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Research Article

Performance Analysis Of Submerged Gallium Arsenide Photovoltaic Cell With Varying Water Conditions

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ARTICLE INFO **ABSTRACT**

This study investigates the performance of submerged gallium arsenide (GaAs) photovoltaic (PV) cells under various water conditions, aiming to enhance the understanding and efficiency of underwater solar energy systems.Unlike conventional polycrystalline materials, which suffer from structural and electrical homogeneity issues, GaAs offers superior characteristics, including higher efficiency and better resistance to environmental degradation. The research focuses on analyzing the impact of different water types, including sea water, deionized water, artificial sea water, and normal tap water, on the performance of GaAs PV cells at varying depths up to 30 cm. Experimental results reveal that the power output and efficiency of the PV cells are significantly influenced by the water's transparency and impurity levels. Among the tested conditions, deionized water yielded the highest power output, then artificial sea water, normal water, and sea water. The study also demonstrates the effectiveness of encapsulation in protecting the PV cells across all water types, including natural seawater with salinity and contaminants. This study contributes to the domain of renewable energy by supplying information on optimizing submerged PV cell performance and highlights the potential of GaAs solar cells for sustainable energy generation in marine environments.

Keywords: Photovoltaic cell, underwater solar power, efficiency, water conditions.

I. INTRODUCTION

solar-powered cells, which directly generate electricity from sunlight, are key components of renewable energy systems. The efficiency and performance of these cells are critical for the viability of solar energy as a sustainable power source. One method proposed to enhance the performance of PV cells is to submerge them in water, which can improve cooling and reduce operating temperatures. This study aims to analyze the performance of submerged Gallium Arsenide (GaAs) PV cells under varying water conditions to assess the impact on efficiency and output.

GaAs is a semiconductor material known for its high efficiency in converting sunlight into electricity, making it a popular choice for PV cells, especially in space applications. However, like all PV cells, GaAs cells are susceptible to performance degradation due to temperature increases during operation. By submerging GaAs PV cells in water, it is hypothesized that the cooling effect of the water can help maintain lower cell temperatures, thereby improving efficiency and overall performance.

The efficiency of a PV cell is affected by various elements including temperature The degree of light intensity sunlight, and The spectral distribution of light. Submerging the cells in water can potentially impact these factors. For example, water temperature can affect the cooling efficiency, while the quality of the water (e.g., fresh vs. saline) can influence the electrical conductivity around the cells. Additionally, the flow rate and depth of the water can affect the heat dissipation and light absorption of the cells.

Several studies have investigated the performance of submerged PV cells, primarily focusing on silicon-based cells. However, there is limited research regarding the execution of submerged GaAs solar cells, especially

regarding the impact of varying water conditions. Understanding how distinct water conditions impact the effectiveness of GaAs PV cells is essential for optimizing the design and efficiency of submerged PV systems.
This study seeks to address this gap by conducting experiments to analyze the performance of GaAs PV cells submerged in water under different conditions. By systematically varying water temperature, quality, flow rate, and depth, we aim to evaluate their impact on cell efficiency and output. The results of this research could give insightful explanations of the possible advantages and challenges of employing submerged GaAs PV cells in practical applications.
The rest of this essay is structured as follows: Section 2 offers a review of related writings on submerged PV cells additionally the factors influencing their performance. Section 3 explains the experimental design and methods employed in this investigation. Section 4 presents the outcomes analysis of the experiments. Finally Section 5 wraps off the essay with a discussion of the results and suggestions for upcoming investigations.

LITERARURE SURVY

[1] A. K. Palai, S. K. Mohanty, (2019), "Modeling and performance analysis of GaAs solar cell under various conditions,". In this study, a model for The act analysis of Solar cells made of gallium arsenide (GaAs) under various conditions is presented. The research likely involves theoretical modeling and simulations to understand how factors such as temperature, irradiance, and water conditions affect the efficiency of GaAs cells. This work provide insightful information about the actions of GaAs solar cells beneath different operating circumstances, contributing to the optimization of their performance in practical applications.

[2] D. Arun Kumar, A. Mohanty, S. Ghosh, (2018), "Performance analysis of GaAs solar cell under different water conditions ". In this study, the performance of Gallium Arsenide (GaAs) photovoltaic cells under different water conditions is analyzed. The research likely involves experimental work to assess how different water conditions, such as temperature, flow rate, and depth, impact the efficiency and output of GaAs cells. This research advances our knowledge of the behavior of GaAs cells when submerged in water, which is important for optimizing their performance in practical applications. The results of this research might have effects on the design and execution of submerged GaAs photovoltaic systems with in renewable energy systems.

