Correlating Solar Panel Efficiency and Fill Factor with Hydrogen Production During Electrolysis Under Varying Temperature and Illumination

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***Abstract*—In this research, the factors affecting the efficiency of polycrystalline solar panels were investigated by utilizing the panels to drive the electrolysis of sodium hydroxide (NaOH) and monitoring the amount of hydrogen produced which indicates the rate of electrolysis. Utilizing five polycrystalline solar panels with varying power outputs (20W, 25W, 30W, 40W, and 50W), important parameters including short-circuit current (Isc), open-circuit voltage (Voc), fill factor, etc were calculated to understand their performance. An artificial light source was used to simulate sunlight, while a microcontroller and DHT11 and MQ8 Hydrogen sensor monitored temperature and hydrogen concentration respectively. Results showed that the polycrystalline panels produced sufficient voltage and current to support the electrolysis, and there is moderate to strong relationship between various parameters like fill factor, power output, hydrogen concentration, etc. A Pearson correlation coefficient of 0.9029 indicated a strong relationship between power output and hydrogen production. The study also highlighted that higher fill factors correlate with increased efficiency, which demonstrates their utility as a reliable indicator for assessing performance of polycrystalline solar panels. Additionally, findings from the experiments also indicate that light intensity significantly influences the power output of polycrystalline panels and hence the amount of hydrogen produced during electrolysis that is driven by these panels. This study also provides a practical and accessible framework for evaluating the efficiency of small-scale polycrystalline solar panels and offers directions for future investigations into the long term performance of other types of solar panels under varying environmental conditions.**

Keywords*—*Solar Panels, Electrolysis, Fill Factor, Maximum Power Output, Efficiency, Polycrystalline Solar Panels, Hydrogen Production, Rate of Reaction, Varying Illumination and Temperature, Data Analysis.

I. Introduction

Solar panel, a system consisting of photovoltaic cells is utilized to generate electricity from sunlight. [1] Made of a semiconductor material primarily silicon within a glass frame, it releases electrons and produces an electric charge which in turn produces direct current converted to alternating current by a device called an inverter when exposed to light [2]. Two major types of solar panels include monocrystalline which are made up of a single cell structure and polycrystalline comprising multiple crystal fragments. Silicon wafers of polycrystalline panels are easier to produce at a lower price. Additionally, leftover crystals from the monocrystalline panels production process can be reused, reducing silicon material costs, making these panels less expensive. Monocrystalline panels offer a slightly higher efficiency (15-23%) as compared to polycrystalline panels (13-16%), a slightly longer lifespan of up to 40 years as compared to 25-35 years for polycrystalline panels and a lower temperature coefficient enabling it to perform slightly better under hot climates [3]. However, due to the ease of availability and affordability of the polycrystalline panels, they are more widely used which made us test this type of panels in this research. For solar panels with smaller dimensions available at an affordable price, there is insufficient data about parameters which contribute to their efficiency such as fill factor, maximum power point, and the temperatures and voltages at which optimum values for these parameters are obtained. Additionally, there was room for a convenient and economical method of testing the efficiency of such panels. This research aimed to bridge these gaps by proposing an experimental approach, which makes use of an electrolytic setup, a small electronic device employing a microcontroller and sensors for measuring different test parameters, and an artificial light source mimicking the intensity and wavelength of sunlight to characterize the performance of different small-scale polycrystalline solar panels available in the market. The Fill Factor (FF) of solar cells is an important parameter for measuring the efficiency of a photovoltaic module or panel. It was calculated by the ratio of the maximum power from the solar cell to the product of the open-circuit voltage (Voc) and short-circuit current (Isc) [4]. The fill factor measured for each panel was compared and the rate of electrolysis driven by these panels was also recorded. The performance of solar panels was assessed by observing how effectively they could drive the electrolysis process under different illumination conditions which was done by measuring the increase in inflation of plastic bags tied around the opening through which hydrogen gas is liberated from the electrodes during electrolysis. Industries and businesses will be able to select the most suitable panel for customers based on their efficiency requirements and nature of demand with the help of the information provided by this research. Should the efficiency of similar panels be tested, the method detailed in the paper can be incorporated to do so since it is economical, efficient and feasible.

