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Hybrid Solar-Powered RC Aircraft for Enhanced Flight Endurance

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Abstract:** This paper presents the design and development of a* hybrid solar powered RC aircraft ***aimed at improving flight endurance by utilizing renewable energy sources. Conventional RC aircraft rely primarily on batteries as their power source, which limits the flight duration due to the restricted energy storage capacity of the batteries. To address this limitation, a hybrid energy system consisting of solar cells and batteries is proposed to enhance the aircraft's operational endurance.
A fixed wing RC aircraft is used as the platform for implementing the proposed hybrid system. Photovoltaic solar cells are mounted on the wings of the aircraft to harvest solar energy during flight. The harvested solar energy can be utilized both to power the aircraft and to recharge the battery using a *Maximum Power Point Tracking (MPPT) charge controller****. The proposed design focuses on achieving an optimal balance between solar energy generation and battery storage to ensure efficient system performance. Experimental results indicate that the proposed solar-powered RC aircraft significantly reduces the battery discharge rate, thereby improving the overall flight endurance of the aircraft. Previous studies have reported up to a*** *22.5% reduction in battery consumption* ***for solar-assisted RC aircraft operating under favourable environmental conditions.***

I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) have become increasingly important due to their wide range of applications, including surveillance, environmental monitoring, agriculture, disaster management, and communication systems. Since these systems operate without onboard human presence, they offer advantages such as improved safety, reduced operational cost, and the ability to function in hazardous or inaccessible environments. However, one of the major limitations of conventional UAVs is their limited flight endurance, which is primarily restricted by the energy capacity of onboard batteries. Increasing battery size is not an effective solution, as it adds extra weight, leading to higher power consumption and reduced overall efficiency.

To overcome this limitation, alternative energy sources have been explored, among which solar energy has emerged as a promising solution. Solar-powered UAVs utilize photovoltaic (PV) cells mounted on the aircraft surface to capture solar radiation and convert it into electrical energy. This energy can be used to power the aircraft and simultaneously charge the onboard battery, thereby reducing dependency on stored energy and improving flight duration. Experimental studies have demonstrated that integrating solar energy systems into UAVs can significantly reduce battery usage and enhance overall performance.

The implementation of solar-powered UAV systems involves combining photovoltaic modules, battery storage, and an effective power management setup. In this approach, a conventional RC aircraft can be adapted by integrating solar panels to utilize renewable energy during flight. This integration helps in improving energy usage and extending flight duration. Additionally, proper energy distribution and basic system design play an important role in achieving stable performance and efficient operation of the aircraft.

In this project, a charge controller is used to regulate the power generated by the solar panels. The controller ensures stable voltage output, protects the battery from overcharging, and maintains proper energy flow between the solar panels, battery, and load. Proper placement and alignment of solar panels are also considered important to maximize solar energy absorption during flight.

Despite these advancements, many existing solar-powered UAV systems are complex and expensive, making them less suitable for small-scale or academic applications.

Therefore, this work focuses on the development of a hybrid solar-powered RC aircraft that combines solar energy with battery storage in a simple, cost-effective, and efficient manner. The proposed system integrates lightweight solar panels, a battery unit, and a power management system while maintaining minimal structural modifications.

The primary objective of this research is to demonstrate the effective utilization of solar energy to enhance UAV flight endurance while ensuring simplicity and affordability. This approach contributes to the development of sustainable and environmentally friendly aerial systems, supporting global efforts toward the adoption of renewable energy technologies.

II. METHODOLOGY

The hybrid solar-powered RC aircraft is developed using an integrated design approach that combines structural configuration, solar energy capture, power regulation, and performance analysis. The methodology is organized in a step-by-step manner to ensure optimal use of solar energy while maintaining stable and reliable flight operation.

In general, solar-powered UAVs include key components such as photovoltaic panels, energy storage systems, and power control units that manage energy distribution during flight. The proposed methodology follows these fundamental design concepts while adapting them for efficient hybrid operation.

A. System Design and Architecture

The aircraft is initially developed using lightweight materials to achieve an optimal lift-to-weight ratio, which is essential for efficient flight. The propulsion unit, including a brushless DC (BLDC) motor, propeller, and electronic speed controller (ESC), is selected based on the required thrust and performance criteria.

For better design and analysis, the complete system is categorized into the following subsystems:

1) Airframe structure
2) Propulsion unit
3) Power generation unit
4) Energy storage unit

B. Solar Energy Integration

Photovoltaic panels are installed on the wings to capture maximum sunlight during flight. These panels convert solar radiation into electrical energy, which is utilized to support the aircraft's power requirements.

To enhance energy extraction, a Maximum Power Point Tracking (MPPT) controller is incorporated. This controller adjusts operating conditions to obtain the highest possible output from the solar panels under changing sunlight intensity, thereby improving system efficiency.

C. Hybrid Power System Integration

The proposed model operates on a hybrid energy system that combines solar power with battery storage. The system includes:

1) Solar panels as the primary energy source during daytime
2) Battery as a secondary source for backup and energy storage

During operation, solar energy is first used to run the aircraft. Any surplus energy generated is stored in the battery. When solar power is insufficient, such as during low light conditions, the battery supplies the required energy.

This combined approach ensures stable and continuous operation of the aircraft.

D. Energy Management Strategy

Efficient energy management is essential for increasing flight duration and overall system performance in solar-powered UAVs.

A rule-based control method is implemented to regulate power flow between the solar panels and the battery. The system continuously monitors parameters such as solar output and battery charge level to decide the mode of operation. Based on these conditions, it dynamically switches between direct solar usage, battery charging, and battery discharging to maintain optimal performance.