[3] P. K. Sahu, S. K. Das, (2017), "Effect of water temperature on the execution of GaAs solar panels
In this study, the effect of water. The effect of temperature on Gallium Arsenide (GaAs) solar cell performance is investigated. The research likely involves experimental analysis to determine how changes in water temperature impact the efficiency and output of GaAs cells. This study is important for understanding the thermal behavior of GaAs cells when submerged in water, which can help optimize their performance in different environmental conditions. The findings of this research could be useful for designing GaAs photovoltaic systems that are more efficient and reliable in practical applications.

[4] R. K. Behera, S. K. Mohanty, (2016), "Experimental investigation of GaAs solar cell performance under varying water conditions,". In this study, an experimental investigation of Gallium Arsenide (GaAs) solar cell performance under varying water conditions is conducted. The research likely involves practical experiments to assess how factors such as water temperature, flow rate, and depth affect the efficiency and output of GaAs cells. This research offers insightful information about the behavior of GaAs cells when submerged in water, which is crucial for optimizing their performance in real-world applications. The research's conclusions could have effects on the layout and operation of submerged GaAs photovoltaic systems, especially in terms of maximizing their efficiency and longevity.

[5] A. K. Swain, S. K. Das, (2015) "Performance analysis of GaAs solar cell under different water depths,". In this study, Gallium Arsenide (GaAs) solar cells' efficiency under different water depths is analyzed. The research likely involves experimental work to assess how varying the depth of water above the cells affects their efficiency and output. This research offers perceptions into the optimal depth of water for maximizing the performance of GaAs cells, which is important for designing submerged photovoltaic systems. The findings of this research could inform the development of more efficient and reliable GaAs solar cells for use in underwater or partially submerged applications.

PROBLEM STATEMENT

The problem addressed in this research is the inefficiency of traditional polycrystalline photovoltaic (PV) cells in underwater applications, particularly in submerged solar energy systems. Polycrystalline materials commonly used in PV cells face significant challenges when deployed underwater, such as structural and electrical homogeneity issues caused by dislocation, grain boundary, and point defects, as well as charged

defects and degradation. These issues not only reduce the efficiency of the PV cells but also pose environmental risks.
Moreover, the underwater environment introduces additional complexities, including variations in water quality, depth, and transparency, which can further impact the performance of solar cells. For instance, the presence of dissolved salts, impurities, and particulate matter in seawater can affect the transmission of sunlight, thereby influencing the power output and efficiency of submerged PV cells. Additionally, the spectral shifts and attenuation of solar irradiance with increasing water depth pose challenges to the effective harnessing of solar energy underwater.

Given these challenges, there is a need for alternative materials and technologies that can overcome the limitations of traditional polycrystalline PV cells in underwater environments. This research aims to explore the use of gallium arsenide as a potential material for PV cells in submerged systems, with the goal of improving their performance and efficiency in varying water conditions. By taking care of these issues, The research seeks to aid in the creation of more efficient and environmentally friendly solutions for underwater solar energy applications.

LIMITATIONS

Limited Water Types and Conditions: The study primarily focuses on four varieties of water (deionized water, normal tap water, artificial seawater, and natural seawater). Other water types and conditions, such as brackish water or water with varying levels of turbidity, are not explored. This limits the applicability of the findings to a broader range of underwater environments.

The optical properties of water, including absorption and scattering coefficients, vary across different types of water bodies. These variations influence how light is absorbed and scattered within the water, ultimately impacting the efficiency of solar panels. Researchers study these conditions by manipulating different water parameters to understand their effects on light absorption and scattering, thus informing strategies to optimize panel performance.

Depth Range: The performance analysis of the photovoltaic cells is conducted up to a depth of 30 cm. This depth range may not be sufficient to fully understand the behavior of the cells in deeper underwater applications, such as in marine energy systems or underwater vehicles.

Environmental Factors: The study does not account for other environmental factors that could affect the performance of submerged photovoltaic cells, such as water temperature variations, biofouling, and underwater currents.

Long-Term Performance: The research does not address the long-term performance and durability of the encapsulated gallium arsenide solar cells in underwater conditions. The impact of prolonged exposure to saltwater and other water impurities on the cells' efficiency and lifespan is not discussed.

Scalability: The study is conducted on a small scale, and it is unclear how the findings would translate to larger-scale underwater photovoltaic systems. The scalability of the encapsulation technique and its effectiveness in protecting solar cells in a real-world marine environment are not addressed.

CASE STUDY

The case study focuses on the examination of the submerged system's performance gallium arsenide solar energy cells under Different water conditions. The study examines the impact of various kinds of water (deionized water, normal tap water, artificial seawater, and natural seawater) and varying depths (up to 30 cm) on the output power and efficiency of the solar cells.

