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Research Article

Design and Realization of a Mini Station for Measuring Solar Irradiation, Temperature and Humidity at the Higher Institute of Technology (IST) Mamou

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Abstract

In this work, we designed, built and tested a mini station for measuring solar irradiation, temperature and air humidity at the Higher Institute of Technology (IST), Mamou. For this purpose, we designed a device far from any shading, consisting a 2m in three-piece of mast topped by a squaresh tube bar to which the pyranometer, temperature and humidity sensor are attached, a metal box serving as a shelter for the irradiation and temperature dataloggers, the photovoltaic system equipment and a 20Wp solar panel to supply the system with energy. A grounding device protected the entire system. After parameterization and direct measurements during the test period from August 12 to 20, 2024, seven hundred and forty-two (742) lines of data were recorded and plotted for analysis. The following results were obtained: A coverage rate of 100% and around 75h of sunshine. However, the days 13, 14, 16, 19 and 20 were very sunny, with a maximum value of 1224W/m ², a minimum of 1W/m ² and an average of 142W/m ². Minimum and maximum temperatures were 18 ℃ and 31.7 ℃ respectively, with an average of 11.17 ℃. For humidity, the maximum (99.9%) was recorded almost every morning and evening during the same period, the minimum 7.4% (August 15 at 3:48 P.M) with an average of 95.34%.

Keywords

Mini Station, Pyranometer, Datalogger, Solar Irradiation, Humidity, Temperature

1. Introduction

Over the last few decades, the need to observe and control atmospheric parameters such as solar radiation, temperature, humidity and pressure has become essential for many applications; in particular, energy systems are subject to meteorological conditions, and their dimensioning and optimization necessarily depend on these conditions. The values of these parameters are generated by weather stations, which can be described as instruments or devices made up of a set of sensors that provide information about our environment, such as temperature, solar radiation, humidity, wind speed and direction, etc. [1]. There are several types of sensors available, with which all the above-mentioned quantities can be measured.

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They can be used to display values for temperature, humidity, atmospheric pressure and radiation in a specific room/place [2]. Existing meteorological monitoring systems are usually large mechanical machines requiring maintenance, physical inspection and regular updating. Energy requirements are a major constraint for these devices in remote areas [3].

In the Republic of Guinea, the measurement of environmental parameters is often the responsibility of meteorological services. Most of these services are equipped with conventional stations, which are no longer up to the task in view of increased requirements for data accuracy and more frequent observations. With a surface area of 245,000 km², Guinea has a varied meteorological network: 45 conventional stations, 12 synoptic stations, 24 climatological stations, 7 agro-meteorological stations, 1 maritime station, reinforced by 4 automatic stations for specific needs, including the one at Conakry airport, installed in 2004 [4]. Access to meteorological information such as solar radiation, temperature, humidity, wind speed and direction remains difficult. To date, there have been no regional or prefectoral studies based on direct measurement of solar irradiation in Guinea, and the acquisition of meteorological data remains a major concern for researchers in the field of energetics and environment. A few pieces of information available indicate an estimated average annual irradiation of 4.8 kWh/m²/d. This value varies from Conakry (4.8W/m²/d) to Kankan (5.5Kw/m²/d) [5, 6]. However, precise knowledge of solar radiation data, for example, or its estimation in the evaluation of solar deposits through the availability of consistent, high-quality irradiation data, is essential for the dimensioning of photovoltaic systems with the aim of optimizing solar system efficiency [7, 8]. The meteorological station helps in the planning of socio-economic activities such as energy production, agriculture, tourism, transport, etc. Solar irradiation on the Earth's surface has a significant influence on a country's economy, including the use of renewable energies, agricultural production, food safety and human health risks [9]. Generally installed in isolated areas, it requires constant sources of electrical power to operate continuously, and photovoltaic modules are a good alternative [10]. With the development and marketing of self-contained, sufficiently accurate mini-sensor recorders, the development of mini weather stations ranging from prototypes to intelligent stations has become a preoccupation for many researchers. Numerous studies have been reported. The first studies were carried out to assess solar potential, such as that by Liu and Jordan [11], which established a relationship between daily diffuse solar irradiation and global irradiation over a horizontal surface; Emmanuel, Esther et al. used a low-cost irradiation and temperature data logging meter, others used daily average relative humidity, temperature maximum and minimum [12, 13]. In 2010, Burnel, Laurent and al [14], in their unit equipped with 35 HOBO-type mini-sensor recorders, established a procedure for calibrating and verifying the measurements made and guaranteeing the quality of the measurements taken in the field by this equipment. Recently, in 2021, 2022 and 2023 Chaib Messaouda, Hamadouch et al. produced a prototype weather station dedicated to renewable energy applications for data acquisition (temperature, humidity, rain gauge, solar irradiation, pressure, noise and wind speed sensor) using various sensors; a prototype weather station that can monitor and collect weather data using an Arduino board of the Leonardo ETH type and other devices capable of measuring temperature, humidity, sunshine, power, voltage and intensity captured by the solar panel; and Faisal Nawab et al, in a comparative study between the empirical method and artificial intelligence (A.I.), demonstrated the effectiveness of the second method in estimating and predicting solar irradiation [15, 16]; we also mention the realization of a weather station connected to a database via a Wi-Fi link, a weather station integrated into the photovoltaic system that can monitor and collect weather data that can be consulted at any time, a theoretical model for assessing solar potential by carrying out a campaign of measurements of global solar radiation in Nouakchott and Dakar, [17, 18, 19]. Our objective is to create a mini station for measuring the three (3) parameters, namely solar irradiation, temperature and air humidity at the Higher Institute of Technology of Mamou using the method of direct measurements on the site during a trial period of eight (8) days from August 12 to 20, 2024. To do this, we designed a mast and installed all the equipment in the first phase, set up the sensors and their dataloggers and design the mini station on site within the IST precinct. In the second phase, direct measurements on-site were carried out and recorded in real time, followed by interpretation of the data, for future comparative study.

