Case Study: Identifying Hidden Energy Losses Using I-V Curve Testing

Introduction

Sometimes a solar power plant does not produce as much electricity as expected. This can be confusing, especially when the monitoring system shows that everything is working. In reality, the plant is losing power quietly. This is where **I-V** (**Current–Voltage**) **curve** testing becomes helpful. This case study shows how **I-V curve** testing helps identify actual problems in a solar power plant and how fixing them can improve its performance.

The Situation

A large solar power plant was experiencing lower daily energy production compared with the designed output. All inverters were ON, SCADA showed normal operation without any alert signal, visually seemed that no major faults were there. But when compared to the plant design, the plant's performance was lower than expected. In this situation the engineering team decided to look deeper and chose **I-V curve** testing to check the solar panels and the health of the electrical connections.

What Is I-V Curve Testing?

I-V curve testing is a medical check-up of a string. An **I-V curve** is a graph that shows **Current** (**I**) on the vertical axis and **Voltage** (**V**) on the horizontal axis. This test checks how much current the module produced, how much voltage it delivered and where it produces maximum **power**.

A healthy **I-V curve** is smooth, tall, wide, and has a sharp knee. Any results that deviate from the healthy smooth I-V curve serves as a warning sign. It means something is wrong, which could be associated with a variety of factors such as dirt on panels, loose connections, shading, or installation issues etc.

How the Testing Was Done

1. Selecting the Strings

Identified the strings which are producing less power compared with the good strings. The good strings will be use as a reference. This will enable a comparison between "healthy" and "problematic" strings.

2. Performing the Test

A portable testing device called **PV Analyzer I-V Curve** Tracer was connected to each string. Testing was done in a stable irradiance of at least **700 W/m²** which is recommended, as per **IEC 61829**. Irradiance and module temperature were recorded while testing. These steps ensured that results are under the same conditions making them fair, meaningful and comparable.

3. Reviewing the Results

The data are adjusted to **STC** using guidelines such as **IEC 60891**, so different strings could be compared accurately. A comparison is made between the healthy measured curves and the problematic curves.

Interpretation of the results

The expectation is healthy strings show smooth and normal curves. However, the strings that didn't exhibit these qualities may be interpreted as follows;

- I-V Curve shows steps or multiple knees → caused by shading, dirty panels or mismatch
- Lower **current** → caused by loose or poorly crimped connectors
- I-V Curve drops sharply near the knee → indicates connector, junction box, or cable issues.
- Lower **current** and power across the whole curve → caused by degraded or damaged modules

These issues were not visible in daily monitoring systems but were clearly exposed by **I-V curve** testing.

What Was Done to Fix the Problems

Based on the findings:

- Faulty electrical connectors were repaired or replaced.
- Dirty panels were cleaned.
- Maintenance procedures were improved to prevent similar issues in the future.
- Damaged modules changed.

Key Takeaways

- A plant can look "normal" but still lose energy
- I-V curve testing finds problems that SCADA cannot show
- Accurate test conditions are very important for correct conclusions
- Regular testing helps avoid long-term energy and revenue loss
- Clear testing and reporting support better technical and business decisions

Conclusion

I-V curve testing is a detailed health check for a solar power plant. It helps identifies what is really happening inside the system, find hidden losses, and enables the right corrective actions to be implemented. When done properly and regularly, it improves reliability, energy production, and confidence in the plant's long-term performance.

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