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An Investigation of the Temperature Effect on Solar Panel Efficiency Based on IoT Technology

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ABSTRACT

Sunlight is effectively transformed into electric current using photovoltaic panels. The rest of the sun's spectrum is linked to harmful radiation, which increases the temperature of the photovoltaic panels and consequently decreases performance, power generation, and efficiency. This paper includes an experimental investigation to investigate the performance of a polycrystalline solar PV panel at varying temperatures. Then this study uses Internet of Things (IoT) technologies to examine how the efficiency of a polycrystalline solar PV panel performs at various temperatures. The K-type thermocouple, an Arduino Uno, a Max6675 module, an ESP8266 (ESP-01) module, the Thing Speak cloud platform, and voltage divider resistors were the components that constructed the IoT-based temperature measurement system. The temperature of a polycrystalline solar panel is determined by experiments, and it may be used to determine the solar panel's efficiency. The efficiency of the solar PV panel gradually decreases as the surface temperature of the panel increases.

KEYWORDS: *Investigation, Efficiency, Polycrystalline Solar PV, Internet of Things (IoT), Temperature*

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1. INTRODUCTION

The three seasons of Myanmar's tropical climate are cold winter (November to February), summer season (March and April), and rainfall (May to October), which is influenced by the southwest monsoon. During the dry season, there is typically 7 to 10 hours of sunshine every day. The weather is more overcast and there are typically only three to four hours of sunshine per day during the rainy season. Due to its location in the southeast of the Asian continent, Myanmar has year-round high levels of sunshine, particularly in the Central Myanmar Dry Zone Area. Myanmar's potential solar energy is approximately 51973.8 Tera Watt-hours per year. Solar energy use is also just getting started [1].

Due to the need to decrease emissions of greenhouse gases, sources of clean energy such as solar power have become more important for electricity generation. When looking for alternatives to the current fossil fuels, solar energy has taken the lead. Solar energy is one of the most promising renewable resources that is currently being used all over the world to help achieve growing needs for electric power. Due to the rise of global warming and extreme weather conditions, many existing countries are forced to look for alternative sources in order to reduce their dependence on fossil-based fuels like coal, etc. Sunlight is converted into electricity using solar power, which can be generated directly using photovoltaics (PV) or indirectly using concentrated solar energy. Initially, photovoltaics was employed as a small- and medium-scale application power source. A remote dwelling is powered by a single solar panel. The number of solar photovoltaic systems has reached millions as the price of solar electricity has decreased. Hundreds of megawatts are produced by solar power plants. Solar photovoltaic technology, which uses sustainable solar energy, is getting less expensive and has a lower carbon footprint [2]. Due to daily variations in sunlight intensity and solar panel temperature, solar panels' efficiency varies under current operating conditions. A number of variables, including solar irradiation, the surrounding temperature, the orientation of the panels, and the installation style, affect the maximum temperature of solar panels. With the solar panel, the temperature measurement system plays an important role. Conventional measurement methods are more labor-intensive, take longer to complete, cost more to store real-time data in remote locations, and have weaker monitoring systems. The Internet of Things (IoT) is an innovative technological concept that enables the Internet to connect things from multiple sectors.

2. LITERATURE REVIEW

(Augustine Ozemoya, James Swart, Christo Pienaar and Ruaan Schoeman, 2013) This study focuses on analyzing and regulating how the temperature of the surrounding air affects a solar PV module's surface temperature, which in turn affects how much output power is generated. With an analysis of and eventual control over variables that affect the solar PV module's surface temperature, this study aims to maximize the output power of a solar PV module. The findings demonstrate that the tilt angle and ambient temperature have a substantial impact on the solar PV module's surface temperature [3].

(Uglješa Jovanović †, Dragan Mančić*, Igor Jovanović* and Zoran Petrušić*, 2017) This study describes a custom-built system that consists of an infrared temperature sensor and a microprocessor for measuring the temperature of solar photovoltaic modules. The created virtual instrument is used to process, display, and store the measurement results on a PC. The proposed strategy delivers reliable readings and greater flexibility while addressing several application-related issues with touch sensors. The proposed approach is particularly well suited to applications where cost affects the kind of measurement device that can be used [4].

