Video#9: Electronic Basics #29: Solar Panel & Charge Controller

Understanding and Maximizing Solar Panel Efficiency

Introduction to Solar Panels

Solar panels are an easy-to-use and regenerative energy source. By simply exposing them to sunlight, they generate an output voltage capable of powering small loads or even larger ones if the size of the solar panel is increased.

Maximizing Power Output

To maximize the power output of a solar panel, we must understand how they are wired and how different conditions affect their performance. This includes series and parallel connections, bypass diodes, and maximum power point tracking (MPPT).

Structure of a Solar Panel

A solar panel consists of multiple individual solar cells. These solar cells can be purchased separately and soldered together to form a complete panel. However, solar cells are brittle, making them difficult to handle without a proper housing.

Voltage and Series Connection

Each solar cell generates a maximum output voltage of around 0.5V when exposed to light. To increase the output voltage, multiple cells are connected in series. For example, a 100W panel consists of 36 cells in series, producing an open circuit voltage of approximately 14.3V.

The Problem with Partial Shading

One major drawback of series-connected solar cells is that partial shading significantly reduces power output. If some cells are shaded, their resistance increases, causing a drastic drop in overall power. For example, covering 1/6 of a panel's surface area can reduce power output by 43%, even though only 17% of the surface is shaded.

Bypass and Blocking Diodes

To mitigate shading issues, bypass diodes are used. These diodes allow current to bypass shaded cells, maintaining higher power output. In large panels, bypass diodes are installed within the junction box. Blocking diodes are also used in parallel-connected panels to prevent reverse current flow and decouple panels from one another.

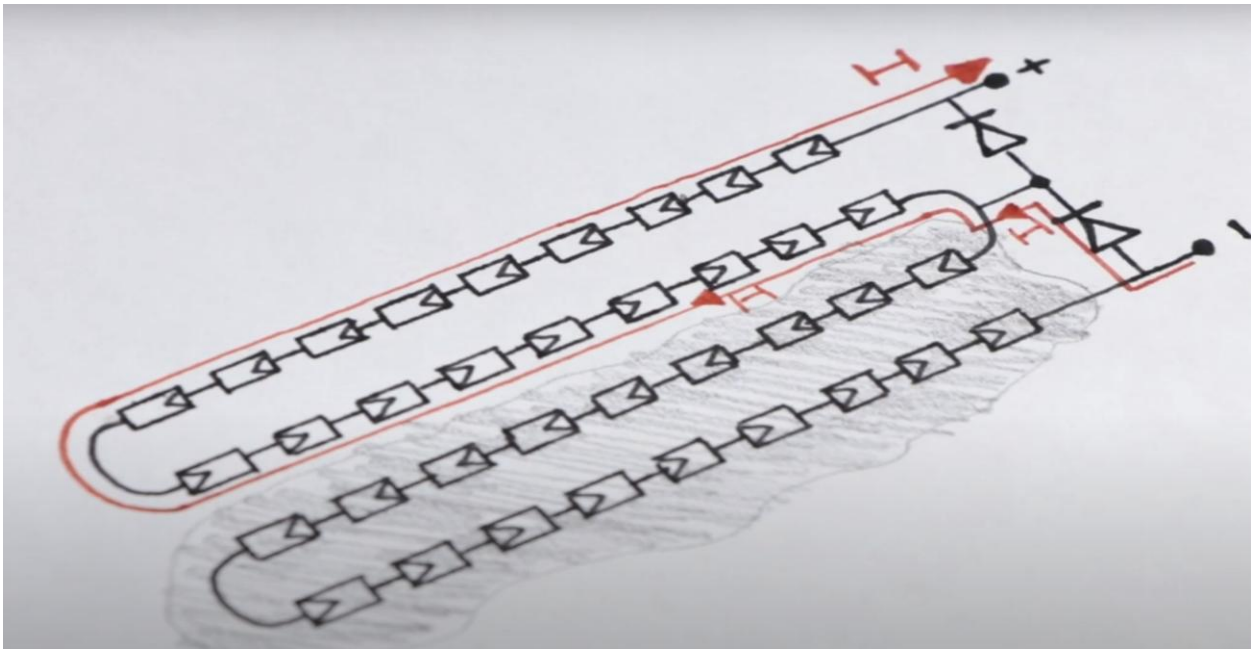


FIG: Bypass diodes configuration

Understanding Real-World Solar Panel Performance

Solar panels rarely produce their rated power output due to environmental conditions. The rated output is determined under Standard Test Conditions (STC), which include:

- **Irradiance:** 1000 W/m²
- **Cell Temperature:** 25°C
- **Air Mass (AM):** 1.5

In real-world conditions, these ideal values are rarely met, leading to lower actual power output.

