# Investigating the Impact of Humidity on the Electrical Performance of Floating Photovoltaic Systems

Andiso Pingilili
*Electrical & Electronic Engineering Technology*
*Eng. Faculty, University of Johannesburg*
Johannesburg, South Africa
Africa219070894@student.uj.ac.za

Ahmed Ali
*Electrical & Electronic Engineering Technology*
*University of Johannesburg*
Johannesburg, South Africa
aali@uj.ac.za

***Abstract*— Context:** Floating photovoltaic (FPV) systems offer a viable solution to land constraints, but their performance is sensitive to environmental conditions. **Problem:** Humidity is particularly critical because water vapor can absorb and scatter incoming solar radiation, reducing irradiance at the module surface and decreasing energy output. **Method:** To experimentally quantify the impact of elevated humidity on FPV electrical performance and determine the extent to which humidity-driven irradiance loss affects power generation**.** An experimental setup using two identical monocrystalline PV panels was deployed. The control panel operated under natural ambient conditions, while the test panel was enclosed with an ultrasonic humidifier to simulate a high-humidity aquatic microenvironment. Electrical and environmental parameters were monitored in real time via a sensor network integrated with a microcontroller and Raspberry Pi. Regression and analysis of variance were used to assess humidity's effect on power output**. Results:** Humidity exhibited an inverse relationship with FPV performance. Regression analysis showed that each 1% increase in relative humidity reduced power output by 16.18 mW. The primary mechanism was identified as the absorption and scattering solar irradiance by humid air, diminishing the optical energy reaching the photovoltaic cells. **Impact:** High humidity imposes a measurable efficiency penalty on FPV systems by limiting irradiance availability. These findings highlight the interactions between variables, where humidity, which is caused by evaporation, adversely affects irradiance levels while indirectly raising PV cell temperature by lowering ambient. These insights are effective for FPV design optimization and site selection in humid regions and support more resilient deployment strategies within sustainable energy infrastructure.

**Keywords:** *Floating Photovoltaic Systems, Humidity, Solar Irradiance, Ambient Temperature, Electrical Performance, Power Output, Efficiency*

## I. Introduction

The increasing energy demand in South Africa, driven by population density and economic growth, has placed immense pressure on the country's existing energy infrastructure, prompting an urgent need to explore sustainable and efficient alternatives. As the country continues to experience rapid industrialization and urbanization, energy consumption is rising faster than supply capacity, leading to power shortages and overreliance on fossil fuels [6]. This has motivated national efforts to diversify the energy mix through renewable energy sources, with solar energy emerging as one of the most promising options due to South Africa's high solar irradiance levels and vast potential for photovoltaic (PV) deployment. Photovoltaic systems have become increasingly prevalent, offering clean, reliable, and scalable power generation [4,6]. However, as land availability becomes increasingly limited and conventional ground-mounted PV systems often experience efficiency losses caused by high operating temperatures, floating photovoltaic (FPV) systems have emerged as a promising alternative. Floating photovoltaic systems consist of solar panels mounted on buoyant structures that allow them to be installed on water bodies such as reservoirs, lakes, and dams, where the floating platforms provide stable support on the water surface. These systems not only conserve valuable land resources but also benefit from the natural cooling effect of water, which helps maintain lower operating temperatures and potentially enhances electrical performance [1].

Countries with abundant solar radiation and accessible water surfaces have shown growing interest in FPV technology, recognizing its potential to contribute significantly to clean energy generation [2]. The performance of FPV systems, however, is influenced by environmental and climatic factors such as temperature, humidity, and ultraviolet radiation. Among these, humidity plays a particularly complex role in determining system efficiency. It affects solar insolation, module temperature, and the optical properties of the photovoltaic surface. While moderate humidity levels may support cooling and reduce thermal stress, prolonged exposure to high humidity can lead to condensation, moisture ingress, and corrosion of module components, ultimately reducing output power and system reliability [1]. Recent studies have reported that FPV systems tend to achieve higher efficiency compared to land-based installations due to water-induced cooling and lower temperature fluctuations [1-3]. Nevertheless, limited research has focused on quantifying the specific influence of humidity on FPV electrical performance, especially in climates where relative humidity fluctuates significantly. Understanding this relationship is crucial for optimizing FPV design, selecting suitable materials, and improving system durability under varying environmental conditions.

This study therefore aims to investigate the impact of humidity on the electrical performance of floating photovoltaic systems. It focuses on how humidity levels affect irradiance absorption, temperature regulation, and overall

energy output. The study follows an experimental comparative approach with strong emphasis on real-time data acquisition and controlled variable testing. This approach is suitable because it allows for direct observation and isolation of humidity effects on electrical performance parameters. By analyzing these interactions, the research seeks to provide insights that will contribute to the design and operation of more efficient and resilient FPV systems.