(Manish Katyarmal, Suyash Walkunde, Arvind Sakhare, Mrs.U.S.Rawandale, 2018) The project is built on the implementation of a new, economically advantageous IoT-based methodology for remotely monitoring solar plants for performance assessment. In addition to real-time monitoring, this will make it easier to perform preventative maintenance and identify plant faults [5].

3. MATERIALS

The selection of these materials and components was critical to ensuring the accuracy and reliability of the data collected during the research. Each component played a specific role in the experimental setup, enabling a comprehensive investigation of the temperature effect on solar panel efficiency.

3.1. Excel Software

Microsoft Excel software was used for data post-processing and analysis. Data collected from experiments was imported into Excel for visualization, calculation of temperature coefficients, and generation of graphical representations.

3.2. ThingSpeak Cloud platform

ThingSpeak is an IoT cloud platform where users may create applications that they develop as well as transfer measurement results to the cloud for analysis and visualization using MATLAB or other software. MathWorks is the company that runs the ThingSpeak service. A MathWorks account must be either newly created or logged into in order to register for ThingSpeak. The web service (REST API) in ThingSpeak is used to create Internet of Things products by gathering and storing sensor data in the cloud.

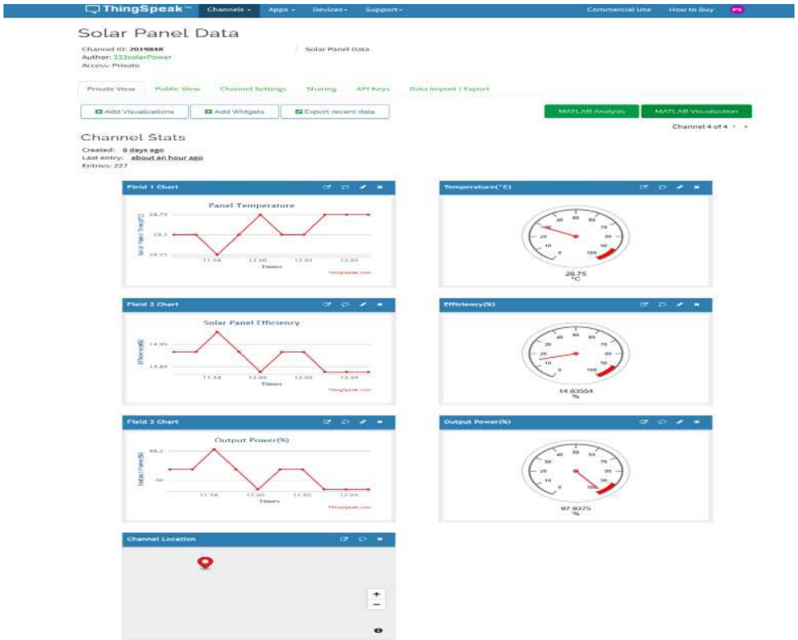

Figure 1. ThingSpeak IoT Platform

3.3. Polycrystalline Solar Panel

Crystalline silicon performs more efficiently than amorphous silicon despite using a lot less material. Not only is silicon abundant on Earth, but it also has a low contamination rate, a high degree of resilience, and vast expertise in the microelectronics industry. The two varieties of silicon cells that are most frequently used in manufacturing are monocrystalline and polycrystalline. Polycrystalline solar panels outperform other panel varieties while requiring more installation area and a greater working temperature than monocrystalline solar panels. Polycrystalline solar panels are more economical than monocrystalline ones since they are easier to make and use more silicon cells. The amount of fossil fuel consumed during production is really small.

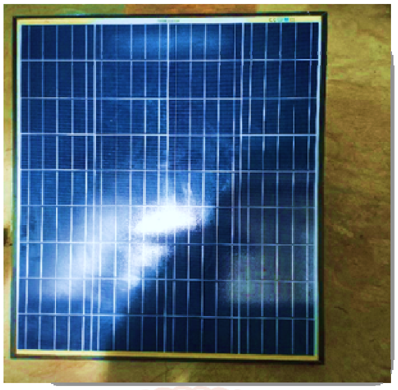

Figure 2. 100Watt Polycrystalline Solar Panel

3.4. Arduino Uno

Based on the Microchip ATmega328P microprocessor (MCU), Arduino.cc developed the Arduino Uno microcontroller board. The board's sets of digital and analog input/output (I/O) pins allow for communication with a range of expansion boards (shields) and other circuits. The board has 14 digital I/O pins, including six that can create PWM, and 6 analog I/O pins. It may be programmed using the Arduino IDE (Integrated Development Environment) [6].

