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Development of a Floating Structured Hybrid Power Plant with Remote Monitoring and Flood Alert

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Abstract: This project presents the design and development of a hybrid solar-hydro power generation system aimed at providing a sustainable, efficient, and reliable source of electricity for remote and rural areas. The system integrates a floating hydropower unit with a solar photovoltaic (PV) setup to ensure continuous power generation under varying environmental conditions. The hydropower unit utilizes a water turbine coupled with a DC motor which will act as generator to convert the kinetic energy of flowing water into electrical energy, while the solar panel supplements power generation during periods of low water flow or dry seasons. The generated DC power from both sources is regulated and stored in a rechargeable battery, which supplies power through a DC to AC inverter for general household and community use. An ESP32 microcontroller with integrated Bluetooth is used as a monitoring unit, replacing separate Arduino and ESP8266 modules used in earlier designs. This reduces circuit complexity, enhances processing efficiency, and enables real-time monitoring through the Serial Bluetooth Terminal. Additionally, a water level sensor is employed to continuously monitor river or canal levels and provide early flood alerts when unsafe conditions are detected. Alert message is sent via GSM Module. The combination of renewable energy sources, smart monitoring, and storage ensures a stable and uninterrupted power supply with enhanced safety. The proposed hybrid system effectively overcomes the limitations of existing standalone hydropower systems by adding solar energy support and battery backup. It demonstrates the potential of combining multiple renewable energy technologies with Real-time monitoring to achieve reliable, clean, and self-sustained power generation suitable for off-grid applications

***Keywords*: Renewable Energy, Hybrid Power Plant, Real-Time Monitoring, Off Grid, Energy Storage**

I. INTRODUCTION

The increasing global energy demand and the environmental impacts of fossil fuel consumption have accelerated the shift toward renewable and intelligent energy systems. Renewable sources such as solar and hydropower are among the most sustainable alternatives, capable of providing clean, green, and decentralized energy solutions. However, each source has limitations: solar systems depend on sunlight availability, while hydropower systems rely on consistent water flow.

At the same time, frequent floods caused by unpredictable rainfall patterns have become a major environmental concern in many regions. Floods not only damage infrastructure and crops but also threaten lives. Hence, there is a growing need for a dual-purpose system that can both generate renewable power and provide early flood warnings.

This project, titled “Development of Floating Structured Hybrid Power Plant with Remote Monitoring and Flood Alert”, addresses both issues simultaneously. The system generates electricity from a floating hydropower setup and a solar panel, stores excess power in a Lead acid battery, and continuously monitors the water level using a sensor.

An ESP32 microcontroller acts as the brain of the system — controlling power flow, reading sensor data, and transmitting real-time parameters to the Serial Bluetooth terminal. Users can monitor the generated voltage, current, power, load power using a mobile. When the water level rises beyond a predefined threshold, a flood alert SMS is automatically sent.

Thus, the system serves as a sustainable hybrid energy source and a smart flood monitoring unit, ideal for rural, agricultural, and flood-prone regions.

II. LITERATURE SURVEY

[1] Home energy management system concepts, configurations, and technologies for the smart grid

The paper titled “Home Energy Management System Concepts, Configurations, and Technologies for the Smart Grid” by Usman Zafar et al. presents an in-depth study of how Home Energy Management Systems (HEMS) optimize energy usage by integrating renewable sources such as solar and wind with smart control and storage technologies. It highlights the role of IoT- based monitoring, wireless communication, and intelligent controllers in achieving efficient and reliable power management within modern smart grids. The paper's concepts are closely related to the proposed hybrid solar-hydro power plant, which also focuses on combining renewable energy generation with intelligent monitoring and storage. Similar to HEMS, the proposed system employs an ESP32 microcontroller for IoT-based data communication and real-time control, along with a battery storage unit to stabilize energy supply from fluctuating renewable sources. Thus, the study supports the foundation of this project by demonstrating that integrating multiple renewable energy sources with automation and smart monitoring significantly enhances reliability, energy efficiency, and sustainability.