## II. Literature Review

This literature review provides a foundational context for the experimental investigation by examining the current body of knowledge on Floating Photovoltaic (FPV) systems, with a specific focus on the role of climatic parameters. It explores the evolution and advantages of FPV technology, establishes the fundamental principles of humidity and its interaction with solar irradiance, and synthesizes existing research on how these environmental factors influence electrical performance. The review also highlights identified challenges, thereby framing the research gap this study aims to address regarding the quantified impact of humidity on FPV system efficiency.

### A. Floating Photovoltaic Systems

The first floating photovoltaic (FPV) system was installed in Japan in 2013, followed by installations in other Asian countries. Since then, the global installed capacity of FPV power plants has grown significantly, increasing from just 100 MW in 2016 to over 3 GW in 2021 [8]. During installation, solar panels are mounted on buoyant platforms made from ultraviolet-resistant, recyclable, and corrosion-resistant materials such as high-density polyethylene (HDPE), which can support up to two and a half times their own weight. These structures are anchored to the submerged ground to maintain system stability and prevent overturning. FPV systems are often assembled onshore and subsequently transferred onto the water surface.

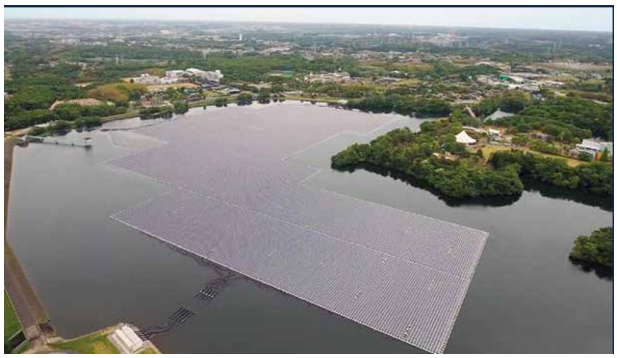

*Figure 1 Japan's Yamakura plant is made up of almost 60,000 solar panels [8]*

FPV technology offers several advantages over land-based systems, enhancing operational efficiency [7]. The water surface provides evaporative cooling, reducing panel temperatures, and increasing energy output. Panels experience less soiling due to lower dust accumulation, minimizing maintenance. FPV systems can also be integrated with hydropower, compensating for reduced hydro generation during dry seasons with higher solar output. Additionally, flat installation areas and minimal nearby obstructions reduce shading, further improving energy performance.

### B. Fundamentals of Humidity and Other Climatic Parameters

Humidity refers to the amount of water vapor present in the air and is classified into three primary categories: absolute, specific, and relative humidity. Absolute humidity quantifies the actual mass of water vapor per unit volume of air, expressed in grams per cubic meter ($g/m^3$). It remains constant unless the air parcel volume changes. Specific humidity measures the mass of water vapor per unit of mass of moist air, making it particularly valuable for engineering and meteorological calculations since it is independent of temperature and pressure variations. Relative humidity, expressed as a percentage, represents the ratio of the current water vapor content to the maximum possible temperature [9–11].

In tropical and humid regions, the high presence of surface water contributes to elevated humidity levels through continuous evaporation. This abundance of atmospheric moisture influences how incoming solar radiation is absorbed and scattered, thereby affecting the performance of floating photovoltaic (FPV) systems. A portion of solar energy is absorbed or reflected by atmospheric constituents such as clouds, gases, and aerosols before reaching the Earth's surface. High humidity exacerbates this effect, as water vapor absorbs portions of the solar spectrum, particularly in the infrared range, while increased haze scattering reduces the amount of usable irradiance reaching photovoltaic modules. Consequently, FPV systems operating in humid environments may experience reduced efficiency [9-11].

Relative humidity interacts with other climatic parameters such as evaporation rate, wind velocity, ambient temperature, and solar intensity [9–11]. These variables can be quantified using a correlation coefficient (R), which measures the strength and direction of their linear association. An |R| value approaching 1 indicates a strong correlation, while values near 0 suggest weak or negligible dependence [11]. Understanding these interrelationships is essential for assessing how humidity collectively influences FPV electrical performance under varying environmental conditions.

### C. Solar Irradiance

Solar irradiance is the total radiant power emitted by the sun that falls on a given unit area, typically measured in Watts per square meter ($W/m^2$). It represents the energy input that photovoltaic (PV) modules convert into electricity, making it one of the most critical climatic parameters for solar energy generation [5]. Humidity directly influences solar irradiance by affecting how sunlight is absorbed, reflected, and scattered as it passes through the atmosphere. Solar radiation undergoes various interactions, including reflection, refraction, scattering, and diffraction, which depend on the properties of the medium, such as the presence of molecules, aerosols, water vapor, and variations in air density. Solar irradiance incidents on a PV module can be divided into three components: direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), and global horizontal irradiance (GHI). DNI is the most intense component and is primarily captured by panels equipped with tracking systems. DHI results from sunlight scattered by clouds and atmospheric particles, while GHI represents the total solar radiation received on a horizontal surface [1,5].