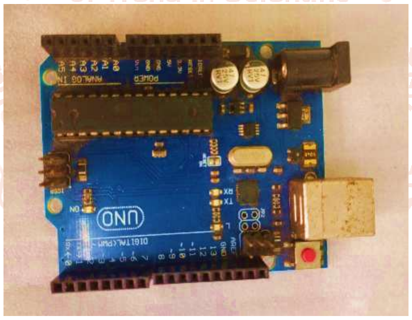

Figure 3. Arduino Uno Board

3.5. K-Type thermocouple

The K-type thermocouple has the broadest operating temperature range. It is composed of a magnetic negative leg and a nonmagnetic positive leg. K-type thermocouples provide a number of advantages over other thermocouples, including the ability to perform in a variety of atmospheric and harsh environmental conditions. They are cost-effective, quick to respond, portable, and trustworthy.

Figure 4. K-Type Thermocouple

3.6. MAX6675 module

A powerful 12-bit analog-to-digital converter (ADC) is included inside the MAX6675 thermocouple-to-digital converter. In addition, the MAX6675 has a digital controller, an SPI-compatible interface, cold-junction compensation sensing and correction, as well as related control logic. In thermostatic, process-control, or monitoring applications, the MAX6675 is intended to cooperate with an external microcontroller or other intelligence.

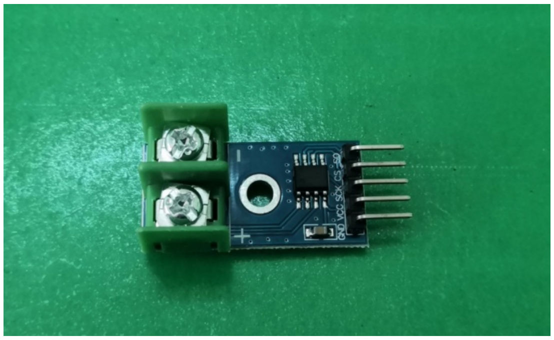

Figure 5. MAX6675 module

3.7. ESP8266 module

A Wi-Fi module called the ESP8266 ESP-01 provides microcontrollers access to wireless networks. The ESP8266 ESP-01 module then processes all the results of the calculation from the Arduino Uno in order to save them on the Internet of Things (IoT). The IoT platform Thingspeak is used for assessing these results at any time.

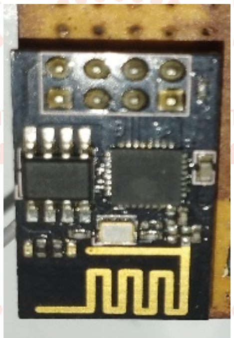

Figure 6. ESP8266 module

4. DESIGN PROCEDURE

A ThingSpeak Cloud platform, a polycrystalline solar panel, an Arduino Uno, a K-type thermocouple, a MAX6675 module, an ESP8266 module, and two resistors are used in the suggested measuring system architecture. Microsoft Excel may be used to evaluate data in real-time. In Fig. 6, the system of materials structure is represented.