[2] An evaluation of battery degradation and predictive methods under resistive load caused by intermittent solar radiation
The study investigates how battery degradation occurs under the variable charging/discharging conditions typical of solar-irradiation systems, focusing on lead-acid batteries subjected to a resistive load driven by intermittent solar radiation. It compares several lifespan prediction methods—including the coarse average approach, weighted Ah aging model, global battery aging model, and the rain-flow counting (RFC) method—to estimate depth of discharge (DoD), temperature impact, cycle life loss, and remaining lifespan (with estimates ranging between about 8.3 and 8.9 years). In relation to proposed hybrid solar-hydro power plant, the paper's findings highlight the importance of designing the battery storage subsystem carefully—especially in systems with fluctuating input from renewable sources (like solar and hydro) and intermittent loads—and underline how critical it is to monitor DoD, temperature, and cycle characteristics in order to optimize battery longevity and system reliability.

[3] Multi-Objective Sizing of Solar-Wind-Hydro Hybrid Power System with Doubled Energy Storages Under Optimal Coordinated Operational Strategy
In this project, the paper "Multi-Objective Sizing of Solar-Wind-Hydro Hybrid Power System with Doubled Energy Storages Under Optimal Coordinated Operational Strategy" provided valuable insight into how hybrid renewable systems can be optimized for maximum efficiency and reliability. The authors emphasized the importance of balancing multiple energy sources—solar, wind, and hydro—along with enhanced energy storage capacities to ensure continuous power generation under varying environmental conditions. The study used a multi- objective optimization approach to minimize cost and maximize power reliability through coordinated control between generation and storage units. This concept strongly supports the approach taken in the proposed hybrid solar-hydro system, where the combination of two renewable sources and a properly sized battery storage system ensures a stable and uninterrupted power supply. The paper also highlighted that strategic coordination between sources and energy storage greatly improves performance and lifespan, which directly aligns with the design goal of achieving an efficient and sustainable hybrid energy solution for rural electrification.

[4] Prototype Development of an Automatic and Floating Structured Hydropower Plant
In our project, the paper "Prototype Development of an Automatic and Floating Structured Hydropower Plant" provided the fundamental basis for understanding compact and portable hydropower generation using renewable energy. The study focuses on developing a floating hydropower prototype equipped with a Pico-hydro turbine, Permanent Magnet DC (PMDC) generator, and IoT-based monitoring system to generate clean energy from flowing water sources. It successfully demonstrates the use of automation and real-time monitoring through cloud platforms such as Blynk, making renewable energy systems more accessible and efficient for remote and off-grid regions. The prototype achieved a power output of approximately 204 W at 480 rpm, proving its practical viability for small-scale power generation. This research directly influenced our project, as we aim to extend its concept by integrating solar energy, battery storage, and flood alert mechanisms to develop a more reliable and sustainable hybrid solar-hydro power system. Furthermore, by replacing the Arduino and ESP8266 modules used in the existing model with a single ESP32 microcontroller, our design minimizes circuit complexity, enhances processing efficiency, and improves system reliability, making it a more advanced and integrated renewable energy solution.

[5] Eco-Friendly Energy From Flowing Water: A Review of Floating Waterwheel Power Generation
In our project, the paper "Eco-Friendly Energy From Flowing Water: A Review of Floating Waterwheel Power Generation" provided valuable insights into the potential of floating waterwheel systems as a sustainable and eco-friendly method of harnessing energy from natural water flow. The review emphasizes how these systems can generate clean power from rivers, canals, and tidal streams without the need for large dam constructions, thereby reducing environmental impact. It highlights that floating hydropower systems could contribute up to 10% of global renewable energy production, with tidal barrage and floating waterwheel technologies identified as the most efficient due to their predictability and high energy density.

This study aligns closely with our project goals, as we build upon the same concept of renewable energy generation from flowing water while enhancing it by integrating solar energy, battery storage, and remote monitoring monitoring using ESP32. Through this approach, our project aims to develop a more reliable, efficient, and environmentally sustainable hybrid solar-hydro power system suitable for rural and off-grid applications.