Inputs:
1. **Type of Water**: Deionized water, normal tap water, artificial seawater, and natural seawater.
2. **Depth of Submersion**: Ranging from 0 cm to 30 cm.
3. **Solar Cell Material**: Gallium arsenide.
4. **Encapsulation Status**: Before and after encapsulation.

Outputs:
1. Amperes(A) are used to measure current(I).
2. Voltage: Expressed in volts(V)or v.

Power Output (P): Calculated using the formula P = V * I, measured in watts (W).
1. **Efficiency**: Percentage of solar energy converted into electrical energy.

II. METHODOLOGY

In this methodology outlines the steps for preparing and testing Gallium Arsenide (GaAs) solar cells under varying water conditions. Here's a more detailed breakdown of each step:

- **Preparation of Solar Cells:** Gallium arsenide solar cells are fabricated and encapsulated according to standard procedures to ensure consistency and reliability in performance.
- **Submersion Setup:** A submersion setup is constructed to immerse the solar cells in different types of water (e.g., fresh, saline) at varying depths. This setup likely includes a clamp-screw mechanism to secure the cells at specific depths.
- **Performance Testing:** The solar cells are tested for their current, voltage, and power output under ambient conditions (i.e., not submerged) to establish baseline performance. Subsequently, the cells are submerged in water, and their performance is measured again to assess the impact of submersion on efficiency.
- **Data Analysis:** The performance data collected from the solar cells is analyzed to determine the effects of water type and depth on efficiency. Statistical analysis may be used to identify any significant differences and trends in the data.

This methodology provides a systematic method for approaching studying the performance of GaAs solar cells under varying water conditions, allowing for a comprehensive analysis of their behavior in different environments.

PROPOSED SYSTEM

The proposed system involves the use of encapsulated gallium arsenide photovoltaic cells for underwater applications. The encapsulation technique is designed to protect the solar cells from water impurities and environmental factors, ensuring their efficient performance in varying water conditions. This system has potential applications in marine energy systems, underwater vehicles, and other aquatic environments where harnessing solar energy is feasible.

Overall, the study proposes a system that leverages the advantages of gallium arsenide solar cells and encapsulation technology to optimize the performance of underwater photovoltaic systems. Additional investigation and development are required to resolve the restrictions and

Explore the scalability of the proposed system for practical applications.

Performance tests of Solar cell

The act tests of the solar cell, particularly focusing on gallium arsenide (GaAs) photovoltaic cells, are crucial for evaluating their efficiency and suitability for underwater applications. In this study, How well does the GaAs solar cell is assessed under various conditions, including before and after encapsulation and when submerged in different types of water at varying depths.

Before Encapsulation (BE) Under Ambient Condition (AC):

The initial tests are conducted on the solar cell before encapsulation and under ambient conditions without water. The current (I), voltage (V), and power (P) values are measured using a power analyzer. The performance is represented through I-V and P-V curves, which Display a decrease in the maximum power output (Pmax) as the water's depth rises. This decrease is attributed to the reduction in solar irradiance due to spectral shifts underwater, affecting the solar cell's power production.

After Encapsulation (AE) Under Ambient Condition (AC):

After encapsulating the solar cell, its performance is reassessed under ambient conditions. The encapsulation is expected to provide a protective layer, potentially enhancing the cell's durability and efficiency. The measurements of current, voltage, and power are again recorded to evaluate any changes in performance due to the encapsulation process.

Underwater Performance Tests:

The encapsulated solar cell is then subjected to performance tests under different water conditions: deionized water (DI), normal tap water (NW), artificial seawater (AW), and natural seawater (SW). The solar cell's underwater depth is varied from 30 cm to assess the impact of depth on performance. The following observations are made:

- **Deionized Water (DI):** The solar cell exhibits higher power output in DI water due to its clarity and minimal total dissolved solids (TDS), which allows for better penetration of sunlight.
- **Normal Tap Water (NW) and Artificial Seawater (AW):** The performance in NW and AW is lower compared to DI water, primarily due to the presence of impurities and salts that reduce water transparency.
- **Natural Seawater (SW):** The performance in natural seawater is the lowest among the tested water types, likely due to the high salinity and additional impurities like sand and dust particles.

Throughout these tests, the output power and efficiency of the solar cell are closely monitored.
The results indicate that water clarity, depth, and the presence of impurities significantly impact the solar cell's performance underwater. These findings are critical for optimizing the design and deployment of underwater photovoltaic systems, particularly in marine environments where solar energy can be harnessed for various applications.

III. RESULTS & DISCUSSION

The results and discussion section of the study on the performance of submerged gallium arsenide photovoltaic cells under varying water conditions provides a comprehensive analysis of the experimental findings.

