A Cutting-Edge Implementation of IoT-Based Monitoring for Floating Solar Cells with Dual-Axis Tracker

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***Abstract*—Solar power has emerged as a significant and vital renewable energy sector, finding diverse applications such as in commercial settings, solar heaters, and solar pumps. Its adoption has contributed to mitigating the shortage of integrated grid electricity. However, the key challenge remains in optimizing energy extraction from solar sources. A promising solution lies in the utilization of Dual Axis tracker-based solar panels, which facilitate efficient solar energy utilization. Presently, conventional solar power plants necessitate vast land areas and exhibit certain limitations. Considering the context of overpopulated countries like Bangladesh, floating solar power plants offer a more viable alternative to land-based counterparts. This paper delves into the investigation and implementation of Floating Solar Cells (FPV) equipped with dual-axis tracker technology to maximize solar energy capture. The dual-axis tracking capability allows for precise sun tracking, resulting in a significantly higher energy yield. To analyze the photovoltaic (PV) and current-voltage (IV) curves, a MATLAB Simulink model is employed, while meteorological data is collected using Homer Software. The research focuses on the implementation of the project at the Teesta Barrage in Lalmonir Hat Zila. Additionally, an Internet of Things (IoT) integration enables remote plant monitoring and real-time data acquisition. Our investigation concludes that dual-axis trackers represent the optimal solution for maximizing energy harvesting from available resources, and the adoption of Floating Solar Power Plants stands as an efficient means of sustainable energy generation, particularly in densely populated nations like Bangladesh.**

***Index Terms*—IoT, Solar Cell, Tracker, Dual Axis, Renewable energy, Solar energy, Power, FSPP, FPV, MATLAB, Homer.**

I. Introduction

In everyday life, the electricity demand is much higher than the amount of electricity that can be made With the depletion of non-renewable resources such as coal and oil, the time has come to transition to renewable energy sources [1]. The majority of the world's areas have at least one economically viable renewable energy source (wind, sun, hydro, or geothermal), and some have many such renewable energy sources [2]. Solar energy is usually recognized as the planet's most plentiful and limitless source of energy [3]. Solar farms are frequently constructed on agricultural and wastelands, which does not constitute a fully sustainable use of land resources [4].

PV panels have a negative temperature coefficient, which indicates that their efficacy in converting solar to electricity increases as the temperature decreases [5]. Floating solar photovoltaic (FPV) is a unique application in which solar arrays are suspended over bodies of water to make use of the solar module's negative thermal coefficient [6]. Due to the multiple benefits of FPV, water may become a new focal point for solar site selection [7]. It's difficult to ignore the fact that land for solar PV installations is always going to be pricey. It is possible to find big bodies of water in various sections of the nation, which can lower the cost of land preservation as well as the operational costs associated with power-generating expenses [8], [9].

Several research works have been done before on this topic on the dual-axis solar tracker as well as floating solar power plant and feasibility analysis. Chowdhury, R. et al. presented the FPV power project in Kaptai with the available surface area, and economic and environmental advantages, which illustrates a comprehensive model of overall energy generation in the Kaptai floating PV power plant. By analyzing simulated data, theoretical basis, computation, per-unit cost, and advantages in various aspects, it is possible to create electrical production using this approach [10]. Another author named Rahman, Md Wazedur et al. works on Converting existing motorways into solar lanes and floating solar PV plants would expand Bangladesh's energy-producing options. Theoretical and modeling data are used to optimize these ideas' electricity generation. So, it's time to upgrade the solar infrastructure to include solar lanes and floating solar PV plants [1]. Sendhil Kumar Natarajan et al. publication provides a thorough explanation of the plant's floating and revolving structures. The solar panel should be tracked in two axes for maximum efficiency, namely the azimuthal and altitude axes as a result, a dual-axis tracking system is used, with the process outlined [11]. Another author DD Prasanna Rani et al. proposed IoT-based smart solar energy monitoring systems. By

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incorporating IoT, the project is based on the usage of the most up-to-date, cost-effective way for remotely monitoring the operation of a solar plant. Plant maintenance, issue diagnosis, and real-time monitoring can all benefit from it [12].