II. Literature Review

Titiek Suheta et al. [5] built a prototype for generating solar power using monocrystalline and polycrystalline solar panels. The panels used were positioned at -7.290764 latitude and 112.779205 longitude and their orientation was kept at 08:00, 10:00, 13:00, and 16:00 to increase the output voltage. Results obtained during the evaluation of the performance of the panels for 10 days showed that the average voltage obtained for monocrystalline solar panel was higher at 16.292 volts than polycrystalline solar panel at 12.700 volts with average temperatures kept at 32.012 ℃ and 39.563 ℃ respectively for both types of panels. Insights obtained during the study attribute the better performance of monocrystalline solar panels to the material used to build them which is pure silicon and their black color. Polycrystalline solar panels had a higher value for average current which was 0.8264 Amperes at 39.563 ℃ which was higher than the monocrystalline panels. However, the study is conducted at a single location (ITATS campus), which may not reflect the performance of solar panels in different climatic conditions. Additionally, The 10-day testing period may not adequately capture long-term performance and reliability of the solar panels. **Subhash Chander et al. [6]** have analyzed a monocrystalline solar cell's photovoltaic parameters under the variations of cell temperature. The temperatures ranged between 25-60 degrees Celsius, while light intensities were 215-515 watts per square meter. A relationship between these parameters and the cell temperature was obtained wherein the open circuit voltage, maximum power, fill factor and efficiency decreased with cell temperature. The temperature coefficient of the open-circuit voltage, fill factor, and the maximum output power was negative while positive for the short circuit current. However, the study only investigates cell temperatures between 25-60 °C. This limited range may not fully capture the performance of solar cells under extreme temperature conditions that can occur. Additionally, the experiments were conducted at fixed light intensities (215-515 W/m²). This approach may overlook the effects of varying light conditions, such as fluctuating sunlight throughout the day, which can significantly impact solar cell performance. **Khanna Vandana et al. [7]** discussed the drawbacks of the traditional two-diode model in representing large-area industrial silicon solar cells. the ideality factors of the two-diode model did not match the theoretical values indicating a need for a better model for this, the authors came up with a three-diode model that includes variable series resistance dependent on current flow. the main goal of the model was to better represent the different current components in industrial solar cells. The three-diode model was created as part of the technique, and parameters were estimated from the illuminated current-voltage (I-V) characteristics using the Particle Swarm Optimization (PSO) algorithm. I-V parameters of the manufactured solar cell samples were measured. The Mean Absolute Error (MAE) of the PSO method was utilized to analyze the two- and three-diode models. Between September and March, the panels reached maximum radiation. at angles greater than 30 degrees. Their fill factors varied from 0.74 to 0.76, and their efficiency peaked between 30 and 39%. The paper by **Lyu-Guang Hua et al. [8]** discusses how to determine the ideal tilt angle for solar panels to maximize power output from photovoltaic (PV) systems. The study examined the performance of polycrystalline and monocrystalline panels at various angles, with a particular focus on a 1 MW system at Sukkur IBA University. The researchers simulated panel performance at tilt angles ranging from 0 to 90 degrees using MATLAB-Simulink. In 2019, data from the 21st day of every month was evaluated for fill factor, efficiency, and irradiance. It was determined that 29.5 degrees was the ideal tilt angle. **Etienne Saloux et al. [9]** accurately characterized photovoltaic (PV) cell arrays under different environmental conditions, such as temperature and solar irradiance as most traditional solutions involve complex, time-consuming numerical calculations. To further simplify this, the researchers came up with a simpler model for PV panels that allowed engineers to determine key parameters like short-circuit current, open-circuit voltage, and maximum power point (MPP) without complex calculations. The model was based on a single-diode approach and used data provided by PV manufacturers to estimate essential parameters. Then, The model was tested by comparing its results to reference values across different solar irradiances and temperatures. It showed accurate estimations of key PV parameters and was easy to use, providing quick performance assessments for design engineers. Future research can be focused on exploring thermodynamic efficiency and improving real-world applicability.

The study by **O. Khaselev et al. [10]** addressed the challenge of efficiently converting solar energy into hydrogen fuel using integrated photovoltaic (PV) and electrolysis systems. Multijunction PV/electrolysis configurations that utilized advanced materials to maximize energy capture and conversion were also investigated. Specifically, the study evaluated two types of configurations which include a n/p and n/p-GaInP/GaAs(Pt)/KOH electrolyte cell and a triple-junction p–i–n a-Si(Pt)/KOH electrolyte cells. Results showed that the a-Si system achieved a solar-to-hydrogen conversion efficiency of 7.8% and the GaAs/GaInP2 system demonstrated a significantly higher efficiency of over 16%. **Thomas L. Gibson et al. [11]** studied the generation of solar energy from photovoltaic (PV) modules to perform electrolysis of water, without emitting carbon dioxide. This renewable method of hydrogen production had low efficiency (2–6%), which necessitated a larger PV array which increased the hydrogen generation cost. The study focused on enhancing the efficiency of the PV-electrolysis system by aligning the voltage and maximum power output of the photovoltaics with the operating voltage of proton exchange membrane (PEM) electrolyzers. This optimization improved the hydrogen generation efficiency to 12% for a solar-powered PV-PEM electrolyzer capable of producing sufficient hydrogen to power a fuel cell vehicle. **Nelson A. Kelly et al. [12]** discussed the inefficiency and high costs associated with solar hydrogen generation systems that convert only 2%-6% of solar energy into hydrogen fuel. The researchers proposed a mathematical model to predict and optimize the efficiency of photovoltaic (PV) and electrolyzer systems. The primary objective of developing the model was to match the maximum power output of PV modules with the operating voltage of proton exchange membrane (PEM) electrolyzers to enhance overall efficiency. The model can be optimized to account for various parameters with two methods that are DC-DC Converter Optimization (DDO) and Direct Connection Optimization (DCO). Results obtained from testing showed that the highest efficiency is 33 V, which decreases with increasing temperature. **N.A. Burton et al. [13]** discussed the current status of solar-powered electrolysis and suggested methods through which the process can become more efficient such as applying magnetic fields, light energy fields, ultrasonic fields, and pulsating electric fields and also analyzed the improvements made by employing these methods. Observations show that the fields can alter the molecular dynamics of water such as decreasing hydrogen bonding and altering the spin state and that future innovations to increase efficiency require the consideration of these parameters. **Mirzaei, Mohsen et al. [14]** investigated the solar energy potential in Iran, particularly focusing on the performance of photovoltaic (PV) panels in the semi-arid climate of Rafsanjan. The study identified the problem of underutilization of solar energy despite high irradiance levels. It involved installing two types of PV panels at a fixed tilt angle of 34° in Rafsanjan, collecting data on solar irradiance, ambient temperature, and module temperature over 359 days in 2014. Monocrystalline and polycrystalline PV panels were tested to assess their efficiency under local conditions. Performance tests were conducted in real environmental conditions and the findings indicated significant energy generation potential, with PV cells producing between 155 to 385 Wh/module.day, sufficient for isolated regions. Limitations of this study include focus on a single location which makes broader regional assessments to generalize findings across Iran necessary.