2. Materials and Method

2.1. Presentation of the Study Area

The Higher Institute of Technology (IST) of Mamou is a public higher education establishment in Guinea. Created on August 25, 2004, it is located more than 4km from the town center, in the Télico district of Mamou's urban commune. The Mamou prefecture is located in central western Guinea, between latitudes 9°54' and 11°10' north and 11°25' and 12°26' west, with an average altitude of 700 m and a surface area of 8.000 km² Its climate is of the “foutanian” type, characterized by the alternation of two (2) seasons of equal duration, a dry season from November to April and a rainy season from May to October, with an average temperature of 25°C and average annual irradiation of 4.8W/m²[20]. Laboratory for Teaching and Research in Applied Energy (LEREA), of University Gamal Abdel Nasser, Conakry, the renewable energies laboratory and mechanical design and manufacturing at IST were the main frameworks of this study. In this work, in addition to the laboratory fabrication and design’s materials, we used round and square tubes for mast fabrication, a pyranometer, a temperature/humidity sensor and their dataloggers, a 20Wp photovoltaic panel, a 12V/20A PWM-type charge controller, a 12V/120W battery, copper cables, a multimeter, a GPS and a laptop computer (Figure 4). In terms of softwares, Matlab R2022b, Microsoft Excel 2010, F-LINK and USBLogger Management (supplied with the hardware) were used jointly.

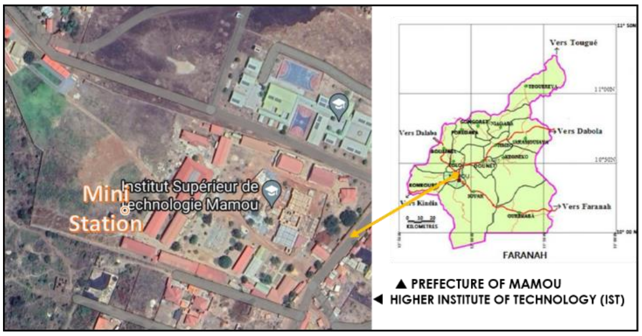
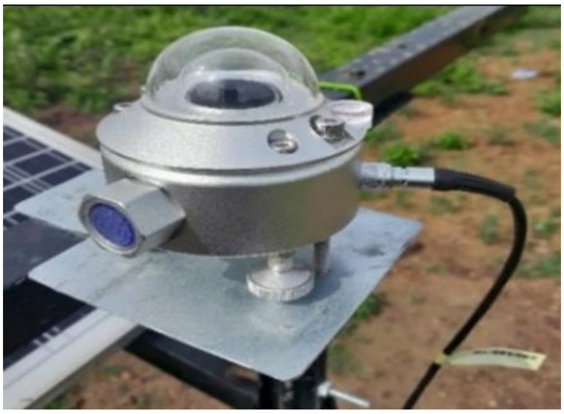


Figure 1. *Showing the study area and our measuring station's site.*

2.2. Experimental Device

The system produced includes measuring equipment mainly consisting of irradiation, temperature and humidity sensors. Each sensor is identified by its own serial number. For irradiation, it is a thermopile pyranometer model TBQ-2L BGT-HJX-TF1 and datalogger DL LOGGER, SN: 0090450A01 connected by a coaxial cable. These two devices interact according to a constraint of equality of sensitivity set at 10.598 $\mu V/W*m^2$; an accuracy of less than 5% and a capacity of 32768 data. The range of measure is 0 to 1887 W/m^2. For temperature and humidity, we deployed an advanced RS-ZHCOS-03-5 sensor, its datalogger, the USB Datalogger Management System software with a response time of 5 seconds and a storage capacity of 260,000 to 2,080,000 lines of data. External measuring range is -40 ℃ to +80 ℃ and 0 to 100% (Figures 2, 3). With a 1,5m stake and 25 mm^2 copper cables, an earth connection was made for the protection system.



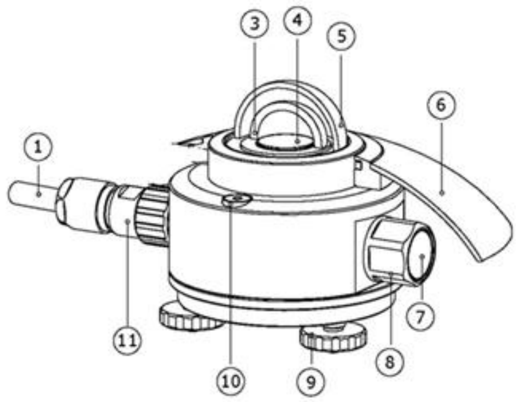


Figure 2. *The pyranometer with an essential's parts.*

1. transmission cable; 3/5 Out/Inner quartz protecting glass dome; 4. Sensor; 6. Barn doors; 7. Dryer; 9. Adjusting horizontal bolt; 10. Spirit level; 11. Connector

