to the inverter.
Fault Scenario	A short circuit **within one string**.	An overload or short circuit **downstream of the box**.
Current Rating	Low (e.g., 15A). Sized just above the string's max current.	High (e.g., 63A, 100A). Sized for the sum of all strings.

Feature	String Fuse	DC MCB (Main Breaker)
Primary Function	**Selective Protection.** Isolates only the faulty string.	**Isolation & Cable Protection.** Disconnects the entire system.
Operational Use	Automatic operation for faults. Not a switch.	**Manual operation** for safe isolation. Automatic for faults.

Scenario to Illustrate the Difference:

- **A module in String #3 fails short-circuited.**
    - **The String #3 Fuse** blows. It isolates only String #3. Strings #1, #2, #4, etc., continue to operate normally. The system only loses the power from one string.
    - The DC MCB does nothing in this scenario because the total current hasn't exceeded its rating.
- **The main DC cable between the combiner box and inverter gets pinched and short-circuits.**
    - **The DC MCB** trips (or a dedicated fuse for that line blows). It interrupts the massive fault current coming from *every single string combined* to protect the cable from burning up.
    - The string fuses do nothing because the fault is not in any single string; from their perspective, the current flowing out of them is still normal.

In summary: The **string fuse** is for **internal, selective protection**. The **DC MCB** is for **main isolation, switching, and protecting the output circuit**.

Both are essential for a safe, functional, and maintainable PV system.