Because Bangladesh is a riverine country, it can leverage its extensive coastline to its advantage. The utilization of coastline areas presents a significant opportunity, particularly in addressing power shortages. Introducing floating solar power plants emerges as a promising solution to tackle the electricity deficit in Bangladesh. These floating solar panels with dual-axis trackers offer greater efficiency compared to traditional land-based power plants, especially in the coastal regions.

This paper focuses on the implementation of Floating Photovoltaic (FPV) technology with a dual-axis tracker, proposing a 15MW plant to be installed at Teestha Barrage, Lalmonirhat, along with a comprehensive cost analysis. Additionally, an Internet of Things (IoT) system is integrated into the tracker to enable remote monitoring of the plant. The analysis involves using a basic MATLAB Simulink model to study the PV (Photovoltaic) and IV (Current-Voltage) curves. The findings indicate that the FPV system with a dual-axis tracker proves to be more efficient than conventional PV systems, providing a more effective means of harnessing solar energy.

II. Overview of the System

The Block diagram of the entire system is shown in this section in Fig 1 a complete photovoltaic system is displayed here, from the generation end to the distribution end. Since the produced current is DC, we use an inverter to convert it to AC, and a transformer sets up this power to be delivered to users or the grid.

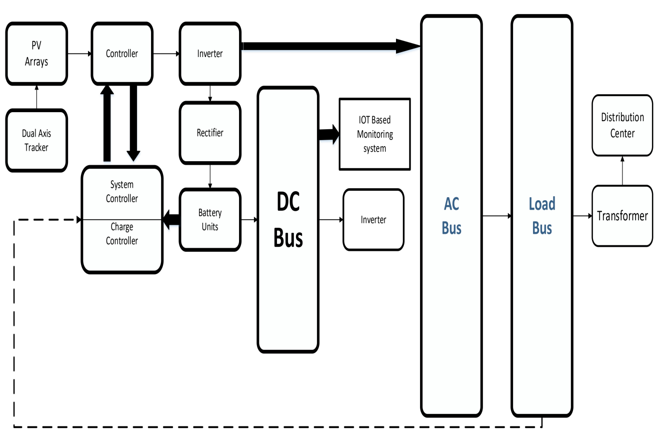

Fig. 1. Block Diagram of the whole System

III. System Design

This section describes the system design methodology, details of the design simulation, and the system flowchart.

A. Flowchart

The flowchart of the proposed system is shown in Fig. 2.

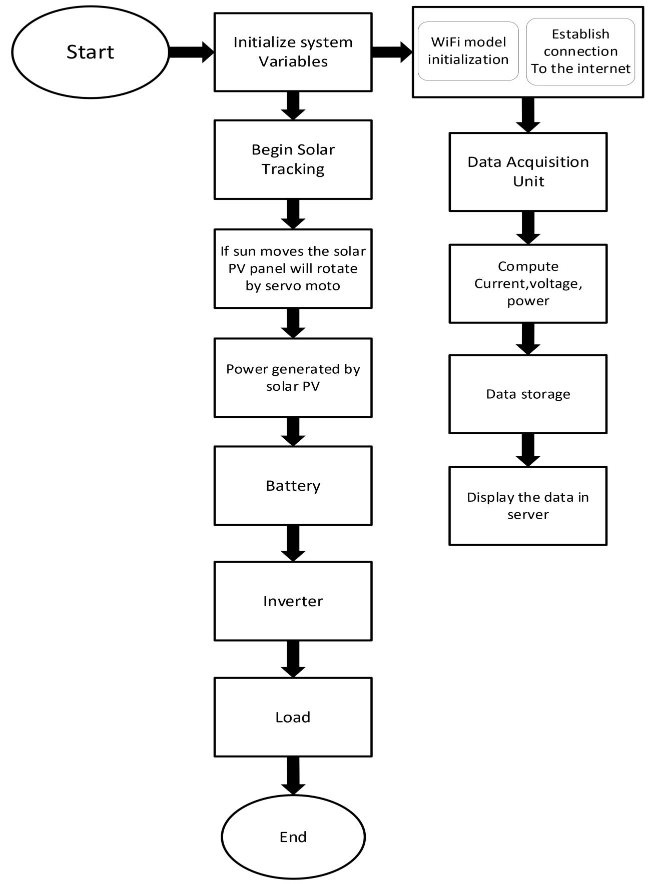

Fig. 2. Flowchart of the system

Initial, there is two system starting at a time Solar tracking being started and WIFI model initialization. For solar, If the sun moves the solar PV panel will rotate by servo motor. Power is generated by solar PV and that goes to the battery then the inverter then lastly load. Again in the wifi model, firstly Establish a connection to the internet it will gain Data from solar PV like Voltage, Current, and Power. The data will be stored on the server and finally displayed on the data server.