Mobi Mathew et al. [15] analyzed the performance of different photovoltaic (PV) modules in a tropical environment. The problem of suboptimal energy output from PV systems due to high temperatures and humidity, which affects module efficiency was identified during the study. The study focused on a comparative analysis of mono and polycrystalline PV modules to determine their performance under varying load conditions for stimulating different operational scenarios by measuring current-voltage (I-V) characteristics, alongside environmental data collection. Findings from the study indicate that outdoor performance of the selected PV modules is close to the performance at STC. Mono c-Si has an efficiency of 13.39 % whereas poly c-Si modules have 13.20 % efficiency. Additionally, parallel combinations of these modules were found to be more efficient as compared to series combinations. **Sarayu Vunnam et al. [16]** studied the performance of various photovoltaic (PV) array configurations under different shading patterns, specifically focusing on a 6×6 Total-Cross-Tied (TCT) PV array. The research addressed the inefficiencies caused by shading on PV systems. It involved analyzing the performance of Monocrystalline, Polycrystalline, and Thin-film materials under six distinct shading scenarios. MATLAB/Simulink simulations were employed to model the PV arrays and assess their performance metrics which include global maximum power (GMP), fill factor, and efficiency. Testing revealed that Monocrystalline arrays consistently outperformed other types of PV modules, generating over 100 W more power than Polycrystalline and 16 W more power than Thin-film arrays under shading conditions. **Benyounes Raillani et al. [17]** studied the impact of temperature and irradiation on the efficiency of mono-crystalline silicon solar cells which in turn is the most important for energy production. key parameters like current voltage, fill factor, i versus v curves, and photovoltaic systems are modeled using MATLAB/Simulink following a simulation-based approach. Later, the authors found that higher irradiation increases power output. In contrast, higher temperatures reduce overall performance. For better power generation the authors used Perturb and Observe (P&O) algorithm with a DC-DC converter. The paper shows that the authors were focused on simulations alone as there were no experimental validations, something that future work should include. **Anit Seapan et al. [18]** studied the impact of temperature and irradiance on the performance of crystalline silicon photovoltaic (PV) devices, mainly focusing on Imp (current) and Vmp (voltage) at maximum power. To predict this parameter without the diode data a new novel approach was used. While performing experimental tests using MATLAB/Simulink it was found that imp remained stable with different temperatures and for VMP, it was seen that it was more sensitive.lastly, the authors came up with an equation that could accurately predict PV performance. **Erdem Cuce et al. [19]** studied the effects of light intensity and temperature on silicon photovoltaic module performance. The high initial cost of PV systems was seen as a challenge even with their low operational costs and environmental benefits. The research revolved around an experimental setup that included a solar simulator and measurement devices after that statistical analysis was performed using the Bouzidi method to extract performance parameters. The result of the following experiment showed that parameters like shunt resistance (Rsh) are sensitive to environmental changes. The authors even went ahead and introduced a new solar intensity coefficient and highlighted gaps in comprehensive experimental and statistical analyses. The limitations of the research were experimental conditions. **E. Radziemska et al. [20]** addresses the challenge of optimizing the performance of photovoltaic (PV) modules under varying environmental conditions, specifically changes in illumination levels and temperature. It involves the development and implementation of a maximum power point tracking (MPPT) unit. By doing so, it aims to enhance the energy harvested from the PV module, even as environmental conditions fluctuate. Measuring the voltage decrease and temperature increase during the initial irradiation phase to derive the temperature coefficients for the PV module. Additionally Conducted experiments to observe the effects of illumination levels and temperature changes on the I-V characteristics of the PV module. **M. Piliougine et al. [21]** proposed a novel embedded electronic system designed for precise I-V curve tracing under outdoor conditions. The methodology involves developing a microcontroller-based I-V tracer that integrates a power conditioning circuit for accurate data acquisition. The system allows for in situ measurements without interrupting power generation, ensuring real-time monitoring. The testing approach includes comparing I-V curves of tested and reference modules positioned closely to minimize temperature discrepancies, thus enhancing measurement accuracy. Results indicate that the proposed system yields I-V curves closely matching theoretical values, with a mean relative error under 3%, demonstrating its effectiveness in outdoor conditions. Despite its advantages, the study acknowledges limitations such as potential inter-module temperature variations.