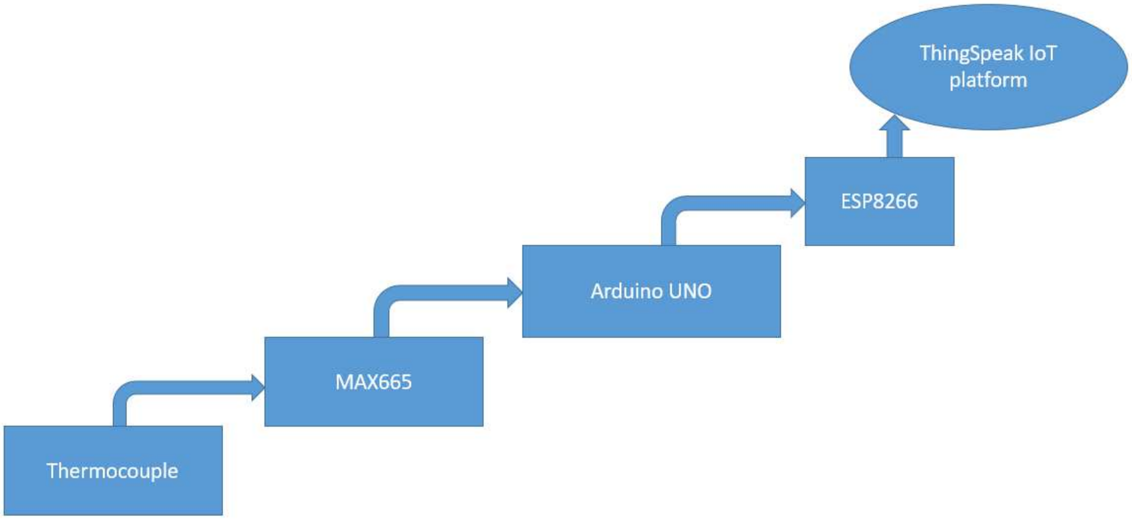

Figure 7. Block Diagram of Circuit

For the experiment, a 100-watt polycrystalline solar panel with known specifications was selected. The efficiency of solar panels is evaluated using this panel as the foundation. The selected solar panel is integrated with a K-type thermocouple and a MAX6675 module. At a specific place on the panel, the K-type thermocouple and MAX6675 module gather real-time temperature data. Temperature data is transmitted to the Arduino Uno for processing. Data is transmitted to the ThingSpeak Cloud platform through the ESP8266 module. The ThingSpeak Cloud platform allows for data storage and remote monitoring. Using Excel software, data and patterns are visually represented, making it easier to understand the findings.

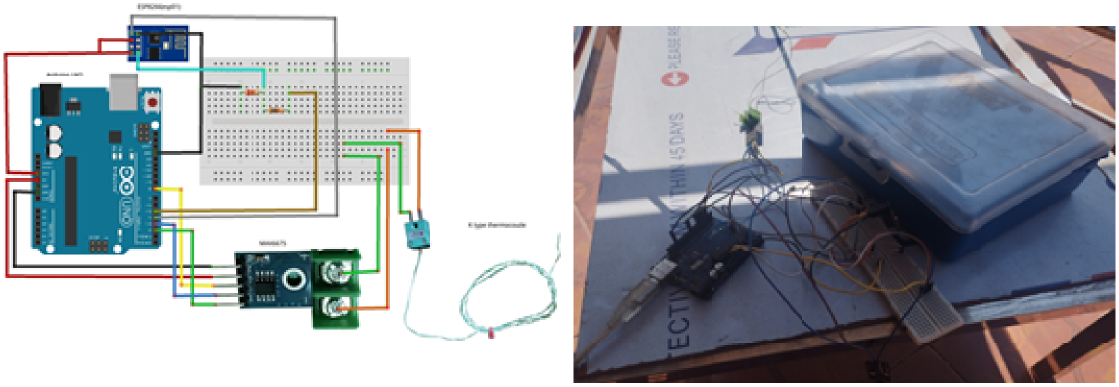

Figure 8. IoT based Temperature measurement System

Figure 9. Solar Panel Temperature Measurement System

The method used to examine how temperature affects solar panel efficiency is based on well-known photovoltaic principles. Multiple effects on crystalline silicon cells due to temperature variations have been noted. In particular, these cells' efficiency demonstrates a significant decrease with increasing temperatures, similar to the well-known temperature coefficient phenomenon. Temperature increases have been related to decreases in the voltage and fill factor of the solar panels, which could have an effect on overall performance and power output. The efficiency of solar panels (η_{pv}) was calculated using the following formula for evaluating these temperature-dependent changes:

$$\eta_{pv} = \eta_{STC} - \mu_{pv} (T_{cell} - T_{STC})$$

In this equation, η_{STC} represents the reference efficiency of the solar panel under Standard Test Conditions (STC), μ_{pv} denotes the temperature coefficient of the solar panel, T_{cell} corresponds to the measured solar panel temperature, and T_{STC} signifies the solar panel temperature under Standard Test Conditions. Short-circuit current ($\mu_{I,sc}$), open-circuit voltage ($\mu_{V,oc}$), and maximum power (μ_{mp}) were found to have temperature coefficients of 0.06%, -0.38%, and -0.55%, respectively.