In floating photovoltaic environments, clouds, particularly low, thick clouds, can significantly reduce direct irradiance. The water surface beneath FPV systems can also reflect

sunlight, sometimes enhancing irradiance depending on surface conditions and the angle of incidence. Refraction, which bends light as it passes through layers of varying atmospheric density, slightly affects the apparent position of the sun and consequently the angle of incoming light, especially near sunrise and sunset. Scattering caused by interactions with water vapor, aerosols, and clouds redistributes solar radiation in multiple directions, contributing to diffuse irradiance, which is particularly important in humid conditions where direct sunlight is often diminished. Diffraction, although less influential on energy yield, contributes to the complexity of light behavior in the atmosphere [7,10].

Water vapor absorbs specific wavelengths of solar radiation, particularly in the infrared spectrum, leading to attenuation of the incoming energy. High humidity therefore reduces the solar irradiance received by floating photovoltaic modules and introduces non-linear variations in irradiance. These variations directly impact the electrical output, affecting current, voltage, and power generation [10].

### *D. Ambient and Module Temperature*

While solar radiation determines the energy input to a photovoltaic (PV) system, ambient temperature strongly influences the operating temperature of PV cells, which directly affects their efficiency. In silicon-based modules, efficiency generally decreases as operating temperature rises; a relationship quantified by the module temperature coefficient. Elevated module temperatures reduce the open-circuit voltage and slightly increase the short-circuit current, resulting in an overall decline in power output [8,12].

In floating photovoltaic (FPV) systems, ambient temperature interacts uniquely with the water environment. One well-documented advantage of FPV installations is the cooling effect provided by the underlying water body. The high thermal mass of water, combined with convective heat transfer from the underside of the modules, typically lowers operating temperatures compared to similarly configured land-based systems. This water-induced cooling can enhance energy yield, partially mitigating the efficiency losses associated with high ambient temperatures [8,12].

### *E. Module Electric Performance and Measurement*

The primary metric for evaluating the performance of floating photovoltaic (FPV) systems is the consistent measurement of their electrical output. The module's ability to convert sunlight into electricity is influenced by multiple environmental factors, including humidity, solar irradiance, and ambient temperature, which interact synergistically rather than independently. Previous studies have consistently demonstrated a strong relationship between humidity and key electrical outputs, with the humidity coefficient of determination ($R^2$) indicating a significant influence on module current, voltage, and power [1,12]. The coefficient of determination quantifies the proportion of variation in the dependent variable that can be explained by the variation in the independent variable within a regression model.

### *F. Challenges and Limitations of Floating Photovoltaioc Systems*

The primary challenges and limitations of Floating Photovoltaic (FPV) systems revolve around design integrity, operational reliability in harsh environments, economic uncertainties, and environmental impact. From a technical perspective, FPV systems face challenges in ensuring structural integrity against heavy wind gusts, which necessitates robust mooring and anchoring systems, particularly in offshore installations where rough conditions like waves and high winds increase the overall load and risk of damage [5].

The electrical performance and reliability in the harsh, high-humidity aquatic environment is also a concern, with debate existing on whether this accelerates module degradation. The systems are prone to certain forms of dust accumulation, such as bird droppings, due to the moisture. Economically, the cost of implementing such systems is a significant barrier. Many suitable water bodies are far from urban centers, increasing the cost of grid connection. South Africa's grid limitations in some rural areas can constrain the integration of FPV systems unless combined with energy storage solutions [3,6].

Environmental and ecological concerns pose a significant limitation, as the reduction in sunlight penetration caused by FPV arrays can negatively impact the water body's ecosystem and biodiversity, potentially affect the survival of aquatic life and hinder photosynthesis.

## III. METHOD

In this work, a systematic methodology involving literature review, data collection, experimental design, and system testing was employed to provide a rigorous analysis. A detailed survey of studies relevant to floating photovoltaic systems, with a specific focus on humidity effects, was conducted. The studies encompassed fundamental aspects such as an introduction to floating photovoltaic technology, essential components, and system planning and design. Relevant data on FPV system components, operational parameters, and environmental conditions were gathered from published studies and manufacturer specifications. This informed the design and operation of the experimental system. The FPV system was built using the identified components. Careful attention was given to materials, buoyant structure selection, and module placement to ensure stability and optimal performance under varying humidity conditions. The constructed system was tested under controlled environmental conditions to measure key electrical parameters, including current, voltage, and power output. Observations focused on how variations in humidity affect system performance, and the measured results were analyzed. Figure 2 shows the systematic workflow adopted in this study.