B. Circuit Diagram

The circuit diagram of the system a shown in Fig. 3 and Fig. 4 respectively. The setup consists of two circuits. In the first circuit (Fig. 3), a solar panel is connected to two resistors (10k and 47k) using the voltage divider rule. The current sensor is integrated, and solar data is sent to a server through the Arduino. In the second circuit (Fig. 4), four LDRs are used to control the rotation of a solar panel. Data from the LDRs and resistors is sent to the Arduino, which then decides when to rotate a servo motor. The servo motor is controlled using Arduino's digital pins 9 and 10.

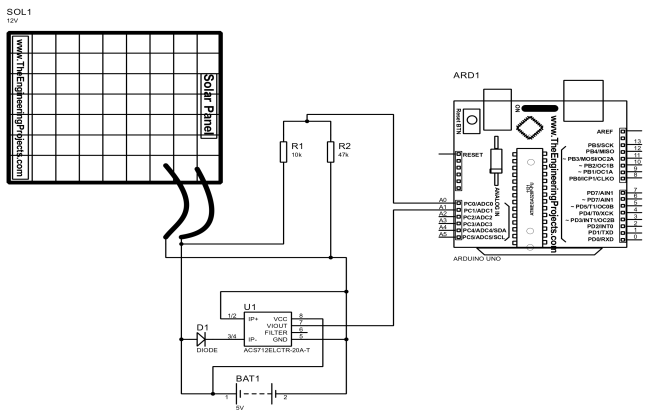

Fig. 3. Circuit diagram of our Proposed System (PV system)

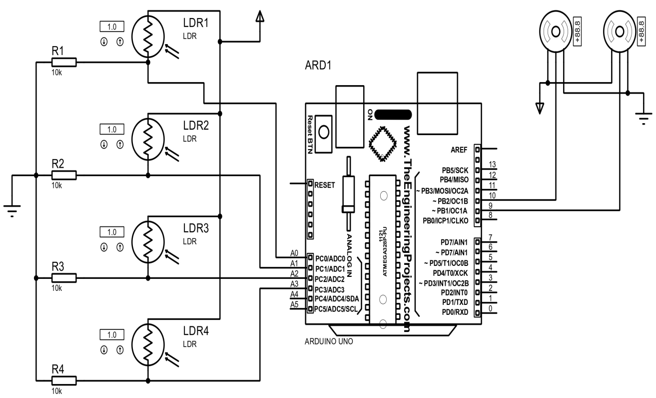

Fig. 4. Circuit diagram of our Proposed System (Rotating part)

IV. Result And Analysis

A. prototype of our proposed system

The prototype presented in Fig. 5 and Fig. 6 involves an ideal PV monitoring system utilizing various components such as Arduino Uno, ESP8266, ACS712 (current sensor), voltage sensor, capacitor, resistor, buck converter, two servo motors, a 12-volt solar panel, a 12-volt battery, and LDRs. The system aims to provide a cost-effective solution for monitoring remote energy yields and performance through computer or mobile devices like smartphones. The system employs a 12-watt solar module to measure string voltage, string current, and output power. The ESP8266 microcontroller with Wi-Fi capabilities is used to develop this PV monitoring system.

B. Thinkspeak

We developed a model that collects solar data and stores it on the open-source server ThingSpeak. The server provides visualizations of the data, including current vs. time, voltage vs. time, and power vs. time plots. Real-time voltage output data is displayed on the server as well (Fig. 7).