III. METHODOLOGY

A. Specifications of Solar Panels used for Experiments

Five polycrystalline solar panels having different power outputs were procured for conducting the experiments. The first panel which is shown in Fig 1, has a peak power output of 20W, a power tolerance of +/-3%, and operates at a maximum power voltage (Vmp) of 17.5V and a maximum current (Imp) of 1.14A. It has an open-circuit voltage (VOC) of 21.6V, a short-circuit current (ISC) of 1.29A, and an efficiency of 15.50%. The dimensions of this panel were 490×350×25 mm and it weighed around 2 kg. The second polycrystalline panel which is shown in Fig 2, with a power output of 25W, a conversion rate of 18%, and length, breadth and height of 56 cm, 35.5 cm and 2.2 cm respectively, and weighs only 350 g. It operates at 12.04V and delivers a current of 1.96A. The third polycrystalline panel which is shown in Fig 3, has a power output of 30W, 12V operating voltage with a current range of 2.5A. The fourth polycrystalline panel with 40 W power output shown in Fig 4, operates at 19V with a current of 2.1A. It has an open-circuit voltage of 22.68V and a short-circuit current of 2.21A. The fifth panel, which is a 50W polycrystalline panel shown in Fig 5, delivers 12V power and a current of 4.16A, it measures 66.5 cm x 77.5 cm x 3.5 cm, and weighs about 4.92kg. These solar panels were used for driving the process of electrolysis during the experiments conducted during this research to correlate the efficiency of these solar panels with the rate of electrolysis and the amount of hydrogen produced during electrolysis.

Fig 1. 20 W Polycrystalline Solar Panel

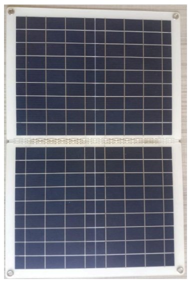

Fig 2. 25 W Polycrystalline Solar Panel

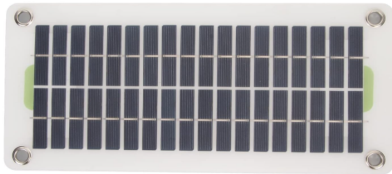

Fig 3. 30 W Polycrystalline Solar Panel

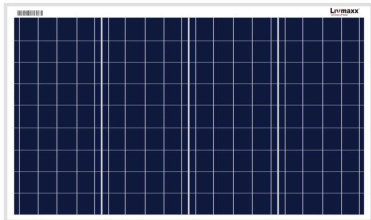

Fig 4. 40 W Polycrystalline Solar Panel

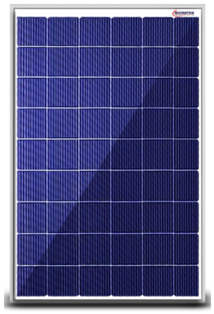

Fig 5. 50 W Polycrystalline Solar Panel

B. Measurement of Solar Panels Characteristics

The key parameters for all polycrystalline solar panels were measured and recorded in a CSV file. The short-circuit current (Isc) was measured by connecting the positive and negative terminals of the solar panel through an ammeter, which created a short circuit and the maximum current output under standard test conditions (STC) was recorded for all test panels. The open-circuit voltage (Voc) for all five test panels was measured by connecting a voltmeter across the panel's terminals with no load attached to it, which provided the maximum potential output when the panel was exposed to sunlight under STC. The obtained values were recorded in the CSV dataset. The maximum power output (Pmax) for each panel was obtained by calculating the product of the maximum current (Imp) and maximum voltage (Vmp), values for which were obtained from the panel's specification label. The Fill Factor (FF) for all the panels was calculated with the formula shown in Fig 6. The fill factor (FF) indicates the efficiency of a solar cell. It is calculated by taking the ratio of maximum power point (MPP) with the product of short circuit current (Isc) and open circuit voltage (Voc). The maximum power output is calculated with the formula shown in Fig 6. The fill factor is also denoted as the largest square which fits inside an IV curve as shown in Fig 7.