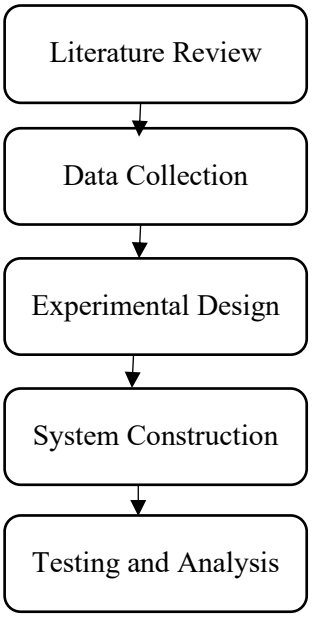


*Figure 2 Systematic Workflow Adopted in Study*

The performance of a photovoltaic (PV) system is determined by its capability to convert solar energy into electrical energy over a given period, relative to the system's rated power output. A summary of the experimental setup designed and deployed to analyze the effects of humidity on the electrical performance of the floating photovoltaic (FPV) system is presented in the following subsections:

### *A. Experimental Setup*

The experiment was conducted using two identical floating photovoltaic testbeds: a control setup exposed to natural environmental conditions, and a test setup subjected to artificially elevated humidity levels. While humidity was treated as the primary variable of interest, other environmental factors such as irradiance, temperature, and wind speed were not controlled but continuously monitored throughout the experiment to account for their potential influence on system performance.

### *B. System Design*

Each testbed consisted of a 10 W monocrystalline solar panel mounted on a custom buoyancy platform constructed from high-density Styrofoam, which was waterproofed to prevent water absorption and ensure long-term stability during testing. The platforms were placed on static bodies of water contained within transparent plastic tubs, simulating the operational environment of floating photovoltaic (FPV) systems. Both the control and test systems operate under natural outdoor conditions. To increase the humidity level around the test panel without introducing shading effects, an ultrasonic humidifier was placed inside the container near the test setup. This arrangement allowed the test environment to achieve elevated relative humidity levels while maintaining equal exposure to solar irradiance and ambient temperature. The two systems were positioned adjacent to each other to ensure similar environmental exposure and facilitate direct performance comparison. The figures show the setup for the experiment.



*Figure 3 Three -panel setup*



*Figure 4 Control and Test Panel*

### *C. Sensor Integration and Data Acquisition*

Data acquisition was achieved using a network of calibrated sensors interfaced with an Arduino Mega microcontroller and a Raspberry Pi 4 microcomputer. The Arduino Mega served as the primary data collection hub, acquiring readings from multiple sensors measuring voltage, current, humidity, temperature, and irradiance. These readings were transmitted in real time to Raspberry Pi 4 via the Arduino USB cable, which provides a serial communication interface. The Raspberry Pi received the incoming data stream, parsed it into individual sensor measurements, and logged it for analysis. This setup allowed continuous monitoring and storage of environmental and electrical parameters, leveraging the Arduino for sensor interfacing and the Raspberry Pi for data management, processing, and storage. The following sensors were used:

- **INA219** sensors to measure voltage, current, and power output,
- **DHT22** sensors to monitor ambient humidity and panel temperature, and
- **DS18B20** waterproof sensors to record water temperature.

A third monocrystalline reference panel, calibrated under standard test conditions (STC) in compliance with IEC 60904-2 and IEC 60904-4, was installed in the same plane as the

array to serve as an irradiance reference. The reference panel's output current, measured across a small 27 Ω resistive load, was used as an approximation of short-circuit current. Since the current is directly proportional to the incident irradiance within the panel's linear response range, it was converted to irradiance (W/m²). This relationship is described by:

Reference panel:

Isc = 1.1A

Iref = continuously measured

Relative irradiance:

$$G_{rel} = \frac{I_{ref}}{I_{sc}} \times 100 \quad (1)$$

Control panel with operating load:

$$P_{cont_raw} = V_{control} \times I_{control} \quad (2)$$

Test panel with operation load:

$$P_{test_raw} = V_{test} \times I_{test} \quad (3)$$

Normalize control and test power:

$$P_{cont_n} = \frac{P_{cont_raw}}{G_{rel}} \quad (4)$$

$$P_{test_n} = \frac{P_{test_raw}}{G_{rel}} \quad (5)$$

The normalized power reveals the true gap performance:

$$P_{raw} = P_{cont_raw} - P_{test_raw} \quad (6)$$

$$P_{loss_n} = P_{cont_n} - P_{test_n} \quad (7)$$

Drop in power due to humidity:

$$\%loss = \frac{P_{loss_n}}{P_{control_n}} \times 100 \quad (8)$$

The Raspberry Pi received and timestamped the data transmitted by the Arduino Mega and subsequently uploaded it to the ThingSpeak IoT cloud for visualization and analysis.

### D. Testing Procedure

Both systems were initialized simultaneously, with water levels and load conditions kept identical. Once the target humidity within the test enclosure was stabilized, continuous data logging was performed at 30-second intervals during a 3-hour period each day. Measurements included voltage, current, power output, humidity, ambient temperature, and solar irradiance. All data were retained for analysis regardless of irradiance level, allowing assessment of how variations in humidity influence power output across naturally fluctuating sunlight and temperature conditions. This approach enabled evaluation of the interactions between humidity, irradiance, and temperature, providing a realistic understanding of FPV system performance in high-humidity environments.