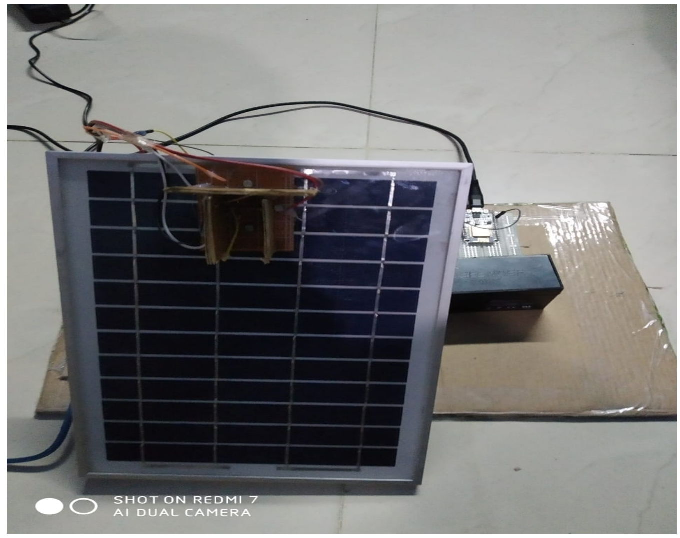

Fig. 5. Front View of our system

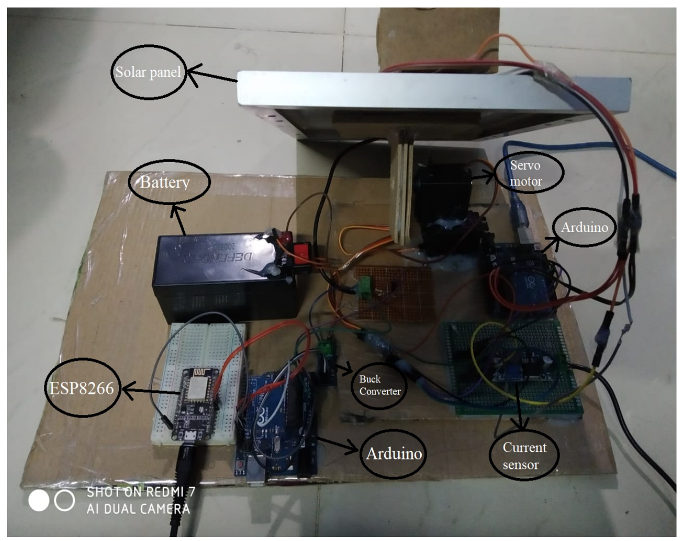

Fig. 6. Back View of our system

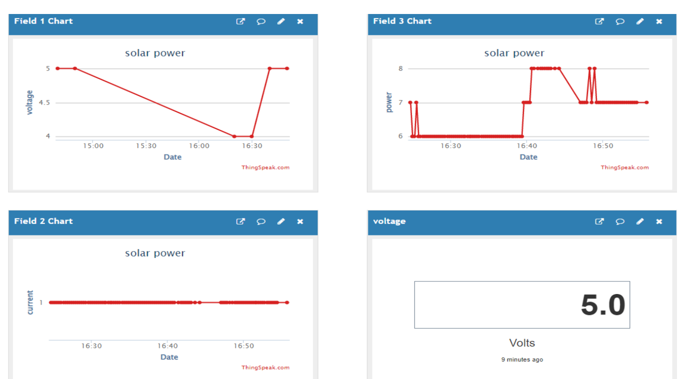

Fig. 7. Displaying data in Server

C. Data Analysis

The observation output Data which we collect from a our developed system a given below:

1) Efficiency of the system: This section describes the efficiency of the system with two parameters. Table I and Table II shows the output data, taken at different time. first took data without rotation condition then again took data in rotation condition at the same time.

with rotation:

TABLE I
OBSERVING REAL-TIME SOLAR DATA AT DIFFERENT TIMES WITH PANEL ROTATION

Time	Voltage(v)	Power(w)	Current(A)
8.00	5	8	1
9:00	5	8	1
10:00	5	8	1
12:00	5	9	1
2:00	5	8	1
3:00	5	8	1
4:00	5	7	1
5:00	5	7	1
6:00	4	7	1
6:30	0	0	0

$$\text{Total power}=\frac{Sum\ of\ Total\ power}{Number\ of\ Data\ Collection}=66\%$$