Results:

The study's results are summarized in terms of the performance of the gallium arsenide solar cell in different water types (deionized water, normal tap water, artificial seawater, and natural seawater) and at varying depths up to 30 cm. Key findings include:

Impact of Water Type: The solar cell exhibited the highest power output in deionized water due to its clarity and minimal total dissolved solids (TDS). Artificial seawater showed slightly lower performance, followed by normal tap water. Natural seawater had the most significant negative impact on the solar cell's execution, likely because of its high salinity and additional impurities.

Effect of Depth: As the the solar cell's depth increased, a decrease in strength output was observed across all water types. This is attributed to the reduction in sunlight penetration underwater, which is further exacerbated by the presence of impurities and salts in the water.

Encapsulation Benefits: The encapsulation of the solar cell provided protection against water impurities and environmental factors, ensuring consistent performance in various water conditions.

Discussion:

The discussion section delves into the implications of these results for underwater photovoltaic systems. Key points include:

Underwater Solar Spectrum: The study highlights the importance of understanding the underwater solar spectrum and its interaction with different water types to optimize the execution of submerged solar power units.

Water Transparency: The clarity of the water performs a crucial part in the efficiency of Underwater solar cells. Deionized water, with its high transparency, allows for better sunlight penetration, resulting in higher power output.

Encapsulation Techniques: The success of encapsulation in protecting the solar cell suggests that further research into encapsulation materials and techniques could enhance the durability and efficiency of underwater photovoltaic systems.

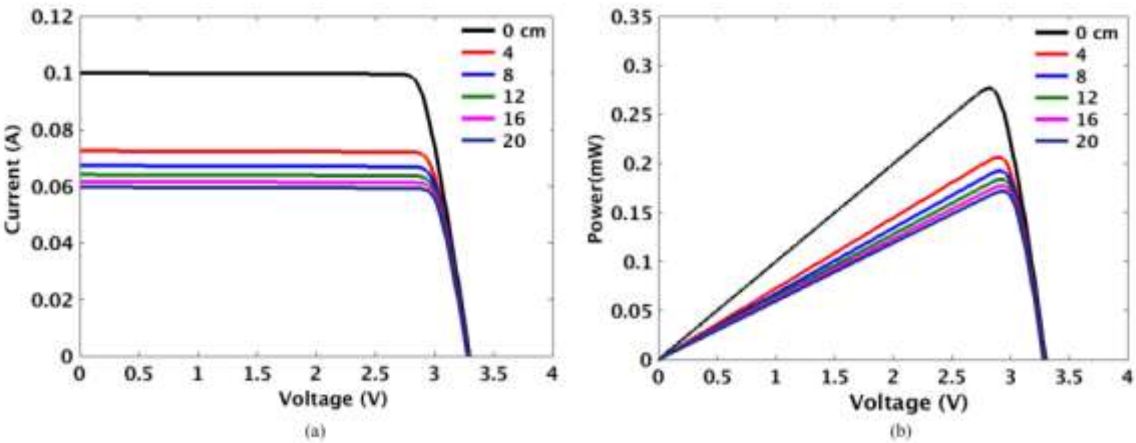


Figure 1: Theroretical Results of the solar cell's I V and P V curves at various depths up to 20 cm.

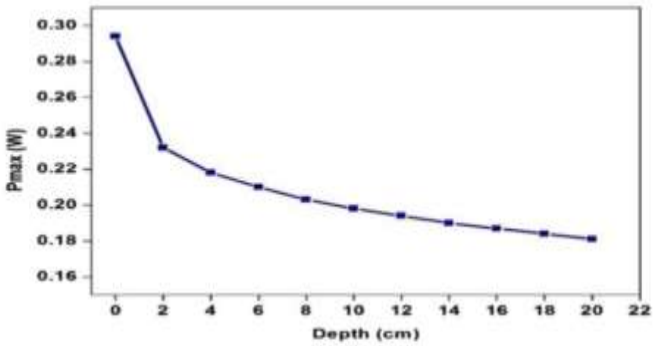


Figure 2: Variation in the solar cell's p max at various depths up to 20 cm from theortical research.


(a)


(b)

Figure 3: Gallium arsenide solar cell (a) Prior to encasing (b) Following encasement.

Figure 4: Setup of Experimentation

As was previously indicated, various types of water were used to conduct the underwater performance investigation of the gallium arsenide solar cell. Using the power screw mechanism, the underwater. The solar cell's depth was adjusted linearly ascending to a distance of 30 cm.

A. Performance due to Normal Tap Water

Figure 6. Displays the solar cell's P-V and I-V curves at various water depths under typical tap water conditions. It is evident that as the depth of the water increases, the properties of
The solar panel, including the maximal current (Imax), maximum voltage (Vmax), and uninterruptible current (Isc), drop, resulting in the maximum power output.