Furthermore, an additional equation was introduced to calculate μ_{pv}, the temperature coefficient of voltage:

$$\mu_{pv} = \eta_{STC} * \frac{\mu_{V,oc}}{V_{mp(STC)}}$$

In this equation, $\mu_{V,oc}$ denotes the temperature coefficient of the open-circuit voltage, and $V_{mp(STC)}$ represents the maximum power voltage at Standard Test Conditions [7].

5. RESULTS AND DISCUSSION

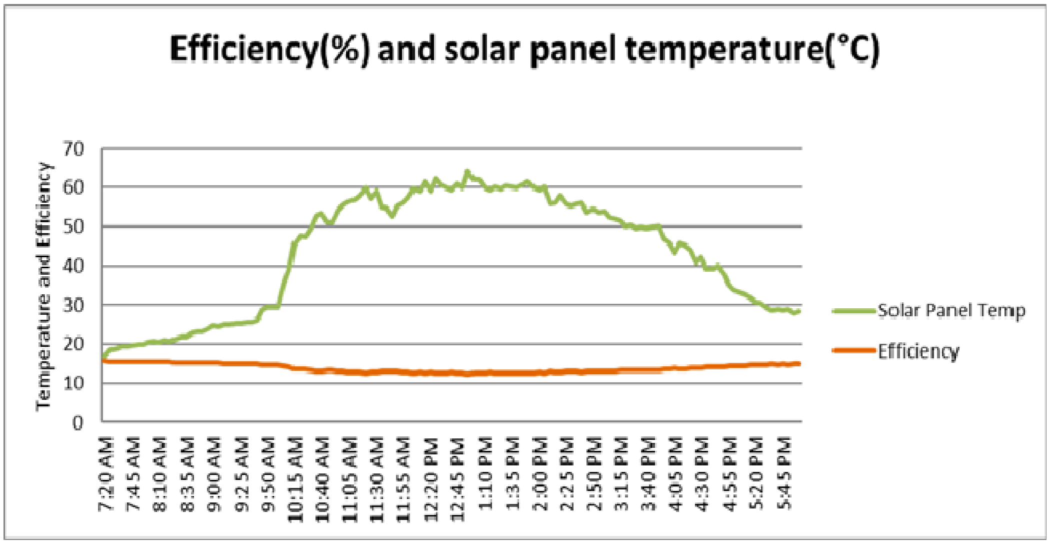

Figure 10. Efficiency and Solar Panel Temperature (Day 1)

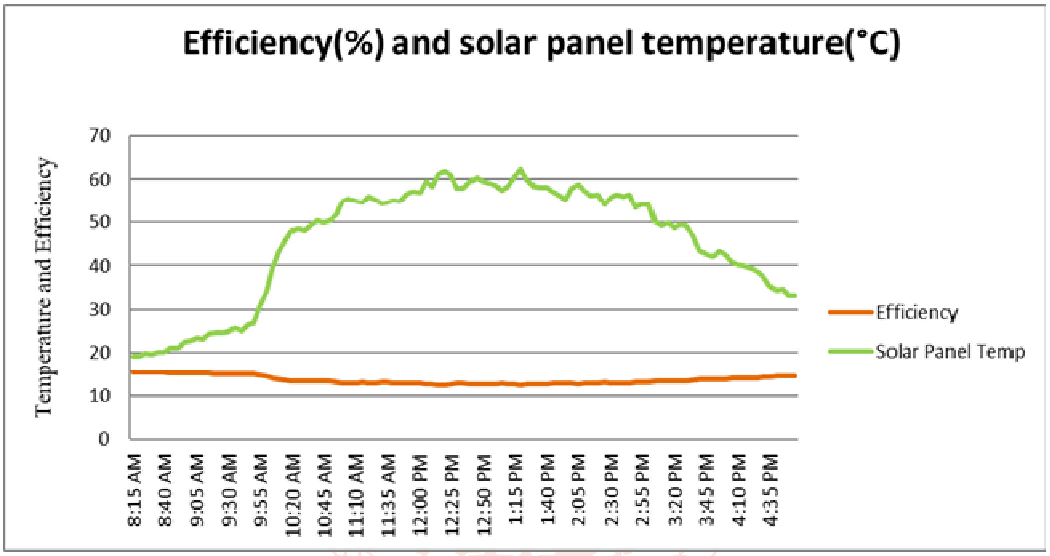

Figure 11. Efficiency and Solar Panel Temperature (Day 2)