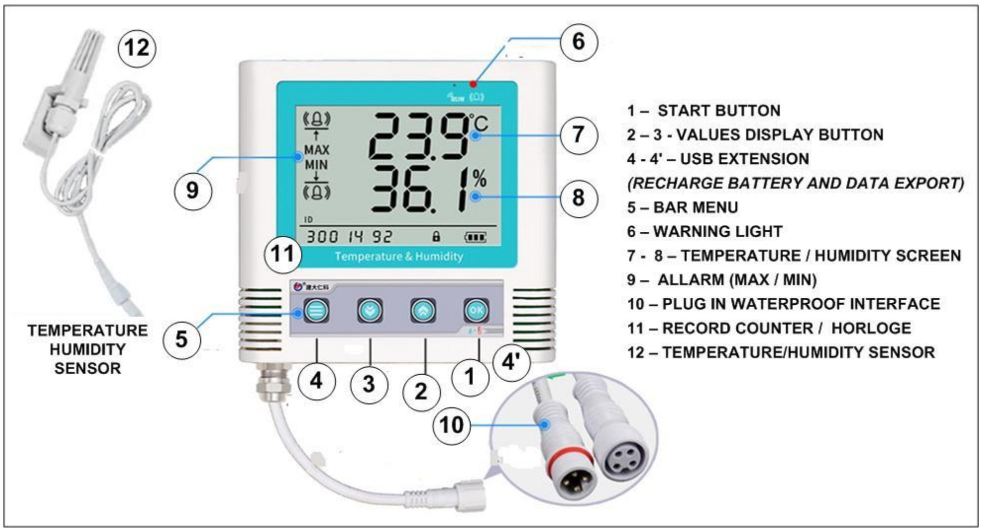


Figure 3. *Temperature and humidity sensor and Datalogger.*

2.3. Method

The methodological approach adopted in this work consisted in designing, building and parameterizing the equipment and testing a mini station for measuring irradiation, temperature and humidity, as well as testing it at the Mamou IST. The information collected is in the form of tables with five (5) columns, including the measurement identifier, the complete date and the values. For validation purposes, they were compared with those of the Mamou meteorological station. Microsoft Excel and Matlab R2022b were used for analysis and graphical representation.

2.4. Realization of the Experimental Device

A mini-meteorological station comprising a pyranometer for solar radiation and a datalogger for air temperature and humidity was built at IST Mamou. In the design and manufacturing phase, a 40mm-diameter pipe bar in two (2) pieces of 1m and 1.25m respectively, and a 35mm squaresh tube bar 91cm long were used to support the equipment (pyranometer and temperature and humidity sensor). A 50mm diameter by 500mm high bundle, cemented 450mm into the ground, holds the 2m mast designed in 2 pieces and all the assembled bars. In the assembly and fixing phase, the parts listed above are fitted together and screwed with 12", 10" and 13" blonds; the pyranometer and temperature sensor are fixed to the bar 2m from the ground, followed by the assembly of a 400mm x 300mm x 200mm box 40cm from the mast and the installation of the photovoltaic equipment, the 2 dataloggers and their settings. The spirit level, the two (2) levelling screws used to adjust the balance of the pyranometer module in horizontal position (Figure 1).

The introduction of the photovoltaic system was motivated by the need to ensure continuous power supply to the equipment in the event of the datalogger battery running out. The pyranometer, sensor and dataloggers are connected by a 3m coaxial cable, and the computer communicates with the dataloggers by USB cables.

The two (2) dataloggers have been set up with manual start-up and a data recording interval of 15 minutes at day and night for an eight (8) days of trial period from August 12 to August 20, 2024.