## IV. Results and Discussion

This section presents the experimental results analyzing the impact of humidity on the electrical performance of the floating photovoltaic (FPV) system. The analysis is structured to first establish the direct relationship between humidity and power output, and then to investigate the interacting roles of solar irradiance and ambient temperature. The experimental results obtained over a four-day data collection period. To ensure data stability and mitigate the confounding variable of fluctuating irradiance, measurements were conducted during two-hour windows on days characterized by consistently gloomy weather and low, diffuse solar irradiance. Graphical representations and statistical regression models are used to quantify these effects. In the regression analysis, the independent variable were humidity (x1), irradiance level (x2), and ambient temperature (x3) and the dependent variable was power output (y), with A representing the coefficient of each independent parameter. The result is as follows:

$$y = A_0 + A_1x1 + A_2x2 + A_33 \quad (9)$$

### A. Direct Impact of Humidity on FPV Power Output

To isolate and quantify the primary effect of humidity on system performance, the normalized power output of both the control and test panels was plotted against relative humidity. The figures present the scatter plots and corresponding linear regressions for this relationship. The analysis reveals a distinct inverse correlation, demonstrating that increased humidity directly leads to a reduction in generated power. The steeper negative slope of the regression line for the test panel under artificially elevated humidity conditions provides clear, quantitative evidence of this performance degradation.

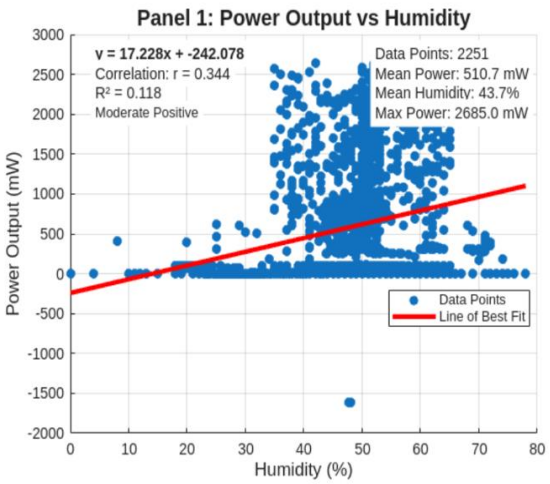


*Figure 5 Power Output vs Relative Humidity Trend for Control Panel*

Figure 4 for the control panel reveals a weak positive correlation between humidity and power output. The low R-squared value of 0.118 indicates that only 11.8% of the changes in power can be attributed to humidity, meaning the relationship is not strong. The slight upward trend suggested by the trendline is a correlation caused by the prevailing low-light conditions. On an overcast day, the primary factor governing power output is the transient and diffuse solar irradiance breaking through the clouds, not humidity. The observed pattern is therefore an artifact of the weather, where minor fluctuations in light correlated with humidity levels, rather than demonstrating a true causal effect. For Panel 1 operating under natural, ambient humidity, the data shows no significant evidence of humidity-induced performance loss under these specific gloomy conditions.

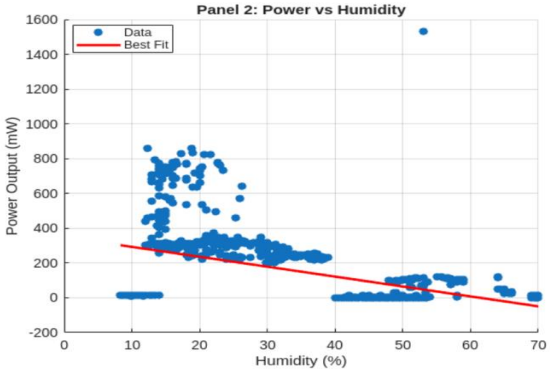


*Figure 6 Power Output vs Relative Humidity Trend for Test Panel*

Figure 5 for the test panel demonstrates a clear and strong negative correlation between humidity and power output. The distinct downward slope of the trendline shows that as humidity increased, the panel's power output consistently decreased. This relationship is visually much stronger and more defined than in control panel. With overall irradiance low and stable, the experimental variable of artificially elevated humidity becomes the dominant differentiating factor affecting performance. The results confirm that in a high-humidity microenvironment, the moisture-laden air further scatters and absorbs the already limited available light, leading to a measurable and significant reduction in electrical power generation compared to the control panel.