III. DESIGN AND COMPONENT SELECTION

A. Load Selection

The first step in the system design is the selection of electrical loads that the system needs to power. In this project, small household loads such as LED light bulbs and mobile phone chargers are considered. LED bulbs typically consume around 5–10 W, while a mobile phone charger requires approximately 20 – 40 W of power. Therefore, the total expected load power is: 20 – 40

B. Floating Structure

First have to consider the weight of components and also should consider the weight of the structure

Weight of,

Battery = 2.3 Kg
Solar Panel = 1.3 Kg
Turbine = 4 Kg
Weight of the supporting structure and electronics will be around 5 kg
Total = 12.6 Kg

PVC pipe is selected for the floating structure.

Length = 75 Cm

Radius = 25 Cm

Two PVC pipes with sealed ends are taken. This will provide enough space to mount all the components.

The maximum payload capacity of the structure is calculated using the Archimedes' principle Volume of a cylinder:

$L = 0.75$ m

$r = 0.25$ m

$V = \pi r^2 L$

$V = 3.1416 * (0.25)^2 * 0.75$

$V = 3.1416 * 0.0625 * 0.75$

$V = 0.147\ m^3$

So one pipe displaces about 0.147 m^3 of water when fully submerged Density of water: ρ=1000kg/m^3 Maximum that can be supported:

$m = \rho V$

$m=1000\times0.147$

$m\approx147$kg

So one PVC pipe can theoretically support about 147 kg if completely submerged.

For two two floating pipes**.**

$147\times2=294$kg

In floating structures, we usually use 50–60% of the maximum buoyant capacity for stability and safety.

Safe payload$\approx0.6\times294$

Safe payload$\approx$176kg

This will be sufficient to float the components even after adding the weight of frame, generator, battery, electronics, and other components

C. Inverter

Since most household appliances operate on 220 V AC, Inverter with 220 V output is selected So that this project have maximum relevance. The load selected is bulb and also phone charger. These loads consume about 20 - 40 watts of power.

A 12 V DC to 220 V AC inverter is selected to power small AC loads from the battery. The inverter used in this project is rated at 200 W output power. Although the practical output power may be slightly lower due to conversion losses, it is sufficient for operating small loads such as LED bulbs and mobile phone chargers.

The relationship between power, voltage, and current is given by:

$P=V\times I$

Where:

P = Power (W)

V = Voltage (V)

I = Current (A)

$I=P/V$

$I=40/12$

$I=3.33$ A

This will be the current drawn from the battery when inverter supplies power to the load. Since the inverter rating is significantly higher than the required load power, it provides sufficient capacity to operate the selected loads safely. The inverter converts the DC power stored in the battery into AC power which can then be used to power the selected electrical loads.

D. Battery

The inverter requires a 12 V DC power source, therefore a 12 V lead-acid battery is selected for the system. The battery used in this project has a capacity of 12 V, 7 Ah. The total energy stored in the battery can be calculated as:

$E=V\times Ah$

$E=12\times 7$

$E=84Wh$

This means the battery can store approximately 84 watt-hours of energy. If the total load is 40 W including the load and the electronics in the system, the approximate operating time of the battery can be estimated as:

$t=E/P$

$t=84/40$

$t\approx 2.1$ hours

Considering inverter losses, the practical operating time will be approximately 2 to 2.5 hours, which is adequate for the intended loads.

E. Hybrid Energy Source Design

The proposed system uses a hybrid power generation approach consisting of a solar panel and a DC generator. Both sources are used to charge the same battery and improve the reliability of the system. Each source is first analyzed individually based on its charging capability, and then their combined operation is considered. The outputs of both sources are connected in parallel through diodes to prevent reverse current flow between them.

1) Solar Charging System

A 12 V, 10 W solar panel is used as one of the energy sources for charging the battery. The rated current of the panel is 0.56 A. The power generated by the solar panel can be calculated using the power equation:

$P = V * I$

$P = 12 * 0.56$

$P \approx 6.72W$

Under ideal sunlight conditions, the panel can generate approximately 10 W of power. The time required to charge the 12 V, 7 Ah battery using the solar panel alone can be estimated as:

t = Battery Capacity/Charging Current

$t = 7/0.56$

$t\approx 12.5$hours

Thus, the solar panel provides a renewable energy source that gradually charges the battery during daylight hours.