$$P_{\mathrm{max}} = V_{\mathrm{mp}} \times I_{\mathrm{mp}}$$

Fig 6. Formula for Calculating Maximum Power Output of Solar panels

$$FF = \frac{P_{MP}}{V_{OC} \times I_{SC}}$$

Fig 7. Formula for Calculating Fill Factor of Solar panels

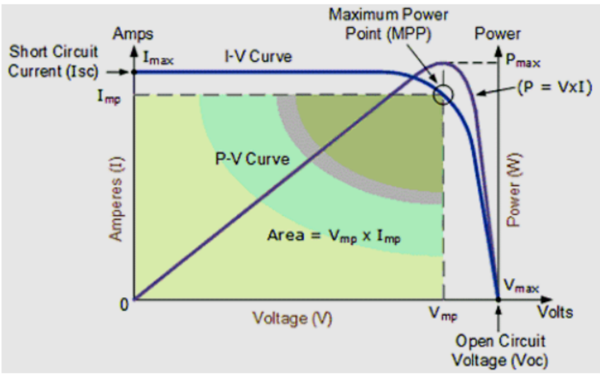

Fig 8. IV Curve of a Solar Cell

C. *Development of Device for Data Collection*

To monitor the conditions during the experiment, a DHT11 sensor (shown in Fig 9) was connected to an Arduino Nano microcontroller for measuring the temperature under the artificial light source where the solar panels were positioned for generating electricity to drive the electrolysis. This allowed for precise tracking of the temperature, which ensured consistency in the data being gathered for testing the efficiency of the panels. Additionally, a MQ8 hydrogen sensor (shown in Fig 10) was integrated into the circuitry to measure the amount of hydrogen liberated during the electrolysis process. Both the sensors provided real-time temperature and hydrogen concentration data which was used correlating the panel efficiency with the rate of electrolysis.

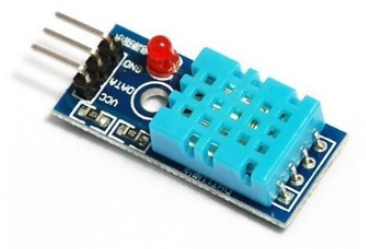

Fig 9. DHT11 Temperature and Humidity Sensor

Fig 10. MQ8 Hydrogen Gas Sensor

D. *Setup for Experiments*

An electrolytic cell was set up to conduct experiments for testing the efficiency of the collected polycrystalline solar panels in driving the electrolysis of sodium hydroxide solution as shown in Fig 13. The setup consisted of two graphite electrodes placed inside a container, whose lid was modified to allow the insertion of the electrodes and attachment of uncapped water bottles. The electrodes were inserted through the mouths of these uncapped bottles, which were attached to the lid with polypropylene based hot melt adhesive, while plastic bags fixed at the bottle mouths collected the hydrogen and oxygen gasses liberating during electrolysis. The electrolyte used was a sodium hydroxide (NaOH) solution, prepared by dissolving 423.53 g to 600 g of NaOH in 2400 ml of water, achieving different concentration levels in the range of 15–20%. The percentage concentration was calculated with the formula shown in Fig 11. The electrolyte was weighed with a high precision weighing scale. Wires from the crocodile clips attached to the electrodes were connected to the solar panels being tested which were placed under an artificial light source to supply the required current for the electrolysis. The artificial light source used in the experiment was a LED light with a brightness of 4100 lux, a power output of 37 watts, and required a DC input of 8.4 volts. The light source has an adjustable brightness control feature and it was mounted on a tripod for flexibility in the positioning of the panels under the light source. The electrolyte's temperature was measured using a laboratory thermometer. Hydrogen sensor, connected to the Arduino Nano, was fixed to the inner wall of the plastic bag attached to the mouth of the bottle containing the cathode to measure the variation in the concentration of hydrogen liberated from it, while oxygen liberating from the anode was collected in another plastic bag fixed to the bottle around the anode. The artificial light source used in the experiment which is shown in Fig 12, was a LED light with a brightness of 4100 lux, a power output of 37 watts, and a DC input of 8.4 volts. This light featured adjustable brightness control and was mounted on a tripod to provide flexibility in the positioning of solar panels under it.

$$\text{Concentration}(\%) = \frac{\text{Mass of Solute}}{\text{Mass of Solute} + \text{Mass of Solvent}} \times 100$$

Fig 11. Formula for Calculating Percentage Concentration of Electrolyte

Fig 12. LED Light used as the Artificial Light Source for the Experiments

Fig 13. Electrolytic Cell Setup with the Device for Measuring Experimental Conditions and Hydrogen Concentration

E. Experiments for Solar Panel Efficiency Estimation and Data Collection

During the experiments which were conducted to evaluate the efficiency of polycrystalline solar panels, several important parameters were recorded in a dataset. The NaOH electrolyte was prepared in different concentrations, varying from 15% to 20% as described in the experiment setup section. The electrolyte's temperature was measured using a laboratory thermometer. Each of the five polycrystalline solar panels was tested individually by placing them under an artificial LED light source. The Arduino Nano-based device was used to monitor and record data throughout the experiments. The DHT11 sensor provided real-time temperature readings of the area under the artificial light source, while the MQ8 hydrogen sensor provided the hydrogen gas concentration accumulated in the plastic bag attached to the cathode. The gathered data, including the electrolyte's percentage concentration, the amount of NaOH and water used, the current and voltage obtained from the solar panels, the pH and temperature of the electrolyte, were recorded in a CSV file. Additionally, important performance metrics such as the short-circuit current (Isc), open-circuit voltage (Voc), maximum power output (Pmax), and fill factor (FF) of each solar panel were measured and recorded in the dataset. The amount of inflation in the plastic bag collecting the hydrogen gas was also recorded, which served as an indicator of hydrogen generation efficiency. The Arduino Nano transmitted the data of the parameters measured by the DHT11 and MQ8 sensors to a computer via a serial port, where a Python script processed and stored the data into a CSV dataset. This CSV file, containing all the sensor data along with the measurements made, became the primary dataset that was analyzed in this study for obtaining insights into the efficiency and performance of the polycrystalline solar panels under varying experimental conditions.