Table I: Descriptive analysis of various types of water

Kind of water	Conductivity	TDS in parts per million	Salinity(%)	pH
Normal water	0.4	252	1	7.1
Sea water	43	35000	3.5	8
Deionized water	0.03	16.7	0	7
Artificial sea water	40.1	30000	3.5	7.9

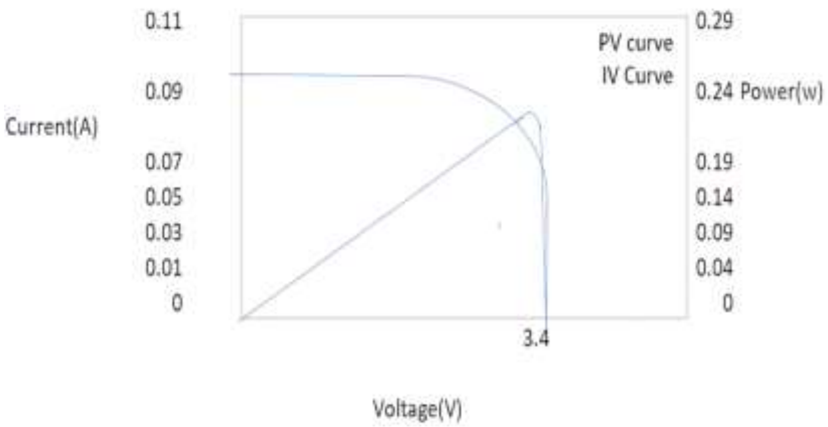


Figure 5(a): Solar cell I-V and P-V curves prior to encapsulation

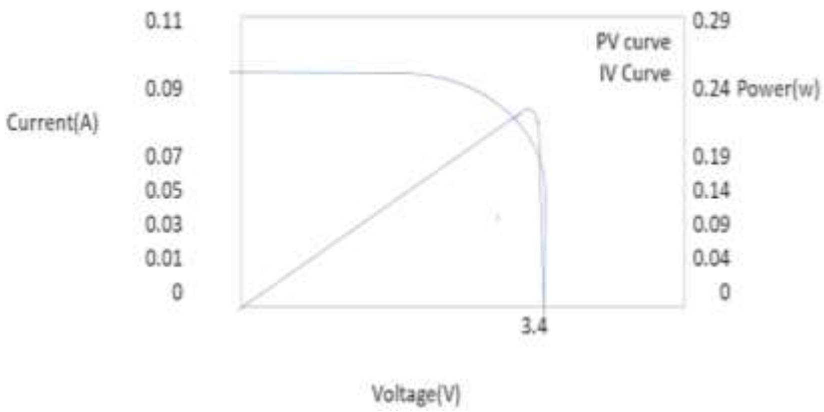


Figure 5(b): I–V and P–V curve solar cell following encapsulation.

The Gallium arsenide solar cells (Pmax) likewise drops. This was mainly caused by a reduction in sun irradiation in relation to spectrum shifts underwater, which therefore reduced the solar cell's power output. All of these factors will therefore have an impact on the solar cell's efficiency.

Generally speaking, the amount of radiation that strikes a solar cell directly affects how much power it can produce. Figure 7 illustrates the variance in Pmax with respect to depth and makes it abundantly evident that the Pmax curve lowers as water depth increases. Because there is no turbulence and the water is stable, Pmax is dropping linearly. In every kind of water, Gallium arsenide solar cells' performance is examined down to a depth of 30 cm.

B. Performance due to Natural Seawater andArtificial Seawater

Comparable tests were conducted with both organic and manmade sea salt to generate 3.5% salinity artificial natural and artificial seawater using DI water. The features of the solar cell in seawater with a salinity of 3.5% are displayed in Figure 8. Due to TDS, other contaminants, and salinity, Pmax for sea water dropped.

When natural sea water is compared to artificial seawater, there is a minor drop in Voc, Isc, and Pmax. This can be explained by the existence of pollutants like dust, Sand, and other fragments. The P-V and I-V characteristics of the solar panel to create synthetic seawater are additionally displayed in Figure 8. These features behave similarly in relation to the water's depth as well.

Figure 9. also displays the Pmax curves with relation to the water depth. As can be shown, Pmax curves get smaller as water depth increases due to the fact that sun radiation below the surface decreases. Pmax curves for natural seawater exhibit a somewhat greater drop in depth as respect to artificial seawater. This is because, when compared to prepared or manufactured seawater, natural seawater has higher TDS. Utilising solar energy in saltwater is a potentially technique for numerous offshore and domestic applications, even if Pmax is dropped slightly more in seawater. The decline in global sunlight underneath the surface is the cause of the curves P-V and I-V decline along with sea profundity.