2) Generator Charging System

In addition to the solar panel, the system uses a DC generator rated at 18 V, 2 A at 2000 RPM. The generator converts mechanical energy from the turbine into electrical energy. The electrical power produced by the generator can be calculated as:

$P = V \times I$

$P = 18 * 2$

$P = 36W$

Since the generator output voltage is higher than the battery voltage, it is suitable for charging the 12 V lead-acid battery. The generator can provide a maximum charging current of approximately 2 A, which allows the battery to charge faster compared to the solar panel.

$t = 7/2$

$t \approx 3.5$hours

Thus, the generator acts as a secondary energy source that can charge the battery when sufficient water flow is available.

3) Hybrid Charging Operation

When both the solar panel and the generator produce similar output voltages, both sources can contribute charging current to the battery, increasing the total charging power. However, if the voltage of one source becomes significantly lower than the other, the higher voltage source dominates the charging process while the other source temporarily stops supplying current.

When both sources operate simultaneously with similar output voltages, the total charging current supplied to the battery is approximately the sum of the individual source currents:

$I_{total} = I_{solar} + I_{Generator}$

$I_{total} = 0.56 + 2$

$I_{total} \approx 2.56$ A

The combined power available from the hybrid system is:

$P_{total} = P_{sola}r + P_{generator}$

$P_{total} = 10+36$

$P_{total} = 46$ W

F. Gear System Design

A gear transmission system is used to transfer mechanical power from the turbine to the generator while increasing the rotational speed of the generator shaft. In this system, a large gear is connected to the turbine shaft and a smaller gear is mounted on the generator shaft. When the turbine rotates, it drives the large gear, which in turn drives the smaller gear attached to the generator. Because the driven gear is smaller, the generator shaft rotates faster than the turbine shaft.

The relationship between the rotational speeds of two gears is determined by the gear ratio, which can be expressed as:

Gear Ratio=Ndriven/Ndriver=ωdriver/ωdriven

Where

N = number of teeth on the gear

ω = rotational speed (RPM)

In this system, a gear ratio of 1:9 is used. This means that for every one rotation of the large gear, the smaller gear rotates nine times. Therefore, the speed of the generator shaft becomes:

Ngenerator=9 * Nturbine

The generator used in the system is rated to produce its specified output at approximately 2000 RPM. Therefore, the required turbine speed to achieve this generator speed can be calculated as:

Nturbine = Ngenerator/9

Nturbine=2000/9

Nturbine ≈ 222 RPM

This means that even if the turbine rotates at approximately 222 RPM, the gear mechanism can increase the speed to about 2000 RPM at the generator shaft, allowing the generator to operate near its rated condition.

Another important relationship in gear systems is the torque-speed relationship. Mechanical power is given by:

$P = T \times \omega$

Where
P = Mechanical power
T = Torque
ω = Angular speed
Since power is approximately conserved in the gear system (ignoring small losses), an increase in speed results in a decrease in torque. Therefore, when the gear system increases the generator speed by a factor of 9, the torque at the generator shaft becomes:
Tgenerator = Tturbine/9
This means the generator rotates faster but receives lower torque. This arrangement is suitable because turbines generally produce high torque at low speed, while generators require higher rotational speed to generate electrical power effectively.
Thus, the gear system helps match the low-speed rotation of the turbine with the high-speed requirement of the generator, enabling efficient conversion of mechanical energy into electrical energy in the hybrid power generation system.