F. Dataset Preprocessing

The prepared dataset was processed to ensure compatibility for analysis. The dataset was inspected for missing values, which were removed from it to avoid inconsistencies. All numeric values, such as temperature, voltage, current, electrolyte concentration, etc were standardized. The hydrogen gas concentration and solar panel surrounding temperature data were filtered for noise, as the real-time data included fluctuations. The dataset was then normalized to a common scale for comparison across different experiments, to evaluate the relationships between solar panel efficiency and amount of hydrogen released which indicates the rate of electrolysis.

G. Data Analysis

Various analyses were conducted to explore the relationships between important parameters recorded from the experiments in the dataset with python libraries like pandas, matplotlib and seaborn. The analysis was focused on finding the relationships between Hydrogen Concentration (ppm) in the plastic bag attached to the mouth of the bottle attached to the lid through which the cathode cathode is immersed in the electrolyte, Fill Factor (FF) of the polycrystalline solar panels, Power Output (W) of the solar panels, Voltage (V), and Current (A) obtained from the solar panels while conducting the electrolysis. Scatter plots with fitted regression lines were generated to understand how the different variables like fill factor, power output, etc affected the hydrogen concentration and hence the rate of electrolysis in the NaOH solution. Relationships, particularly between Hydrogen Concentration and Power Output, as well as between Fill Factor and both Power Output and Voltage were assessed with graphs. Pearson correlation coefficients were calculated to quantify the strength and direction of these relationships, with p-values with values less than 0.05 indicating statistical significance. Line plots were created to illustrate changes in Hydrogen Concentration over time.

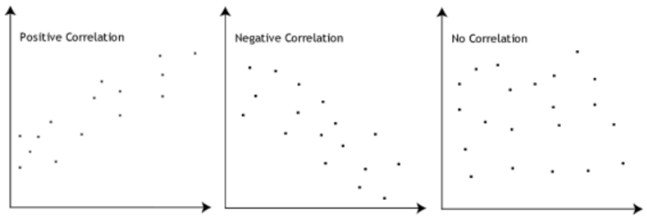

Fig 14. Pearson Correlation Plots Indicating Positive, Negative and No Correlation Between variables

$$r = \frac{\sum (x - m_x)(y - m_y)}{\sqrt{\sum (x - m_x)^2 \sum (y - m_y)^2}}$$

Fig 15. Pearson Correlation formula

IV. Results

The polycrystalline solar panels provided sufficient voltage, current, and power output to support the electrolysis of sodium hydroxide (NaOH). A positive correlation was observed between the Fill Factor and Power Output of the polycrystalline solar panel, with a Pearson correlation coefficient of 0.5301 and a p-value of 2.5889e-03, indicating a moderate relationship. A strong positive correlation was also observed between Fill Factor and Current with a Pearson coefficient of 0.6535 and a p-value of 9.0095e-05. Moreover, the relationship between Power Output and Hydrogen Concentration in the plastic bag accumulating the hydrogen released from the cathode was highly significant, demonstrated by a Pearson correlation coefficient of 0.9029 and a p-value of 8.9123e-12, showing that higher power output correlates strongly with increased hydrogen production which indicates a higher rate of electrolysis. It was also observed that hydrogen concentration increased with the duration of electrolysis. A strong positive correlation was found between Light Intensity and Hydrogen Concentration with a Pearson coefficient of 0.7620 and a p-value of 9.9689e-07, which shows the impact of illumination on hydrogen production during electrolysis when it is supported by polycrystalline solar panels. The correlation between Fill Factor and Hydrogen Concentration was also significant with a Pearson coefficient of 0.3176 and a p-value of 8.7184e-02, suggesting a strong relationship. However, the relationships of the hydrogen concentration which indicates the rate of electrolysis with Electrolyte Temperature had a Pearson coefficient of 0.1104 with p-value of 5.6139e-01 and with the Surrounding Temperature of the solar panel had a Pearson coefficient of 0.0927 with a p-value of 6.2614e-01 were weak and not statistically significant. Overall, these results indicate that hydrogen concentration which indicates the rate of electrolysis has significant correlations with fill factor and light intensity under which the polycrystalline panels are placed.