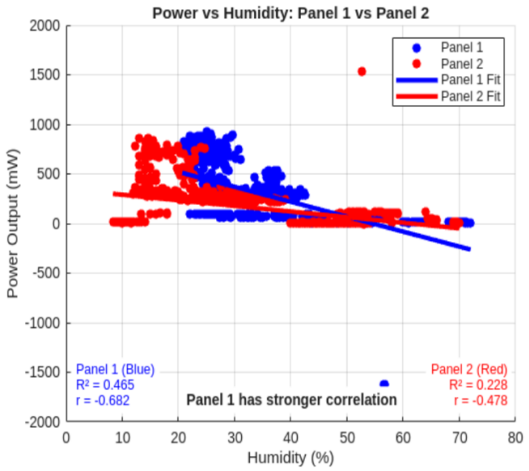


*Figure 7 Combined Power Output vs Relative Humidity Combined Trend*

Figure 6 presents the combined visual of how the two solar panels performed under identical weather conditions, with humidity as the differentiating factor. A consistent performance gap between the two panels was observed. The control panel (panel 1**)** maintains a significantly higher power output across the entire data range compared to the test panel (panel 2). This persistent gap strongly indicates the presence of a constant, negative influence on the test panel's performance. The graph successfully demonstrates the core hypothesis. The test panel consistently underperformed compared to the control panel. The humid air in the test enclosure scatters and absorbs more of the incoming solar radiation, reducing the amount of light that reaches the panel's surface for conversion into electricity. This effect is clearly visible as a sustained power deficit throughout the data collection period.

### *B. Interaction Effects: Ambient Temperature and Humidity*

A statistical analysis was conducted to examine how ambient temperature and humidity interact when assessing humidity's effects on the environment. It is important to recognize that these variables function as inherent elements of the broader environmental system.

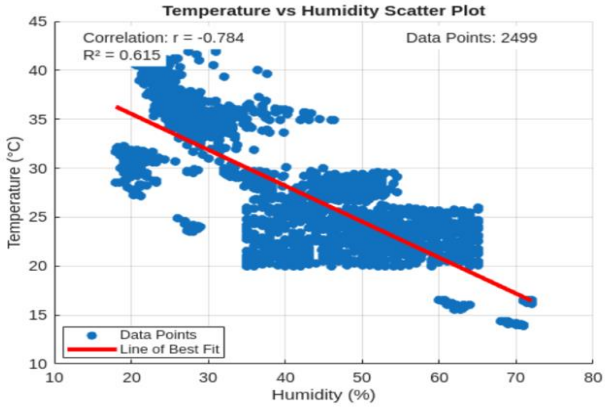


*Figure 8 Ambient Temperature vs Relative Humidity Trend for Control Panel*

Figure 7 presents the relationship between ambient temperature and relative humidity. This graph shows a strong

negative correlation, with a high correlation coefficient r of -0.784 and an $R^2$ value of 0.615. This is the expected natural relationship for the control panel in an open, ambient environment. As air temperature rises, its capacity to hold water vapor increases, causing the relative humidity to drop. This inverse relationship is a fundamental meteorological principle.

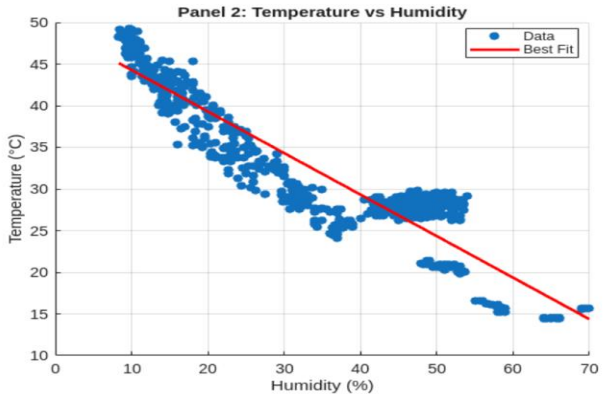


*Figure 9 Ambient Temperature vs Relative Humidity Trend for Test Panel*

Figure 8 presents the relationship between temperature and humidity for the test panel. In contrast, the graph shows no clear correlation between temperature and humidity. The data points are scattered without a definitive trend, and the best-fit line is nearly flat. This is the expected result for the test panel inside its artificially humidified enclosure. The ultrasonic humidifier actively pumps moisture into the air, decoupling the natural relationship between temperature and humidity. The humidity level is now a controlled independent variable, maintained at a high level regardless of temperature fluctuations. This is crucial success of the experimental design, as it confirms that the test panel was isolated in a consistently high-humidity microenvironment.

### C. *Interaction Effects: Reference Panel Circuit Current and Humidity*

To directly quantify the efficiency penalty caused by humid conditions, the normalized power loss of the panels is plotted against the relative humidity. This relationship is shown, and it isolates the specific impact of humidity, revealing the correlation between increased atmospheric moisture and declining photovoltaic performance.