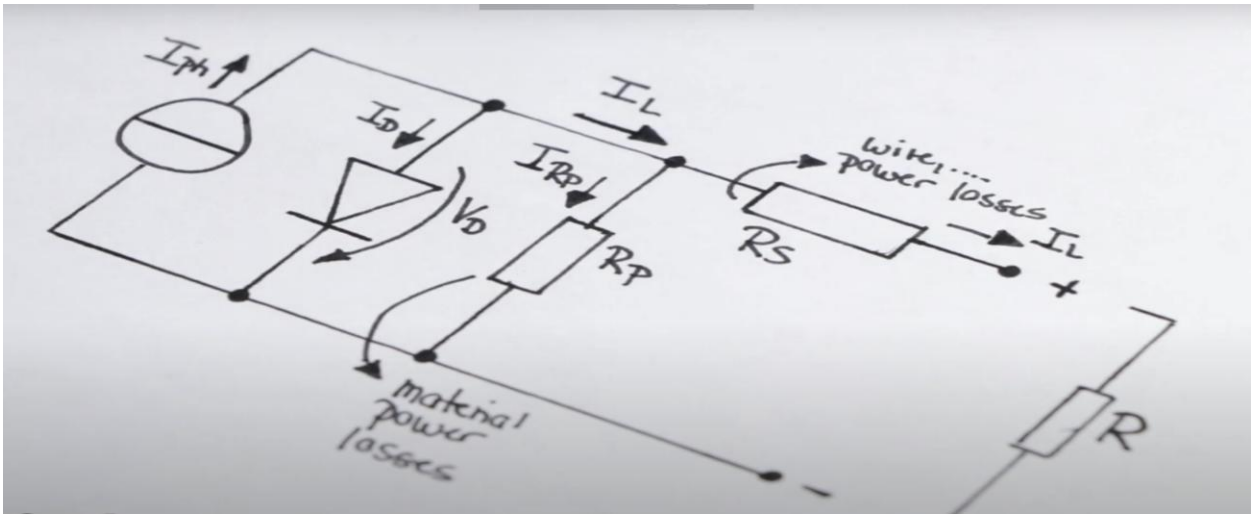
The Relationship Between Load and Power Output

The power output of a solar panel varies depending on the connected load. The solar cell can be modeled as an equivalent circuit consisting of:

1. A constant current source

2. A diode that generates the characteristic voltage (around 0.5V per cell)
3. A parallel resistor representing power losses due to semiconductor defects
4. A series resistor accounting for losses in wires and terminals

By varying the load, we can determine the optimal point for maximum power extraction.



Determining Maximum Power Point (MPP)

To find the **Maximum Power Point (MPP):**

1. A solar panel is connected to a variable resistor
2. Voltage and current values are measured while decreasing resistance
3. These values are recorded and plotted in an XY diagram
4. By multiplying voltage and current values, a power curve is obtained, revealing the MPP

For example, in a 0.6W panel, the MPP was found at 4.4V and 4mA, corresponding to a load resistance of 1100Ω.

Charging a Battery with a Solar Panel

A solar panel's output can be used to charge a battery efficiently. However, simply connecting a fixed resistor is not effective. Instead, charge controllers are used.

Types of Charge Controllers:

1. **MPPT (Maximum Power Point Tracking) Controllers:**

- These controllers use switching converters to track and operate at the MPP, significantly improving efficiency.

2. **PWM (Pulse Width Modulation) Controllers:**
    - These are simpler but less efficient, as they do not actively track the MPP, leading to efficiency losses of up to 40%.

By understanding how solar panels work, how they are wired, and how they respond to shading and load variations, we can optimize their efficiency. Using MPPT charge controllers ensures that the maximum possible power is extracted from the panel. With this knowledge, solar panels can be effectively used for various applications, from small electronic devices to large-scale energy solutions.