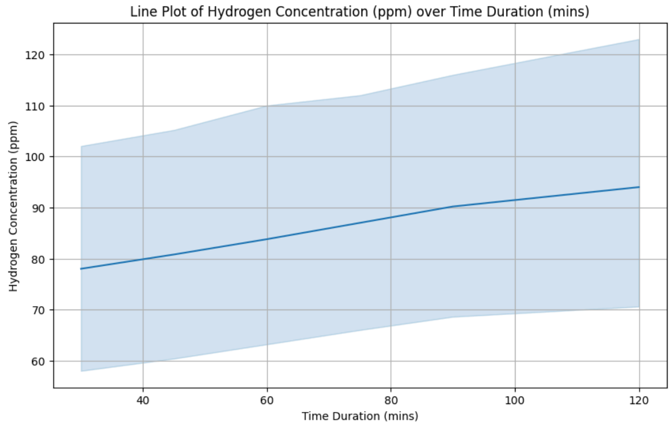

Fig 17. Relation Between Hydrogen Concentration and Time Duration of Electrolysis

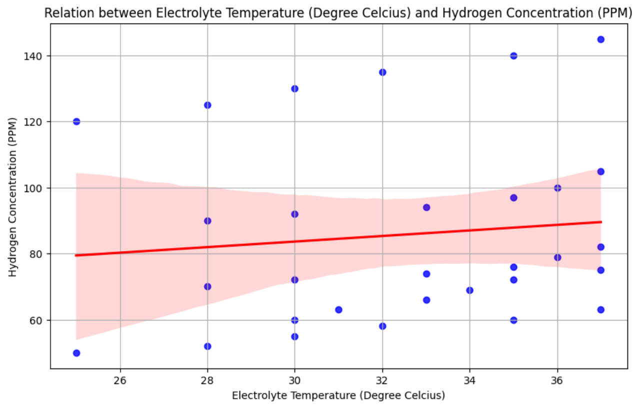

Fig 17. Relationship Between Hydrogen Concentration and Electrolyte Temperature

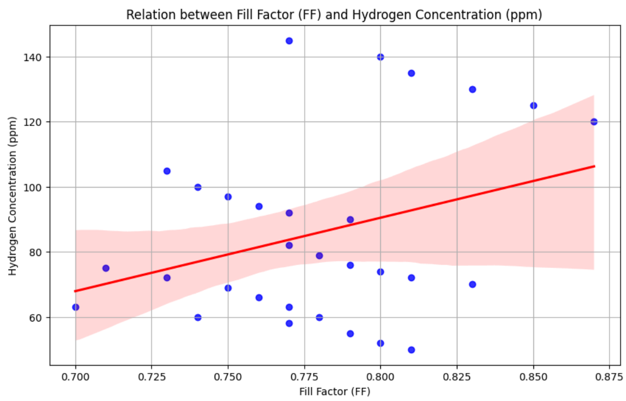

Fig 18. Relationship Between Hydrogen Concentration and Fill Factor

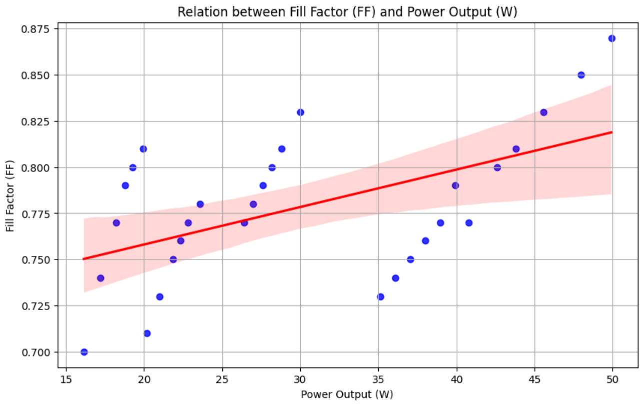

Fig 19. Relationship Between Power Output and Fill Factor of Polycrystalline Solar Panels

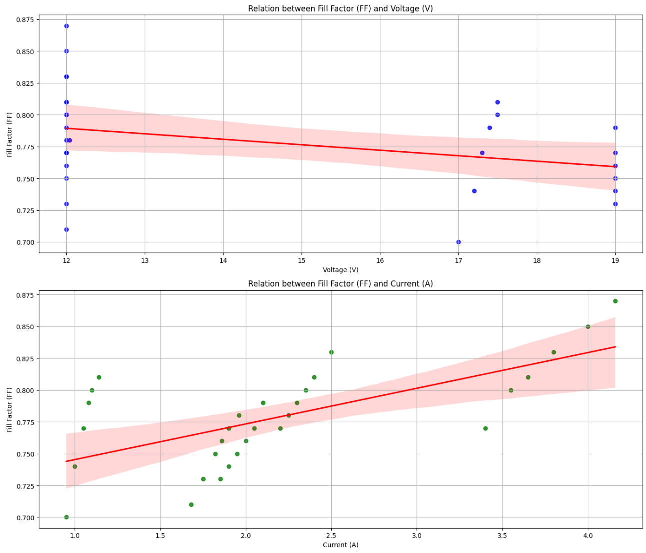

Fig 20. Relationship Between Obtained Current and Voltage with Fill Factor of Polycrystalline Solar Panels