IV. WORKING PRINCIPLE

The working of the power plant can be explained easily by using the a block diagram for that a block diagram is given below.
The system is a floating hybrid power plant that generates electrical energy using two renewable energy sources: solar energy and hydro-mechanical energy. The generated energy is stored in a battery and later converted to AC power for operating small household loads. The system consists of a solar panel, Pelton wheel turbine, DC generator, gear mechanism, charge controller, battery, inverter, and monitoring electronics. The hybrid arrangement ensures that electrical energy can be produced under different environmental conditions.
The solar power generation part of the system uses a 12 V, 10 W solar panel with a rated current of 0.56 A. The solar panel converts solar radiation into electrical energy using the photovoltaic effect. When sunlight falls on the panel, it produces DC electrical power which is supplied to the charging circuit. This power is used to charge the battery during daylight conditions. Since solar power output varies depending on sunlight intensity, the system also includes an additional energy source to improve reliability.
The hydro-mechanical energy generation is achieved using a Pelton wheel turbine with six buckets. When water flows and strikes the buckets of the turbine, the kinetic energy of the water is converted into mechanical rotational energy. The turbine shaft is connected to a gear mechanism which increases the rotational speed before driving the generator. The generator used in the system is a DC generator rated at 18 V, 2 A at 2000 RPM, which converts the mechanical rotation into electrical energy.
A gear system with a gear ratio of 1:9 is used to increase the rotational speed of the generator shaft. The large gear connected to the turbine drives a smaller gear attached to the generator shaft. This arrangement multiplies the rotational speed so that even if the turbine rotates at a relatively low speed, the generator can reach the required speed close to 2000 RPM to produce electrical output efficiently.
The outputs of the solar panel and the generator are combined in a hybrid configuration. Both sources are connected in parallel through diode isolation to prevent reverse current flow between them. The combined output is then supplied to a solar charge controller. The charge controller regulates the charging process and protects the battery from overcharging and voltage fluctuations. It ensures that the battery receives a safe charging voltage and current.
The generated electrical energy is stored in a 12 V, 7 Ah lead-acid battery, which acts as the main energy storage unit in the system. The battery stores approximately 84 Wh of energy and supplies power to the loads when generation sources are unavailable or when additional energy is required.
For operating AC loads, the stored DC energy from the battery is converted into AC power using a 12 V to 220 V inverter rated at 200 W. The inverter converts the low-voltage DC from the battery into standard AC power suitable for household devices. This AC output can be used to power small loads such as LED light bulbs and mobile phone chargers.
The system also includes monitoring and control components. A buck converter module (LM2596) is used to step down the 12 V battery voltage to 5 V, which is required for powering electronic modules. An ESP32 microcontroller is used for monitoring generated voltage and current, while an ACS712 current sensor measures the current produced by the system. These measurements help in calculating the generated power, load power and monitoring the system performance.
In addition to power generation monitoring, the system also includes a flood alert mechanism. An HC-SR04 ultrasonic sensor is used to measure the water level by calculating the distance between the sensor and the water surface. An Arduino Uno microcontroller continuously monitors this water level data. When the measured level exceeds a predefined threshold value, the controller activates the SIM800L GSM module to send an SMS alert to a predefined mobile number. This feature helps provide early warning in case of rising water levels.

Overall, the working principle of the system involves hybrid energy generation, regulated battery charging, energy storage, DC to AC power conversion, and system monitoring. By integrating solar and hydro power sources with energy storage and communication modules, the system ensures reliable energy generation while also providing environmental monitoring capabilities.

V. RESULTS AND ANALYSIS

A. Introduction

This chapter highlights the results of the hybrid solar– hydropower system. The system's design ensures continuous energy generation, cost- effectiveness, and environmental sustainability. The combination of Real time remote monitoring and flood detection adds intelligence and safety, making it suitable for various practical uses in rural, agricultural, and emergency situations.

B. Observations

These are the observations our team had observed from this project. The results are shown here from each measurement phase of "Development Of Floating Structured Hybrid Power Plant With Remote Monitoring And Flood Alert". As the project is a prototype version, the values may vary a bit depending on the circumstances.

1) Solar Panel Alone

As we can see the charge controller shows a reading of 14.4V. This value is the measurement of the solar panel alone that also powers the components like the ESP32, Arduino UNO, etc…. without connecting to the battery at all.

Fig 5.1: Reading from Charge Controller

2) Battery Voltage

The battery used was a 12V Lead Acid battery. As we can see the digital multi-meter shows a reading of 15.8V. This value is the measurement of the battery. So in addition to this when the solar panel was showing 13.1V in the charge controller, now it shows 13.7V. so a change has been observed when these were done.