C. Performance due to Deionized Water

Additionally, it summarises the curves for I-V and P-V from related studies utilising DI water, as Figure 6. illustrates. Despite achieving a comparable performance, DI water's minimal TDS and lack of other contaminants led to greater transparency, which consequently produced a increased output of power when contrasted to the alternative water kinds examined in this article. As Table I illustrates, DI water has extremely low conductivity.

The tank's interior water temperature is 22 °C on average, but all studies conducted with water outside Room temperature is reached in the tank. Table II presents a tabular comparison of Pmax output for several types of water. Because of the TDS in artificial and saltwater, as well as the decrease within solar irradiation underwater, the gallium arsenide solar cell displayed a drop in Pmax output with relation to the water's depth in every kind of water. It's evident that solar PV cells can function well in seawater that is both artificial and natural, despite the fact that their power production dropped in both scenarios.

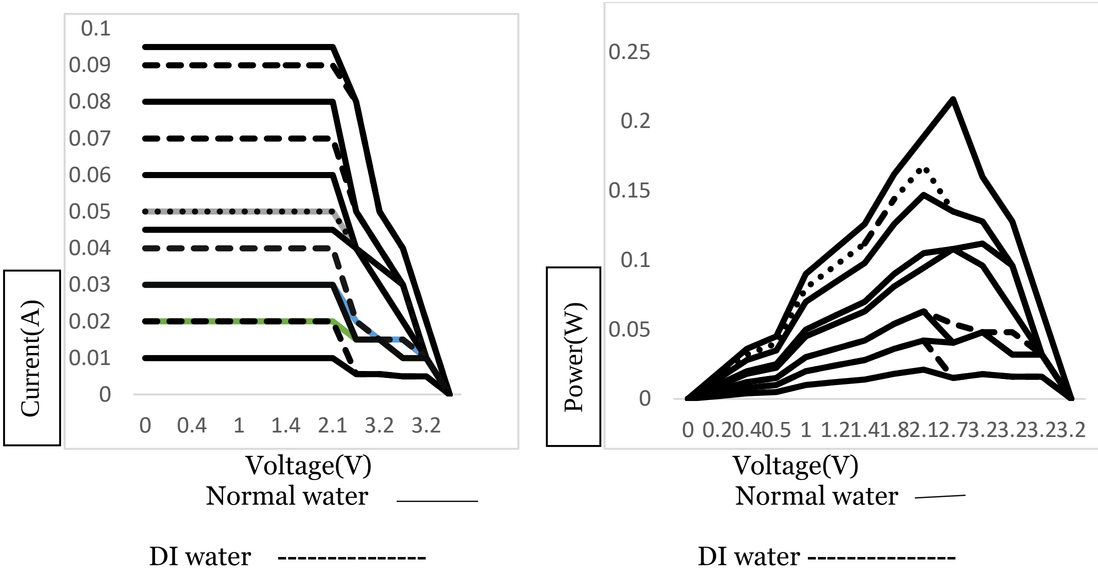


Figure 6: Features of solar cell operating at varying depths with regular and DI water.(a) Curves I-V (b)P-V curves

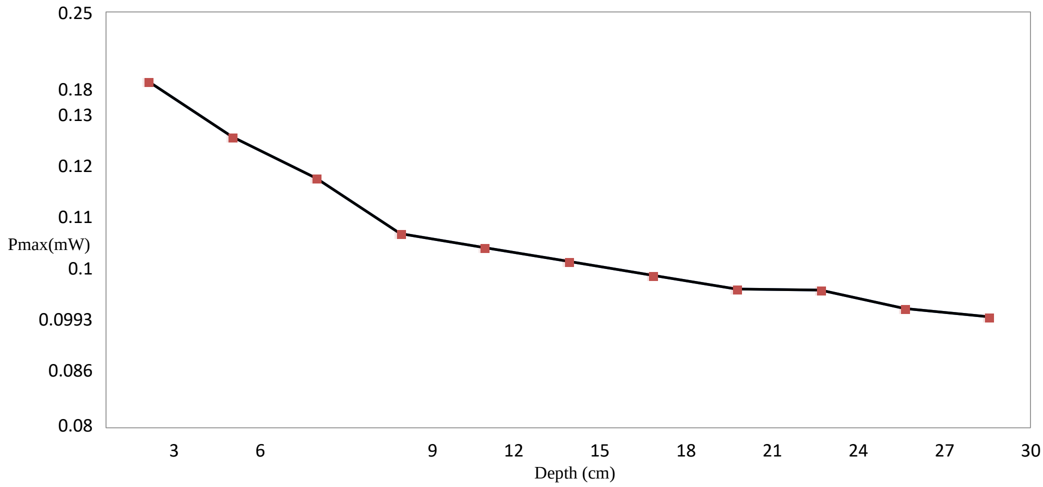


Figure 7: Variation of Pmax of solar cells in various depths using regular water.