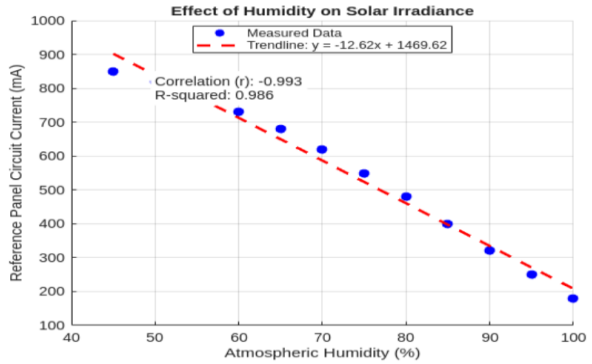


*Figure 10 Reference Circuit Current vs Atmospheric Humidity Trend*

Figure 9 graph presents a clear relationship between atmospheric humidity and solar irradiance, as measured by the reference panel's circuit current. The results a strong negative correlation, with a correlation coefficient r of -0.993 and an $R^2$ value of 0.986. This indicates an inverse linear relationship, where 98.6% of the variation in the available solar energy can be explained solely by changes in humidity. The trendline equation, y = -12.62x + 1469.62, quantifies this impact, for every 1% increase in atmospheric humidity, the incident solar irradiance decreases, causing a 12.62 mA drop in the circuit current of the reference panel.

This graph is critical as it reveals the fundamental physical mechanism behind the power loss observed in the main experiment. It demonstrates that elevated humidity does not merely affect the solar panel's electrical efficiency but directly and significantly reduces the primary energy input, the solar irradiance itself. The moisture-laden air scatters and absorbs sunlight, diminishing the amount of light that ultimately reaches the photovoltaic surface. The near-perfect linearity of the data confirms a consistent and predictable relationship.

### D. *Analysis of Regression Results*

Conducting the regression analysis was fundamentally important as it transformed qualitative observations into quantitative, actionable engineering insights. While visual graphs suggest a relationship between humidity and performance of the photovoltaic system, the regression analysis provided the mathematical rigor to isolate and quantify this effect amidst other simultaneously changing environmental variables like irradiance and ambient temperature. For this study, it specifically enabled a shift from observing that the test panel performed poorly in the humid condition to precisely determining that for every 1% increase in relative humidity, the panel loses 16.18 mW of power. This analysis isolated humidity's specific effect, separating it from the dominant influence of fluctuating sunlight and temperature. The resulting regression equation translates the experimental findings into a practical predictive model and derating factor.

Control panel:

$$y = 1.976 + 0.08x1 + 0.66x2 + 0.06x3 \quad (10)$$

The coefficient regression values, from the result of the regression study equation 10, are as follows: 0.08 for humidity, 0.66 for irradiance level, and 0.06 for ambient temperature. The coefficients reveal the dominant role of irradiance, with a logically positive relationship showing that power increases by 0.657 mW for every unit increase in irradiance, confirming it as the primary driver of energy production. The humidity coefficient is small and positive, a magnitude too small to hold physical significance and therefore attributable to statistical noise. Under normal atmospheric conditions, ambient humidity variations do not exert a meaningful direct influence on electrical performance. The small positive temperature can be attributed to the natural correlation between rising irradiance and rising temperature during the day, and to the cooling effect of the floating setup.

This equation reveals that the panel's performance was governed by solar irradiance ($x_2$), with its substantial coefficient of 0.66 confirming the expected strong positive relationship where sunlight is the primary driver of power

generation. The near-zero coefficient for humidity ($x_1$) at 0.08 indicates that ambient humidity fluctuations in natural environments have no practically significant impact on electrical output, effectively establishing that humidity is not a performance-limiting factor under typical operating conditions.

Test panel:

$$y = 1293.77 - 16.18x1 + 11.21x2 - 28.82x3 \quad (11)$$

The coefficient regression values, from the result of the regression study equation 11, are as follows: -16.18 for humidity, 11.21 for irradiance level, and -28.82 for ambient temperature. The strong negative humidity coefficient of -16.18, which quantifies the core phenomenon under investigation; for every 1% increase in relative humidity, the panel loses 16.18 mW of power. The substantial negative temperature coefficient of -28.82 highlights the expected decrease in PV efficiency with rising temperature, while the positive irradiance coefficient of 11.24 affirms that available sunlight remains a key driver of power. The model's $R^2$ value of 0.427 indicates that these three environmental factors explain 42.7% of the performance variance.

The comparative regression analysis of the control and test panels provides evidence for how humidity directly impacts the electrical performance of floating photovoltaic (FPV) systems. The contrast between the near-zero humidity coefficient of the control panel (+0.08) operating in ambient conditions and the substantial negative coefficient of the test panel (-16.18) subjected to a high-humid microenvironment demonstrates that the unique microclimate over water bodies induces a measurable power loss. It is also evident that the most influential factor affecting the variation in output power is the irradiance level.