Without rotation

TABLE II
OBSERVING REAL-TIME SOLAR DATA AT DIFFERENT TIMES WITHOUT PANEL ROTATION

Time	Voltage(v)	Power(w)	Current(A)
8.00	5	7	1
9:00	5	8	1
10:00	5	8	1
12:00	5	9	1
2:00	5	8	1
3:00	5	7.5	1
4:00	5	7	1
5:00	5	4	1
6:00	4	2	1
6:30	0	0	0

$$\text{Total power} = \frac{SumofTotalpower}{NumberofDataCollection}=60.5\%$$

Improve Efficiency, η=(66-60.5) = 5.5%

V. IMPLEMENTATION

In this section, we present an overview of the implementation of our 15MW FV power plant project, including performance and cost analysis.

A. Site selection

We chose the Teesta barrage in Lalmonirhat district, Bangladesh, as the location for our floating solar panel electricity generation project. The 615m long concrete barrage with 44 radial gates and a discharge capacity of 12,750 cusec makes it a suitable choice for producing a substantial amount of electricity. The planned site is situated in an area where a significant part of the population lacks access to electricity, making the floating photovoltaic power plant beneficial for the local community [13], [14].

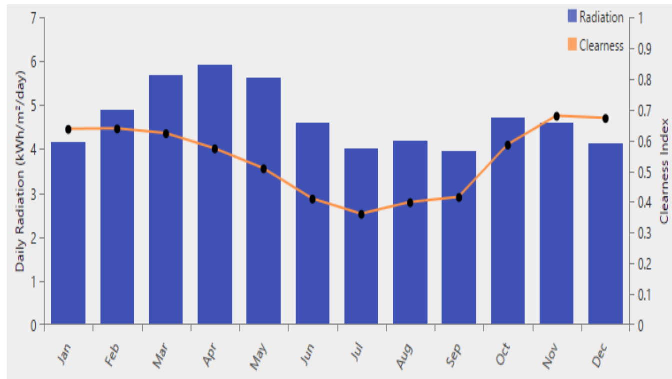

Fig. 8. Monthly Average Solar Global Horizontal Irradiance (GHI) data of proposed site Using HOMER Software.

B. Build PV Module

In this section, MATLAB Simulink was employed as an analysis tool. The Simulink model, based on solar radiation and temperature inputs from our proposed site, can generate voltage, current, and power outputs. The internal block diagram of the suggested model solved using mathematical Simulink equations [15], is shown in Fig. 9. The Sunpower Module SPR-435NE-WHT-D was used in the analysis, and all electrical data can be found in the reference [16].

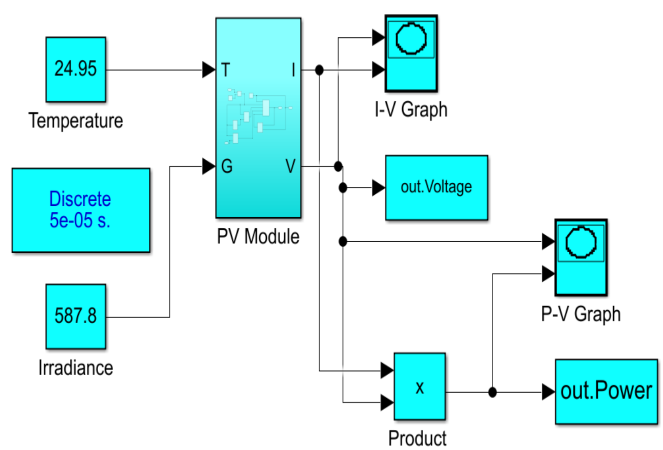

Fig. 9. Model developed simulation of PV modules with MATLAB simulink

C. Simulation Result

The solar PV power generating system's simulation block represents the basic power conversion unit. The P-V and I-V curves are affected by variations in temperature and sun insolation. Fig. 10 and Fig. 11 illustrate the Power vs.

Voltage (P-V) and Current vs. Voltage (I-V) curves at different irradiation levels and temperatures. As irradiation increases, the output power and current also increase.