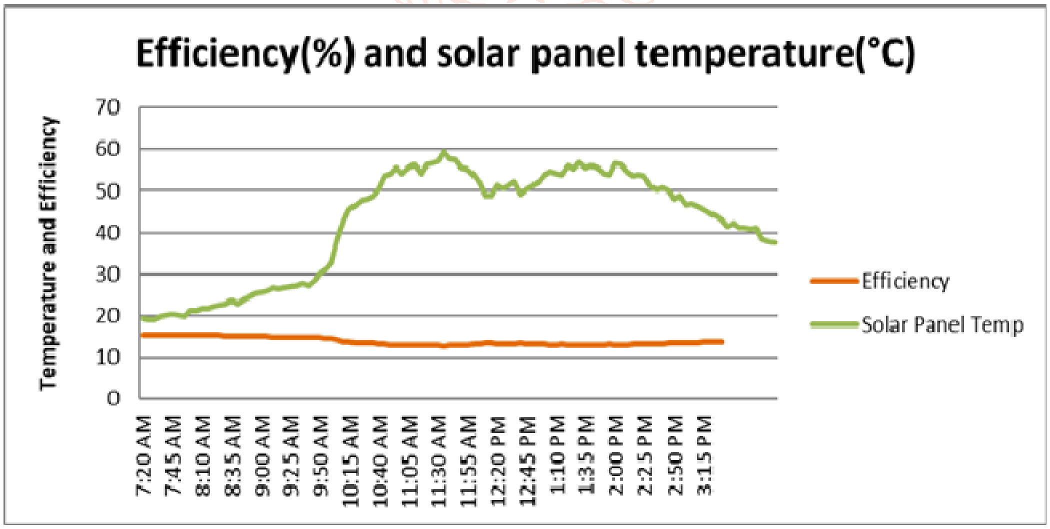

Figure 12. Efficiency and Solar Panel Temperature (Day 3)

The relationship between the surface temperature of a solar panel and its efficiency is seen in figures 10, 11, and 12. The solar cells are enclosed in materials like glass and aluminum, which have low temperatures; thus, the panel's temperature in the morning is lower than the surrounding air. Due to the high solar irradiation at noon, the temperature of the PV module rises more quickly than the surrounding air temperature. The cell temperature of 25°C is defined in the Standard Test Conditions as the reference condition for module performance. As a result, a module's performance and energy output will decline under operating settings where the cell temperature is higher than 25 °C. Significant findings have been discovered from the investigation into how temperature affects solar panel efficiency. As would be expected, crystalline silicon cells' efficiency significantly decreases as temperatures increase. This behavior demonstrates how crucial temperature regulation is for optimum solar panel performance, particularly in situations with changing temperatures found in the real world. Limitations are the main subject of this investigation of how temperature affects solar panel effectiveness. The performance of solar panels can be impacted by a number of environmental factors, although these factors were not properly considered in this study. These factors include humidity, shadowing, and dust buildup. The interplay of these factors, plus the effects of temperature, may have an impact on real-world performance.

6. CONCLUSION

In conclusion, this study highlights the complex relationship between temperature and solar panel efficiency. The quantitative approach, supplemented by temperature coefficients, improves comprehension of these dynamics, even though efficiency declines as temperature rises. This knowledge makes it easier to make well-informed decisions about improving solar panel performance in real-world environmental situations where temperature variations are important. In this study, the effect of temperature on solar panel efficiency was carefully examined in order to better understand the complex dynamics influencing the performance of crystalline silicon cells under various thermal circumstances. The results of this investigation provide significant contributions to the field of renewable energy systems and offer priceless new insights into how solar panels react to thermal changes. This research also advances the collective understanding of the effectiveness of solar panels and their responsiveness to temperature variations. It highlights the potential for additional research projects aimed at improving the effectiveness and longevity of photovoltaic technology. Additionally, it highlights the basic necessity of temperature control in the pursuit of solar energy system optimization. The conclusions drawn from this study serve as a basic pillar in the improvement of solar panel installations' efficiency and sustainability as society advances in using the potential of renewable energy.

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