## V. Conclusion

This study investigated the impact of humidity on the electrical performance of floating photovoltaic (FPV) systems through a controlled experimental approach focusing on static body of water contained in a large transparent tub (57 x 40 x 23 ) cm placed outdoors. The results demonstrate a negative correlation between elevated humidity levels and FPV power output. While the control panel operating under natural ambient conditions showed no significant performance loss due to humidity variations, the test panel subjected to an artificially high-humidity microenvironment exhibited a consistent and measurable power reduction.

The regression analysis provided quantitative insights, revealing that for every 1% increase in relative humidity, the FPV panel lost 16.18 mW of power. This performance degradation was primarily attributed to the fundamental physical mechanism whereby moisture-laden air scatters and absorbs incoming solar irradiance, thereby reducing the primary energy input to the photovoltaic modules. The strong negative correlation ($R^2 = 0.986$) between humidity and the reference panel's circuit current confirmed that humidity directly diminishes the amount of solar radiation reaching the panel surface.

These findings underscore the importance of considering local microclimatic conditions, particularly humidity, in the design, site selection, and performance prediction of FPV systems. In regions prone to high humidity, the potential efficiency penalty must be accounted for to ensure energy yield forecasts and optimal system resilience. Future work should focus on long-term studies to assess material degradation in high-humidity environments and explore mitigation strategies, such as advanced module coatings or optimized system designs, to enhance the performance and durability of FPV technology in diverse climatic conditions.

## References


[1] R Hendarti, J Linggarjati, J. Kurnia, and A. Hanan, “Influence of humidity on the performance of floating photovoltaic systems over ponds in a tropical urban environment,” IOP Conference Series Earth and Environmental Science, vol. 1375, no. 1, pp. 012015–012015, Jul. 2024, doi: https://doi.org/10.1088/1755-1315/1375/1/012015.

[2] C. Ma, R. Wu, Z. Liu, and X. Li, “Performance assessment of different photovoltaic module technologies in floating photovoltaic power plants under waters environment,” Renewable Energy, vol. 222, p. 119890, Feb. 2024, doi: https://doi.org/10.1016/j.renene.2023.119890.

[3] S. Kofi et al., “Comparative performance evaluation of ground-mounted and floating solar PV systems,” Energy for Sustainable Development, vol. 80, pp. 101421–101421, Jun. 2024, doi: https://doi.org/10.1016/j.esd.2024.101421.

[4] J. Tauschinski and K. Bryan, “Climate change drives surge in global energy demand,” @FinancialTimes, Mar. 24, 2025. https://www.ft.com/content/4d4f2770-3c95-4390-b4fc-896c92505672

[5] G. M. Tina and F. Bontempo Scavo, “Energy performance analysis of tracking floating photovoltaic systems,” Heliyon, vol. 8, no. 8, p. e10088, Aug. 2022, doi: https://doi.org/10.1016/j.heliyon.2022.e10088.

[6] R. C.j., K. H. Lim, J. C. Kurnia, S. Roy, B. J. Bora, and B. J. Medhi, “Towards sustainable power generation: Recent advancements in floating photovoltaic technologies,” Renewable and Sustainable Energy Reviews, vol. 194, p. 114322, Apr. 2024, doi: https://doi.org/10.1016/j.rser.2024.114322.

[7] H. Liu, V. Krishna, J. Lun Leung, T. Reindl, and L. Zhao, “Field experience and performance analysis of floating PV technologies in the tropics,” Progress in Photovoltaics: Research and Applications, vol. 26, no. 12, pp. 957–967, Jun. 2018, doi: https://doi.org/10.1002/pip.3039.

[8 ]N. M. Naushad, G. R. Rimon, and M. R. Khan, “Local temperature and humidity aware prediction of degradation, lifetime, and long-term yield of mono- and bifacial floating photovoltaic systems,” Solar Energy, vol. 299, p. 113639, Jun. 2025, doi: https://doi.org/10.1016/j.solener.2025.113639.

[9] D. Bett, “What is humidity and why does it make us feel so uncomfortable?,” BBC Weather, Jun. 11, 2025. https://www.bbc.com/weather/articles/c3rper1zqlro

[10] A. Peci et al., “Effects of Absolute Humidity, Relative Humidity, Temperature, and Wind Speed on Influenza Activity in Toronto, Ontario, Canada,” Applied and Environmental Microbiology, vol. 85, no. 6, Mar. 2019, doi: https://doi.org/10.1128/aem.02426-18.

[11] H. A. Kazem and M.T. Chaichan, “Effect of humidity on photovoltaic performance based on experimental study,” vol. 10, no. 23, pp. 43572–43577, Dec. 2015, Available: https://www.researchgate.net/publication/289546072_Effect_of_humidity_on_photovoltaic_performance_based_on_experimental_study

[12] C. Hong, Z. Qu, W. Xu, and Z. Gu, “Study on water cooling island effects under different climatic conditions,” City and Built Environment, vol. 1, no. 1, Feb. 2023, doi: https://doi.org/10.1007/s44213-022-00004-7.G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*