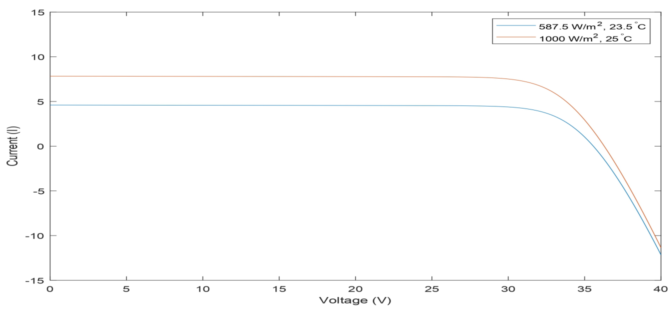

Fig. 10. Power vs Voltage Curve(T=23.34^{o}C, Irradiance 587.5W/m^2 & 1000 W/m^2)

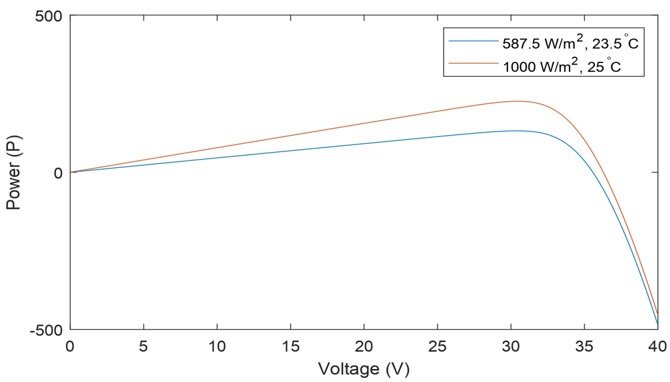

Fig. 11. Current vs Voltage Curve (T=23.34^{o}C, Irradiance 587.5W/m^2 & 1000 W/m^2)

D. Irridiance calculation

From Fig. 8 yearly average solar irradiance in the Teesta barrage area = 4.70 kWh/m^2/day. The latitude of the site is 26.6886Â°N, The longitude of the site is 88.4117Â°E, Total yearly global radiation = 4.70*365 = 1715.5 kWh/m^2
The average day length in Bangladesh is 11-13 hours. So, takes a minimum of 8 hours for calculation, total hours in a year = 365*8=2920 hours per year. Avg. yearly irradiation in (W/m^2) = (total yearly global radiation / avg. daylight) = 587.5W/m^2

E. Required Panel

TABLE III
NOMINAL VALUE OF PV MODULE FROM HOMER SOFTWARE

Parameters	Value
Sizes to be considered	310.315,320,325W
Life Time	25yr
Derating Factor	88%
Tracking System	yes
Slope	22.8degree
Ground Reflectance	20%

If we consider generating power is 15MW. The maximum power of solar panels is 325W. Total solar panel required = (Target power /Maximum output power of selected solar panel) = 46160-unit panel. (For better calculation take 7 extra panels). As per proposed design consider = 70Array unit. Each array unit required panel = (Total solar panel required /Array unit) = 46160/70 = 660 Unit solar panel.

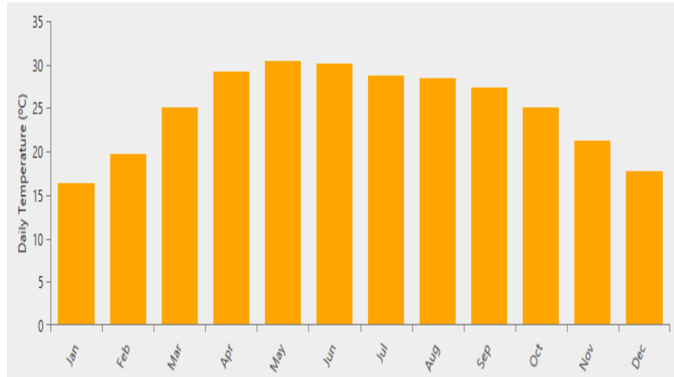

Fig. 12. Monthly average temperature data of proposed site using HOMER Software

F. Required Area

Here, 1.794m^2 is the original panel size for each unit. Consider 2.5m^2, for supporting the panel on the floating structure. Each array unit required area = (Number of total solar panels in each array $\times$ each solar panel unit area) = 1650 m^2. Total area required for our proposed power generation = (Number of arrays times each array required area) = 115500m^2.