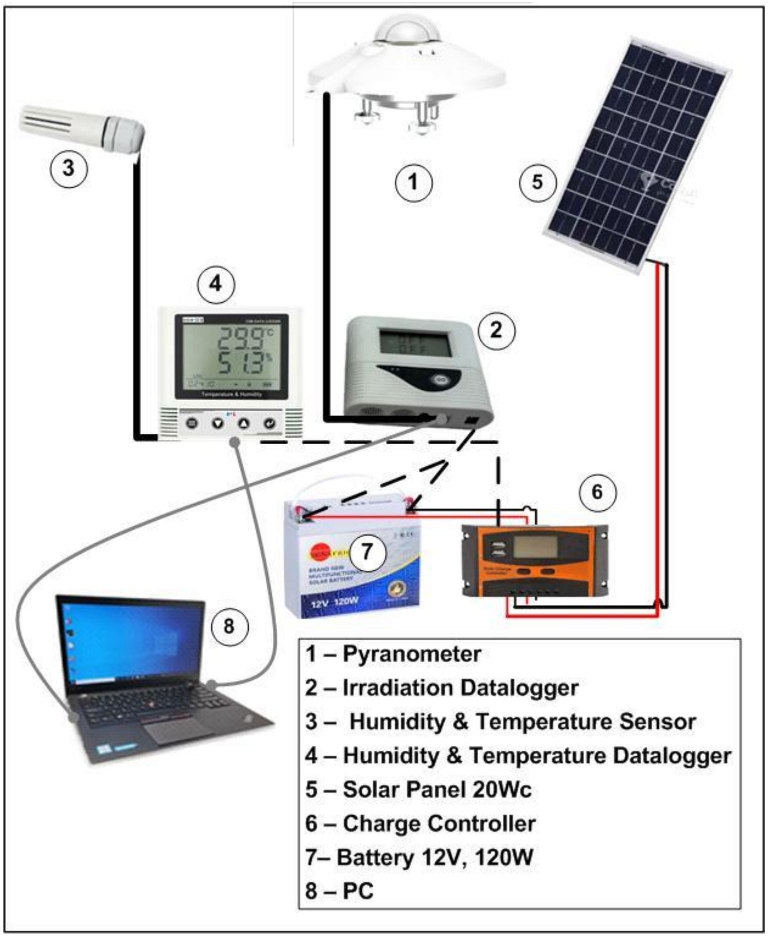


Figure 4. *IST mini station diagram.*

3. Result and Discussions

The IST of Mamou site was used to build a mini station for measuring irradiation, temperature and humidity. The various results obtained during the test period from August 12 to 20, 2024 were: the mast installed far from any shade; The measuring equipment installed, configured and tested; Seven hundred and forty-two (742) lines of data on solar irradiation, temperature and air humidity were collected in xls format and graphed for analysis. The coverage rate was 100% with 75 hours of sunshine; The values of the test information are represented by the Figures 5 to 15.

At the start of the pyranometer station, the first information on irradiation is observed and recorded with a maximum of 1091W/m ²at 1:15 P.M, a minimum of 28W/m ²at 6:15 P.M and the zero value from 6:30 P.M with an average of 584W/m ²(Figure 5).

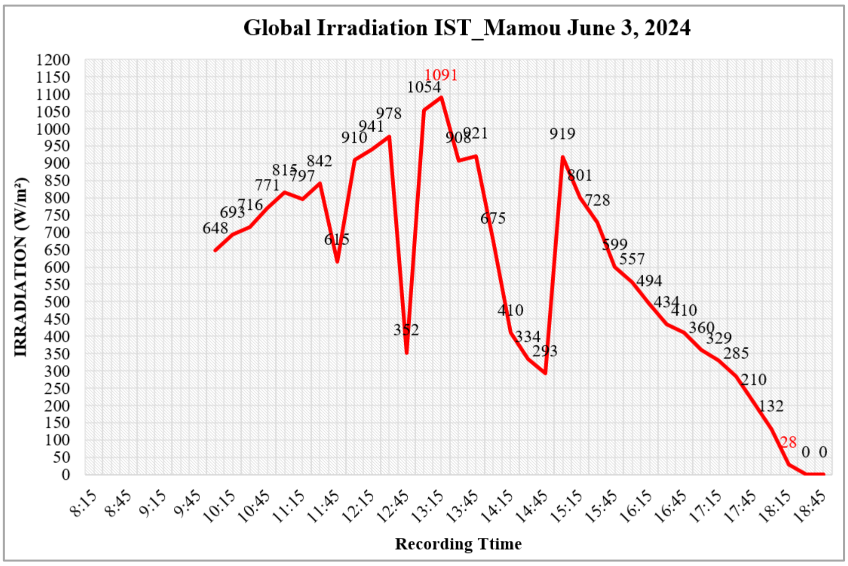


Figure 5. *Showing the first irradiation's measurements.*

3.1. Irradiation

During the test period, irradiation was measured day and night. The days of August 13, 14, 16, 19 and 20 were sunny, with a maximum of 1224w/m ²observed on August 16 at 2:46 P.M, for an average of 142.23 W/m ², and minima of 1w/m ² and 6W/m ²observed on August 20 at 7:46 A.M and 8:01 A.M, with zero values from 6:16 P.M to 7:30 A.M (Figure 6).

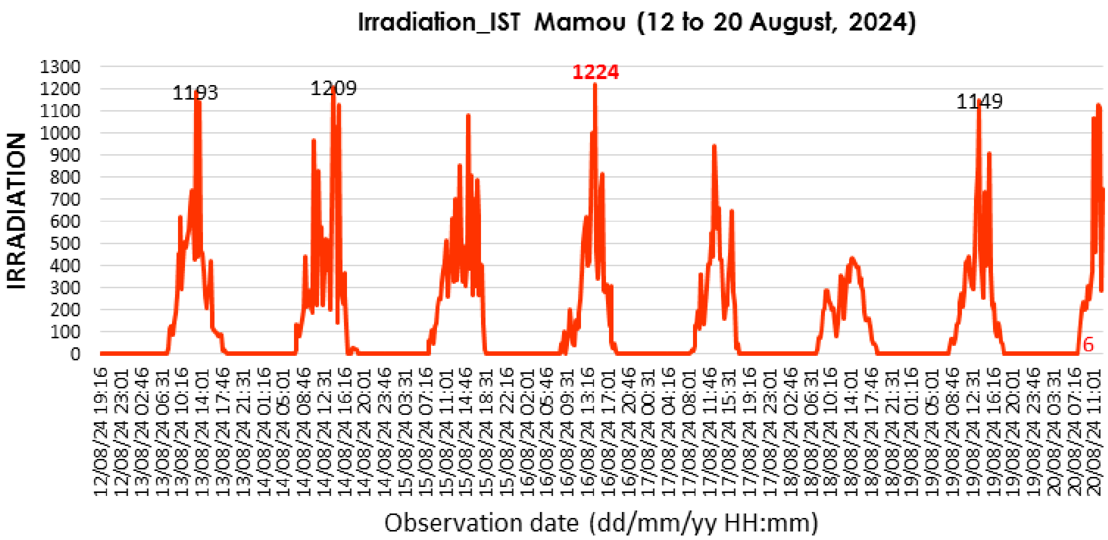


Figure 6. *Showing irradiation's measurement.*

3.2. Temperature

Temperature measurement using the sensor gave a minimum value of 18.6 ℃ and a maximum of 31.7 ℃, observed respectively on August 14th at 7:16 A.M and August 16th at 3:30 P.M (Figure 7). An average value was 22.17 ℃.