Fig 5.2: Reading from Digital Multi-Meter

3) Generator

Here when turbine is spun it produces a current of 160mA at low RPM as shown in the multi-meter and the charge controller changes from 12.9V to 13.1V.

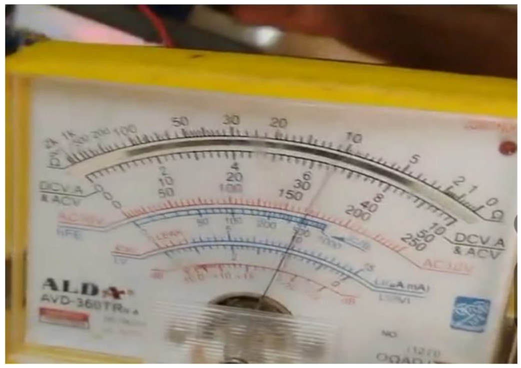

Fig 5.3: Current Reading of Generator from Multi-Meter

Fig 5.4: Before Generator spinning

Fig 5.5: After Generator spinning

4) Solar Panel Current Measurement

As we can see the current is being measured of the solar panel and shows a reading. Before exposing the panel to the sunlight, it shows an ampere of 2mA and when the panel is exposed to the sunlight it shows a reading of 10mA at low sunlight.

When placed under the sun the panel gives a voltage of near 20V, and when the load is connected to the panel it gives a voltage of 15V.

Fig 5.6: Panel not Exposed

Fig 5.7: Reading Taken (Not Exposed)

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Fig 5.8: Panel Exposed

Fig 5.9: Reading Taken (Exposed)

C. *App Interface*

As shown in here, this is the app interface where we view the stats of load current, source voltage, source current, load power, etc.… This is the real time remote monitoring app of our system.

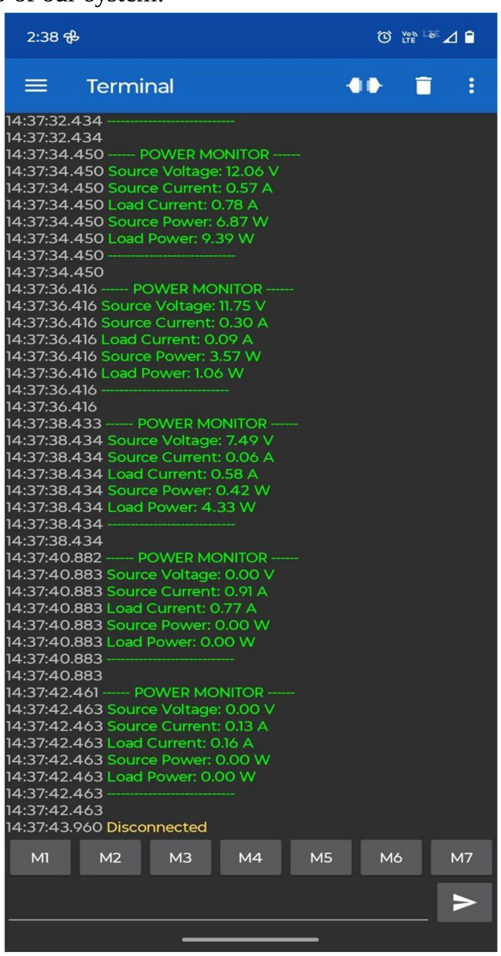

Fig 5.10: App Interface

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D. Flood Alert system

The ultrasonic sensor based flood alert system continuously monitor the water level and sent the flood alert as SMS when water level exceeds certain level. The working of this system is tested.

For the testing the safe water level is put as 20cm. When the water level exceeded the 20cm the alert message received as SMS. The message is sent by the SIM put in the GSM module and message received in the number we set.