TABLE II COMPARISION OF P maximum at 30 CM DEPTH USING DIFFERENT WATER TYPES

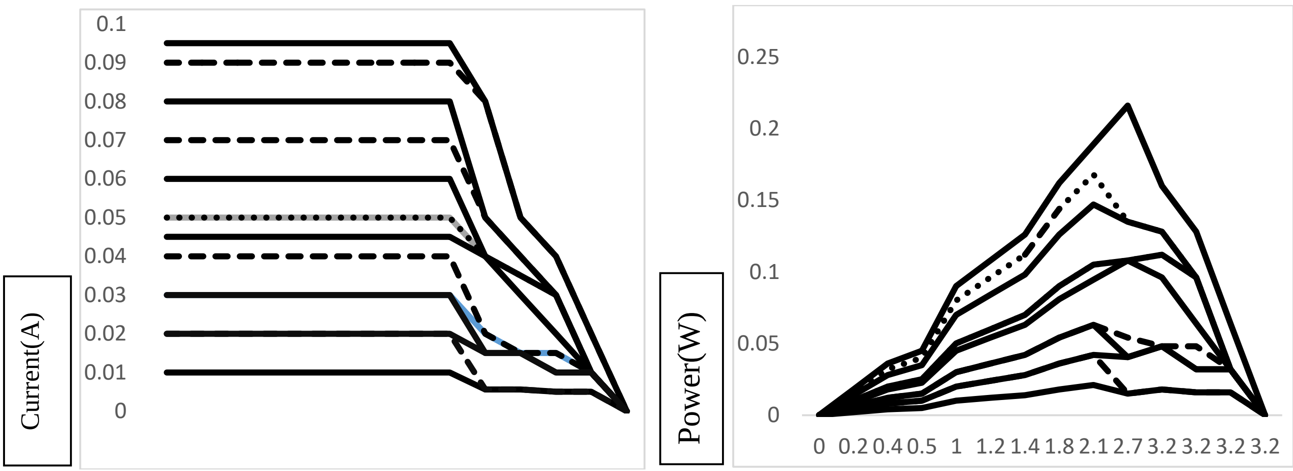
TYPE OF WATER	Pmax(mW)
Normal water	96.6
Artificial sea water	95.6
Sea water	93
DI water	98

Furthermore, it has been noted that the lack of other water and TDS contaminants in DI water results in the gallium arsenide solar cell performing better than in other types of water.
A comparative analysis has since been conducted for the maximum output power (Pmax) an current short-circuit (Isc) in relation to water depths of up to 30 cm.

D. Comparison of various types of water

Table I provides a summary of the Pmax comparison for the four types of water at a depth of 30 cm. This indicates that water generally becomes less transparent as the concentration of dissolved salts rises, leading to an increase in salinity. An increase in water depth also causes a decrease in the short- circuit current Isc, which in turn affects solar radiation levels. Normally, Isc and the light-generating current (IL) are exactly proportionate. When compared to other forms of water that were used, seawater produced less power. Isc is depicted in relation to water depth for each of the four types of water in Fig. 10. 10 displays Isc in relation to the water's depth for each of the four types of water. Because TDS and other contaminants further reduce sun radiation underwater, it has been discovered that Isc is lower in seawater than in other types of water.

Every experiment has been run three times, and the average has been replicated. For each of the four types of water, the average Pmax values are displayed in relation to the water's depth in Figure 11. Pmax has also been shown with a distance variation of up to 30 cm in the ambient environment (without water). Initially, a photodetector calibrates the radiation at the solar cell's surface to 1000 W/m2. The radiation is dropping as a result of changing the distance, which lowers the solar cell's power production. It has been noted that the salinity of the water also affects the Pmax of Gallium arsenide solar cells, in addition to solar radiation. An improved understanding of the underwater Gallium arsenide solar cell was provided by this experimental analysis. It has been discovered that, in addition to solar radiation, salt and other impurities also have an impact on how well solar cells function underwater.