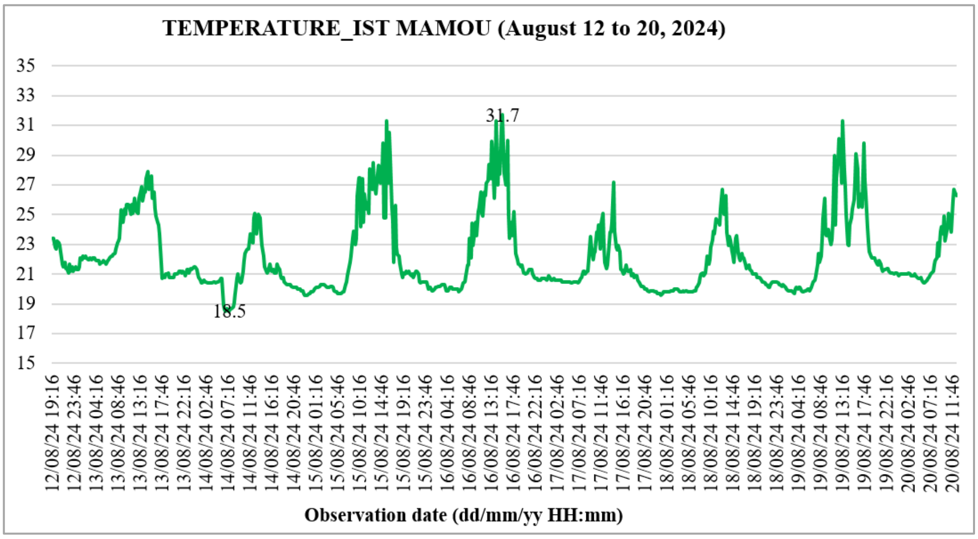


Figure 7. Temperature recorded at IST Mamou.

3.3. Humidity

Humidity measurements showed a maximum of 99.9% observed almost every day at night and in the morning, and a minimum of 57.4% on August 15 at 3:48 P.M (Figure 8), with 95.34% as average value.

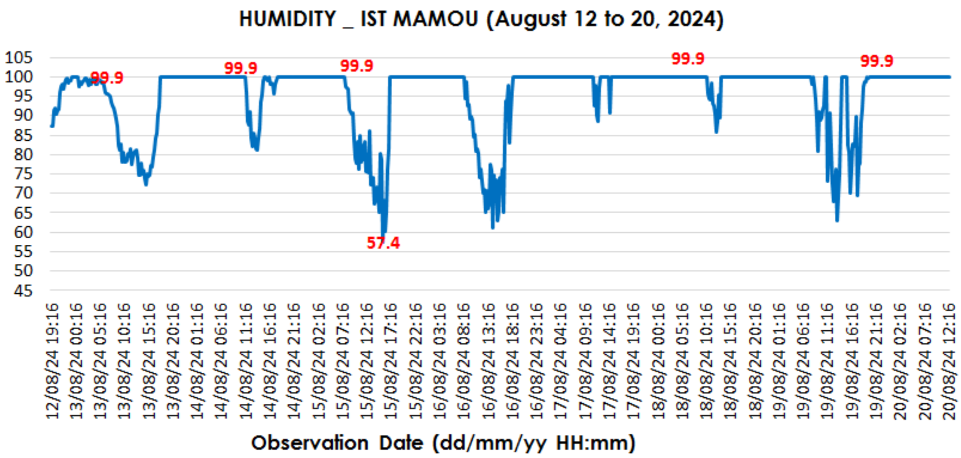


Figure 8. Showing humidity at IST.

3.4. Irradiation - Temperature

During the test period, the range of maximum irradiation values (1193W/m², 1209 W/m², 1224W/m²) were reached from temperatures around 24 ℃ to 31.3 ℃ (Figure 9); this observation corroborates with photovoltaic theory as (Loubna Hadhoum, Naim Akkouche, 2014) on the influence of temperature on photovoltaic cells [21].