G. Power Calculation

Efficiency can be calculated using (Pmax Ã· Area) Ã· (1000) x 100%. Here, Pmax is the solar panel's peak power (in Watts), and the Standard Test Condition (STC) irradiance is 1000 (in Watts/sq.m.). By this simple solar module efficiency formula, we will know how efficient a solar panel is, aside from looking it up on its specification sheet or its nameplate. Additionally, we will now be able to confirm the module efficiency details when we see a solar panel using this method.
After calculating solar efficiency, the output was 190.98 (18.12%) for our selected solar panel which is 325 (W).
Total generation in a year = (Target generation * Yearly avg. day time)= 43,800 MWhr
If the panel works 18.12% efficiency with the tilted surface at irradiation 587.5 W/m2 then the output power = 190.98 Watt according to the calculation. Therefore, electricity production is reduced to 58.76%. Net electricity will be produced in a year (43800 * 0.5876)m^2= 25,736.88 MWh
If we use the Solar tracking method, we can drive into 5.5% extra power. Which is practically done by our solar tracking project. Now, Net electricity will be produced in a year= 27,152.4084 MWh.

H. Cost Estimation

To implement the proposed Floating photovoltaic system in Teesta Barrage, Lalmonirhat district, a thorough cost analysis is crucial. The estimated cost includes photovoltaic modules, inverters, combiner boxes, floating pontoon, surge arrestors, lightning rods, and wiring. The suggested photovoltaic system is designed to have a lifespan of 25 years. The cost per unit of energy will be calculated based on these considerations.

TABLE IV
APPROXIMATE COST ANALYSIS

No.	Components	Cost per unit (BDT)	Lifetime (Years)	Overall Cost (BDT)
01	PV Module	70,000 BDT/KW	25	1050,000,000
02	Dual-axis Solar Tracker	80,000		3,692,800,000
03	Inverter	80,000 BDT/KW	15	795,280,000
04	Floating PV Pontoon	8000 BDT/KW		120,000,000
05	Transformer	40,000,000		40,000,000
06	Generator			460000
07	Anchoring			4,200,000
08	Combiner Box			224,000
09	Wiring Cost			29,761,904
10	Arrestor			16,000
11	Replacement Cost			1000,000,00
12	Maintenance & Operating Cost			1020,000,000
13	Accessories			35,000,000
13	Dual-axis Solar Tracker	80,000		3,692,800,000
Total				6,787,741,904

The total cost of the system is 6,787,741,904 BDT and the net electric energy per year is 27,152,000 kWh. After 25 years, the net energy will be around (27,152,000 $\times$ 25) = 678.8 $\times$ 10^6 kWh. Estimated capacity of the designed system = 15 MW Cost per unit of energy in BDT (produced in 25 years) = (Total cost/Energy produced)= (6,787,741,904 /678.8 $\times$ 10^6) = 9.99 BDT. So, we could be able to generate per unit of energy at 9.99 BDT.

TABLE V
COST ANALYSIS OF PROPOSED PROTOTYPE

Equipment	Quantity	Price (BDT)
Servo motor	1+1	900
Arduino UNO	1+1	900
12VBattery	1	650
ESP8266	1	480
PV Module	1	400
ACS712 Voltage Sensor	1	350
Voltage Sensor	1	180
Resistor	2	4
Total		3864

VI. CONCLUSION

The floating PV power plant is an innovative concept that boosts electricity production without using extra land. Our study focuses on a dual-axis solar tracker for optimal efficiency. The approach can be applied to lakes, dams, or rivers without harming the environment. The prototype is installed in the Teesta River, Lalmonirhat district, Bangladesh, with a proposed 15 MW capacity. MATLAB Simulink results are reliable and substantial, indicating that this method can generate 500 MW of electricity using only 13 percent of the available land. The integration of a dual-axis solar tracker has further increased power output. Additionally, an IoT-based monitoring system allows remote monitoring of the solar power facility. This floating solar plant implementation is a highly effective means of utilizing solar energy.

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