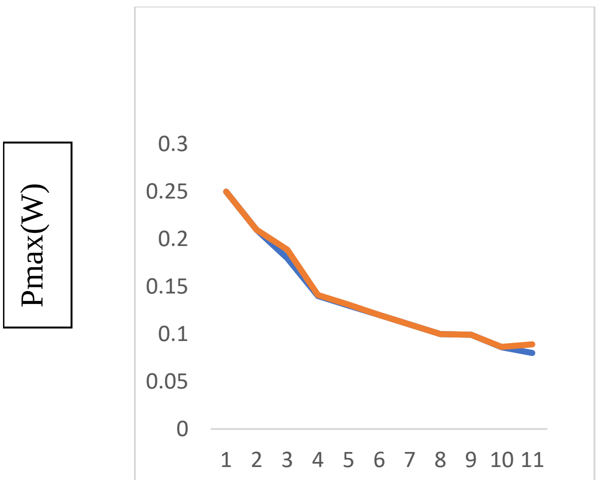


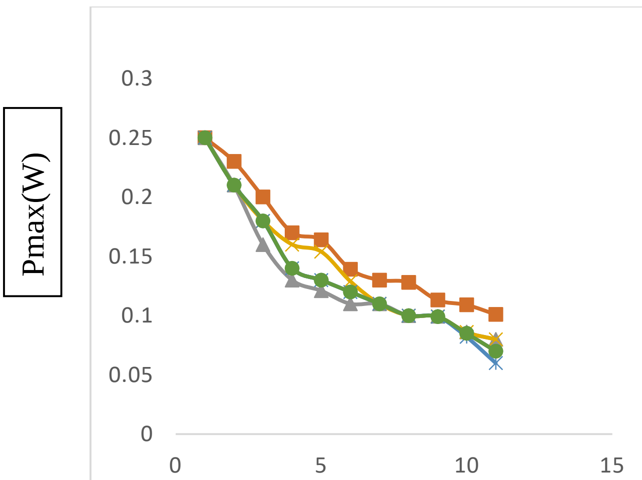
Voltage(V) Voltage(V)

Real sea water ———— Real Sea water ————

Artificial sea water --------------- Artificial Sea water ---------------

Figure 8: Features of solar cells made using actual sea water as well as synthetic sea water at various depths (a) I -V cures (b) P -V curves





Depth(cm) Depth(cm)

Figure 9. Variation of P max at different depths. Figure 11. Comparision of P max with different types of Water

Artificial sea water

Real sea water

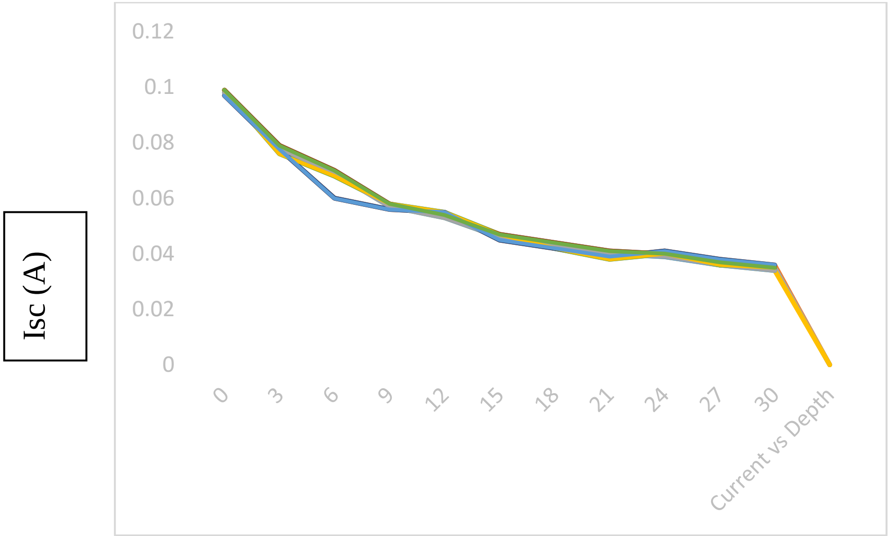
Ambient condition

DI water

Normal water

Artificial sea water

Sea water



Depth(cm)

Figure 10. Comparision of Isc with different types of water

DI water

Normal water

Artificial sea water

Sea water

IV. CONCLUSION

In conclusion, the research displayed in this paper report offers insightful information about the Performance of submerged gallium arsenide photovoltaic cells under varying water conditions. The practical model employed in the study effectively captured the variations in solar irradiance at different water depths, allowing for a comprehensive analysis of the solar cell's performance.

The experimental results demonstrated that the output power and efficiency among the solar cells are influenced by the type of water and the depth at which the cells are submerged. Specifically, the power output was found to be highest in deionized water, followed by artificial seawater, normal water, and seawater, in descending order. This hierarchy is attributed to the varying levels of transparency and the presence of impurities in the different water types.

One of the significant findings of this research is that the encapsulation of the gallium arsenide solar cells proved to be effective in all tested water types, including natural seawater with a salinity of 3.2% and various contaminants. This highlights the potential of encapsulated gallium arsenide solar photovoltaic cells for underwater applications, offering a promising avenue for harnessing solar energy in marine environments.

Overall, this research advances our knowledge of the behavior of photovoltaic cells in underwater settings and underscores the importance of considering water conditions in the design and deployment of submerged solar energy systems. Further research in this area could explore the long-term durability of encapsulated solar cells in seawater and the optimization of their performance for specific marine applications.

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