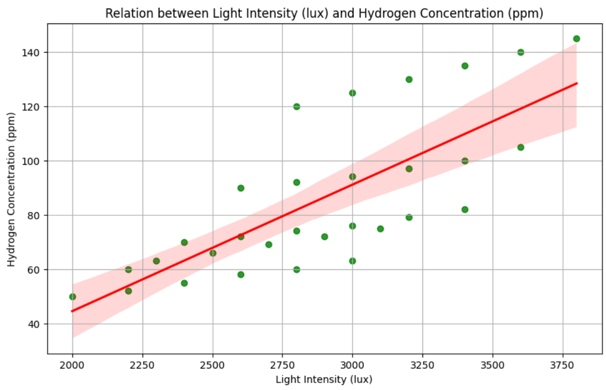

Fig 21. Relationship Between Hydrogen Concentration and Light Intensity of Artificial Light Source

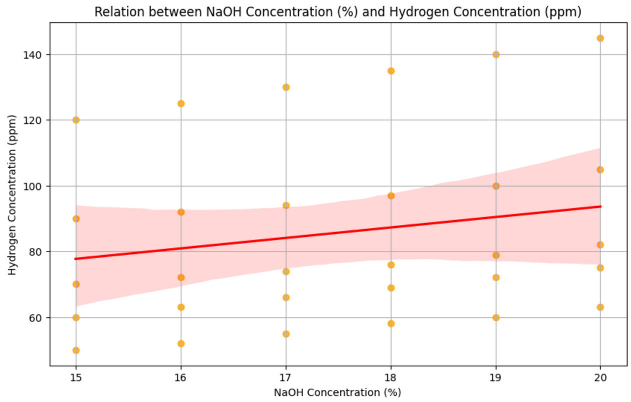

Fig 22. Relationship Between Hydrogen Concentration and NaOH Concentration in Electrolyte

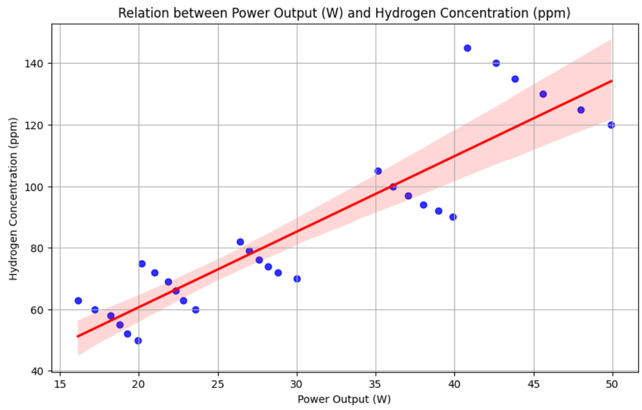

Fig 23. Relationship Between Hydrogen Concentration and Power Output of Solar Panels

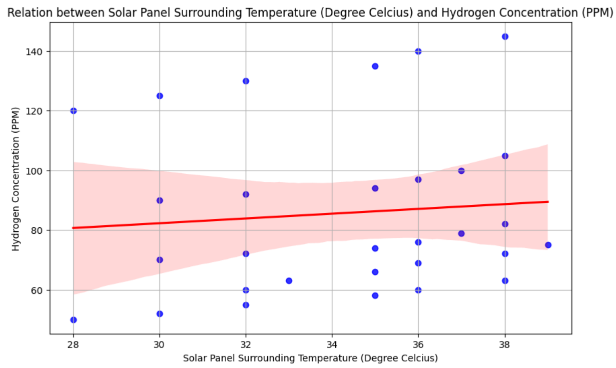

Fig 23. Relationship Between Hydrogen Concentration and Solar Panel Surrounding Temperature

V. CONCLUSION

The relationship between solar panel efficiency and hydrogen production during the electrolysis of sodium hydroxide (NaOH) using polycrystalline solar panels was studied in this research. The findings showed that these panels provided sufficient voltage, current, and power output to support electrolysis effectively. A strong positive correlation was found between the Fill Factor and Power Output, suggesting that fill factor is a reliable indicator of a solar panel's efficiency. A strong positive correlation observed between Fill Factor and Current indicated the importance of fill factor in optimizing solar panel efficiency. The highly significant relationship between Power Output and Hydrogen Concentration showed that higher power output leads to increased hydrogen production. The analysis confirmed that hydrogen concentration increases with longer electrolysis durations and that light intensity strongly correlates with hydrogen production. The correlation of Hydrogen Concentration with Electrolyte Temperature and Surrounding Temperature were not statistically significant. The findings of this research also present opportunities for future study. Subsequent studies could explore different types of solar panels, such as monocrystalline or thin-film technologies, for comparative insights. Additionally, investigating the long-term stability and performance of solar panels under varying environmental conditions can also contribute towards predicting their effectiveness. Finally, scaling up this research to larger systems will be essential for transitioning from laboratory-scale experiments to pilot-scale applications.

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