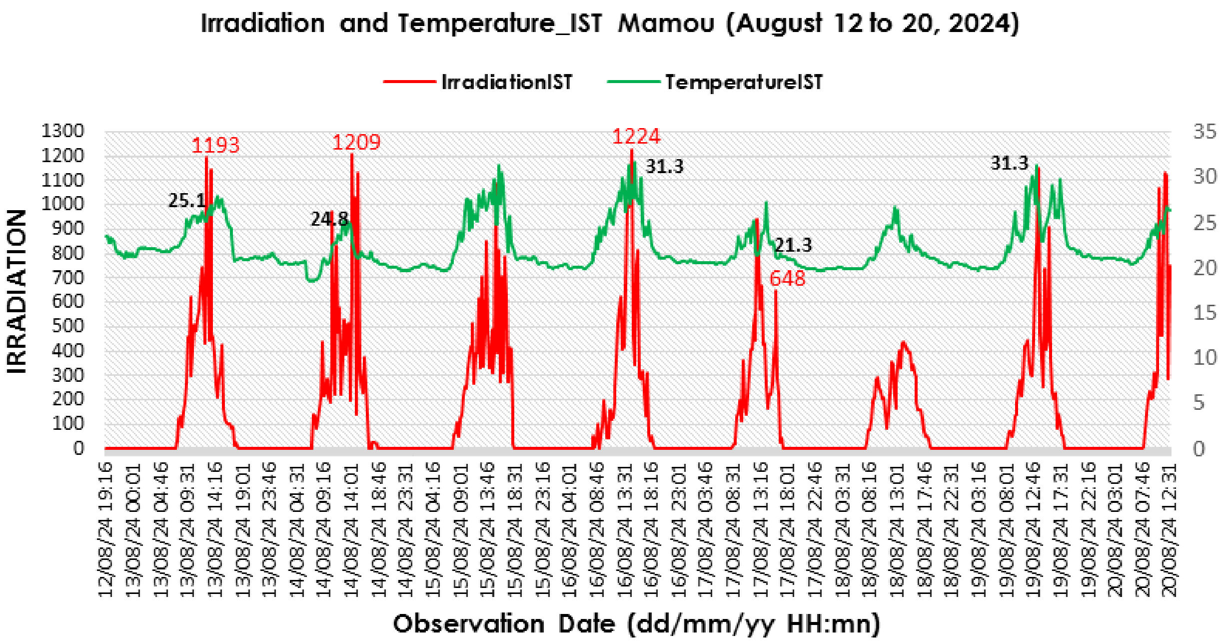


Figure 9. *Showing the variations of irradiation and temperature at IST.*

3.5. Irradiation and Humidity

Figure 10 shows that the variation of irradiation is not proportional to that of humidity. Its maximum values correspond to the minimum values of humidity and so on so falt.

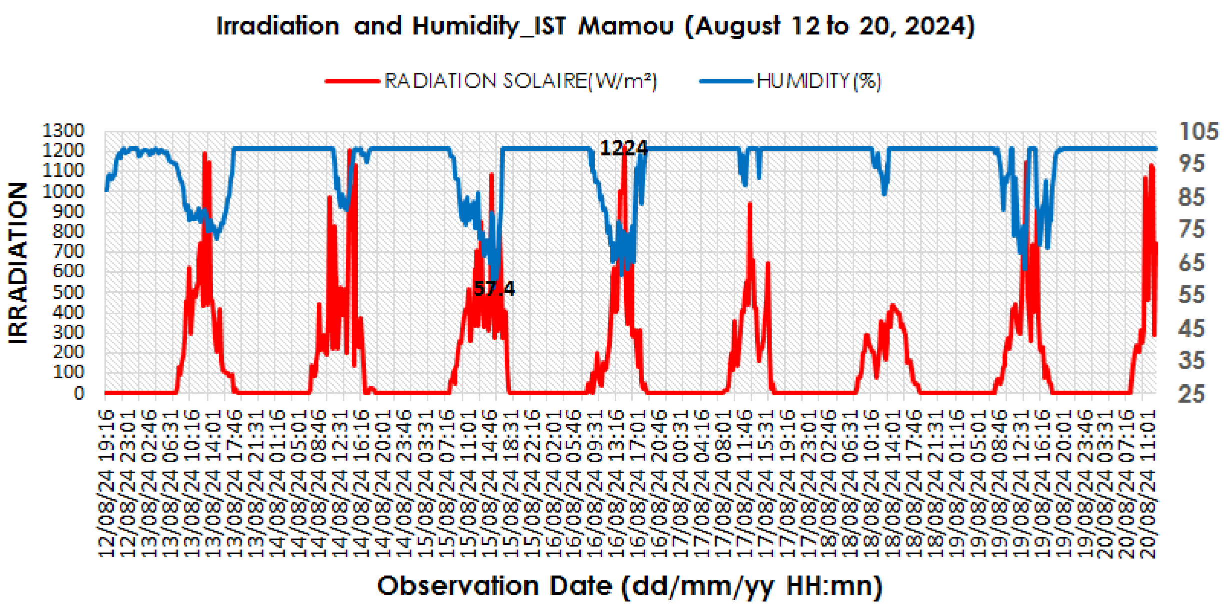


Figure 10. *Showing solar irradiation and humidity recorded at IST.*

3.6. Temperature and Humidity

An analysis of temperature and humidity values shows that maximum temperature values are reached in the afternoons around 1:30 P.M, while humidity tends towards its minimum values. Similarly, minimum temperature and maximum humidity values are observed in the early morning (Figure 11).