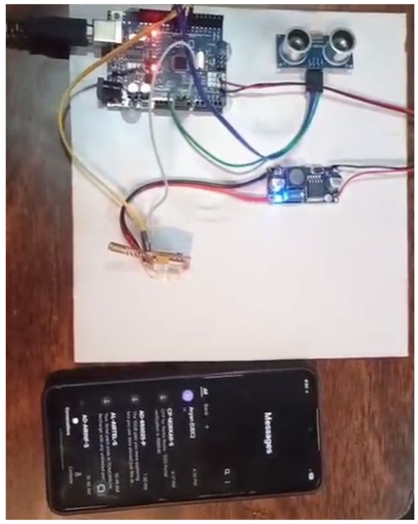
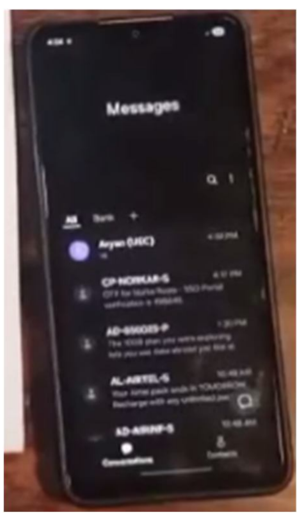
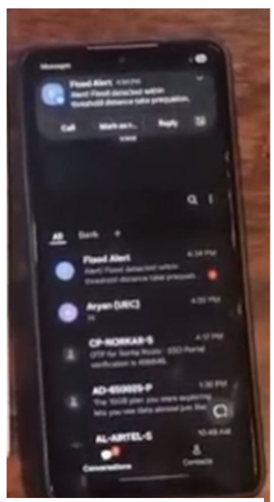


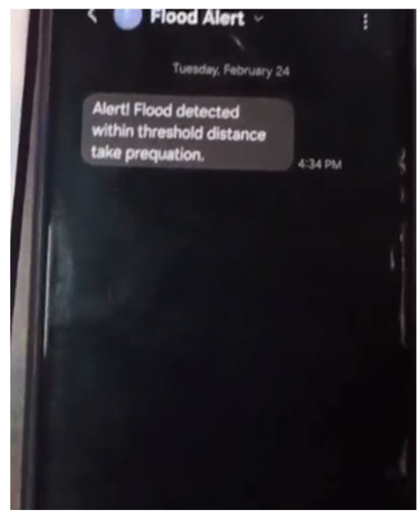
Fig 5.11 Flood alert system



5.12 Interface of SMS App Before Alert Message Is Sent



5.13 Interface of SMS App After Alert Message is Sent



5.14 Alert Message Sent By The Flood Alert System

Thus, from the observations it is clear that the flood alert system works well and sent alert messages when conditions are met.

VI. CONCLUSION

The proposed hybrid solar–hydro power system successfully combines two renewable energy sources to create a reliable, efficient, and sustainable method of power generation. By integrating solar panels with a floating hydropower setup, the system ensures continuous energy production throughout varying environmental conditions. The inclusion of a battery storage unit allows excess energy to be stored and used later, providing a steady and uninterrupted power supply even during periods of low water flow or limited sunlight. The inverter converts the stored DC power into AC, making the generated energy suitable for domestic and community applications.

The introduction of the ESP32 microcontroller with built-in Wi-Fi replaces multiple separate control units, minimizing component count and circuit complexity while enabling real- time Real time remote monitoring through the Blynk platform. The integration of water level sensors further enhances the safety of the system by providing flood alerts when water levels exceed safe limits. These technological improvements make the system compact, intelligent, and user-friendly, ensuring both operational reliability and safety.

Overall, the project demonstrates a practical approach to solving the challenges of power generation in remote and rural areas. It promotes the efficient use of natural resources, reduces dependency on conventional energy sources, and contributes to environmental protection by producing clean energy with zero emissions. The system's simplicity, scalability, and low maintenance requirements make it a cost-effective solution for sustainable electrification.

In conclusion, this hybrid solar–hydro power system represents a step toward the future of renewable energy integration. With further advancements such as AI-based control, improved storage technology, and large-scale deployment, the concept can evolve into a robust and intelligent energy infrastructure capable of meeting growing global energy demands while supporting a cleaner and greener planet

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