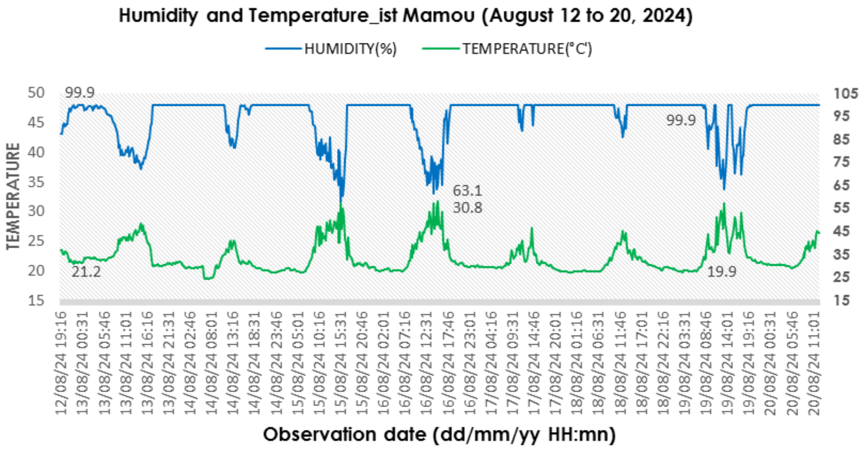


Figure 11. *Humidity and temperature recorded at IST.*

3.7. Irradiation, Temperature and Humidity

An overview of all the irradiation, temperature and humidity data recorded during the test period is shown in Figure 12.

Remarkable irradiation values (1193 W/m², 1209 W/m² and 1224W/m²) correspond to humidity values (77.9%, 81,4% and 63.1%); these irradiation values correspond also to the temperature interval from 26 ℃ to 31 ℃.

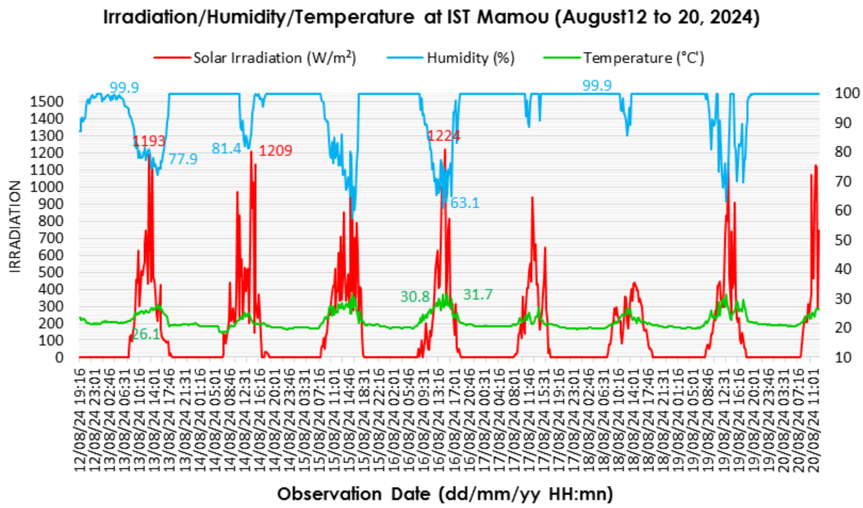


Figure 12. *Irradiation, Humidity and Temperature at IST.*

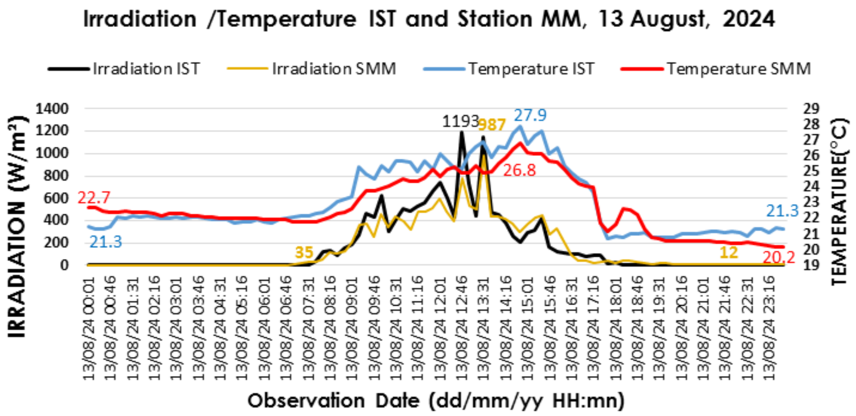


Figure 13. *Showing Irradiation and Temperature at IST and Mamou metrological station.*

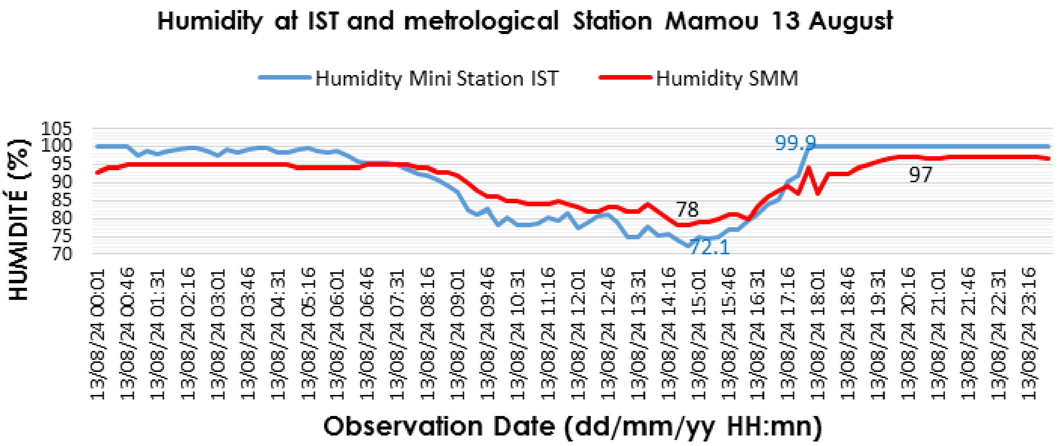


Figure 14. *Showing Humidity at IST and Mamou meteorological station.*

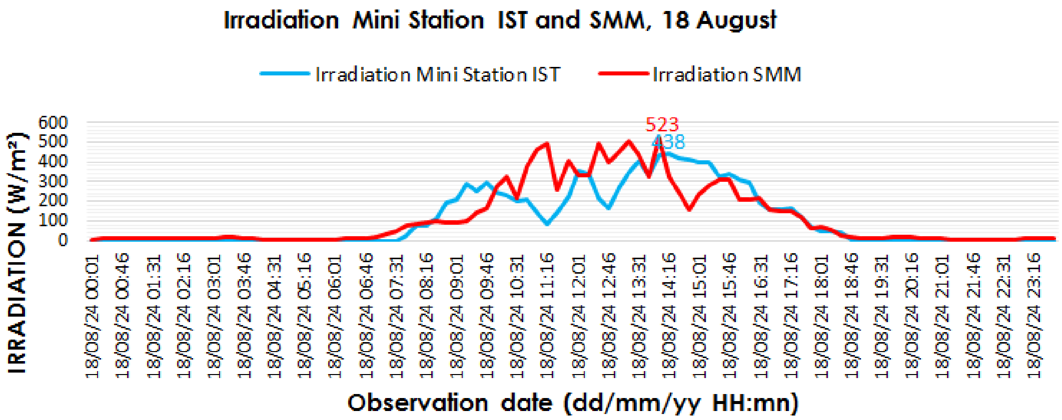


Figure 15. *Showing irradiation at IST and Mamou meteorological station.*

3.8. Discussions

To validate the solar irradiation, temperature and air humidity measurements from our mini station, we compared the values of these parameters measured on-site with readings of the same parameters, at the same period in August from the Mamou weather station (SMM), located 5 km away from IST with 798m of altitude, for the days of August 13 and 18, 2024 (figures 13, 14 and 15). Although synoptic, the curves show broadly the same pattern (figures 13, 14) for one of the sunnier (August 13) and less sunny (August 18) days at IST. Apart from the maintenance issue, some of the discrepancies observed are due not only to the difference in altitude between the two sites, but also to the large coverage of the synoptic station, which covers the Mamou, Pita and Dalaba prefectures. Moreover, during the experimental period, our data, with 100% coverage, remained more reliable than those from the Mamou weather station, which recorded irradiation values above zero during the nights, increasing the number of hours of sunshine with less than 50% coverage (figures 13, 15). Temperature and humidity curves follow the same patterns. Values ranged from 20℃ to 22.7℃ between 7 P.M and 7 A.M, with maximums of 27.9℃ at IST Mamou and 26.8℃ at SMM (figure 13). For humidity, the IST Mamou mini station showed peak values close to 100%, with minimums of 72.1% on August 13, for an average of 91.5%; while the Mamou meteorological station showed values between 97% and 78% (figure 14).

Our approach (direct on-site measurements) described in this work was used with conclusive results in the work of B. Ould BILAL, V. SAMBOU [19] in 2014 to assess the solar potential in Nouakchott and Dakar through a campaign of global solar radiation measurements on a horizontal plane at 1-minute intervals at the Nouakchott site in 2004 and at the Dakar site with a 10-minute measurement interval between 2006-2007.

4. Conclusion

In this work, we designed, built and tested a mini station for measuring irradiation, temperature and humidity at the IST site in Mamou. The mast was erected, the equipment installed and powered by a photovoltaic system without an inverter, enabling 742 lines of day and night data to be recorded at 15-minute time intervals, with 100% coverage during the test period from August 12 to 20, 2024, with a very appreciable coverage rate. With solar irradiation reaching 1224W/m ²(on August 16 at 2:46 P.M) and a minimum of 1W/m ²on August 20 at 7:46 A.M, followed by zero values between 6:16 P.M and 7:30 A.M with an average of 142W/m ² were recorded (figure 6); 18 ℃ and 31.7 ℃ were observed as minimum and maximum temperatures on August 14 with an average of 11.17 ℃ (figure 7). For humidity, the maximum (99.9%) was recorded almost every morning and evening during our test period, with a minimum of 57.4% on August 15 at 3:48 P.M and an average of 95.34% (figure 8). Microsoft Excel and Matlab R2022b were used to compile and graphically represent the information collected on the IST site. In this way, we have designed, realized a measurement platform which information will be used for further studies of solar potential. Its extension by the addition of other sensors will enable researchers in the field of renewable energies and the environment to acquire field data.

Abbreviations

A.I	Artificial Intelligence
A.M	Ante Meridiem
G.P.S	Global Position System
IST	Higher Institute of Technology
LEREA	Laboratory for Teaching and Research in Applied Energy
P.M	Post Meridiem
SMM	Mamou Metrological Station
Wp	Watt Peak

Author Contributions

Ibrahima Maciré Camara: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing

Ansoumane Sakouvogui: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing

Cellou Kante: Investigation, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing

Mawiatou Bah: Funding acquisition, Investigation, Project administration, Resources, Supervision, Validation, Visualization

Conflicts of Interest

The authors declare no conflicts of interest.

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