III. CIRCUIT ANALYSIS

The circuit of the hybrid solar-powered RC aircraft consists of a solar panel, charge controller, battery, ESC, motor, and control system. The solar panel generates DC power, which is regulated by the charge controller to maintain a stable voltage level and prevent battery overcharging. The regulated output is supplied to the battery and propulsion system.

The ESC controls the speed of the BLDC motor based on input signals from the receiver. The motor converts electrical energy into mechanical energy to produce thrust. The receiver and servos are powered through the battery via the ESC's Battery Eliminator Circuit (BEC).

The output of the solar panel varies depending on sunlight intensity. During high irradiance conditions, solar energy is used to power the system and charge the battery simultaneously. In low sunlight conditions, the battery provides the required power to maintain continuous flight.

Some power losses occur due to resistance in wiring and heat dissipation in electronic components. However, the hybrid configuration improves overall system efficiency by reducing the load on the battery and optimizing energy utilization.

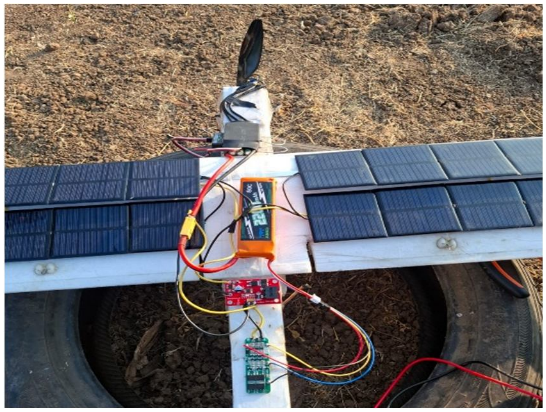

Fig.1:Actual circuit diagram

A. Energy Flow and System Operation

The overall operation of the hybrid solar-powered RC aircraft is illustrated in Fig. 2. The system begins with the solar panel, which converts solar energy into DC electrical power. This generated power is supplied to the charge controller, which regulates the voltage and ensures safe operation of the system. The regulated output from the charge controller is divided into two paths. One path is directed towards the energy storage unit, where the battery stores excess energy for later use. The second path provides direct power to the electronic speed controller (ESC), enabling immediate utilization of solar energy for propulsion.

The ESC plays a key role in converting and controlling the electrical power supplied to the brushless DC (BLDC) motor. Based on control signals, the ESC adjusts the motor speed, which in turn drives the propeller. A power distribution unit manages the flow of energy between the battery and the propulsion system. When solar energy is sufficient, it powers the system directly and charges the battery. During low solar conditions, the stored energy in the battery is supplied to maintain continuous operation.

The BLDC motor converts electrical energy into mechanical energy, which rotates the propeller to generate thrust. This thrust enables the aircraft to achieve and sustain flight. This energy flow mechanism ensures efficient utilization of solar power while maintaining reliable and uninterrupted operation of the UAV.

B. Flow chart

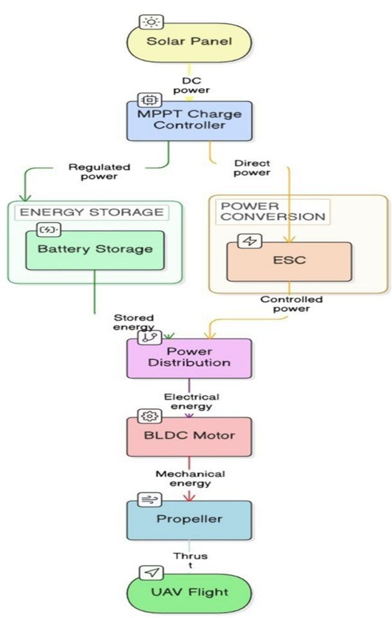

Fig.2: Block Diagram of Hybrid Solar Powered RC Aircraft System

IV. RESULTS

The performance of the proposed hybrid solar powered UAV system was evaluated through both ground testing and flight testing. The primary objective of these tests was to assess the effectiveness of solar energy integration in enhancing flight endurance and reducing dependency on battery power.

A. Ground Test Results

The initial testing was carried out under direct sunlight conditions to verify the operation of the photovoltaic system and the charge controller unit. The solar panels successfully generated electrical energy, and the charge controller regulated the output to safely charge the battery. It was observed that the battery voltage increased when the motor was not in operation.

B. Flight Test Results

Flight tests were conducted for the UAV with and without the solar power system. The observations from the flight tests are as follows:

- The rate of battery discharge was reduced considerably for the solar power system.
- The UAV showed an increase in flight duration compared to normal battery operation.
- The solar panel helped provide power for the UAV’s propulsion system under favorable sunlight conditions.
- Smooth and continuous flight was ensured for the UAV with the solar power system, even with varying solar intensity.

This is in line with previous studies, which showed that solar-powered UAVs showed a reduction in battery consumption of up to 22.5%.

C. Performance Analysis

The integration of solar panels did not significantly affect the aerodynamic performance or flight stability of the UAV. Although the solar panels added some additional weight to the system, this was compensated by the continuous generation of electrical power during flight. The Maximum Power Point Tracking (MPPT) system played a crucial role in maximizing the energy efficiency of the solar power generated and utilized by the UAV.

Based on the experimental results, it can be concluded that the proposed hybrid system improves the overall flight endurance of the UAV while enhancing energy utilization efficiency and reducing dependency on battery power. The results also demonstrate that the integration of solar energy is a feasible and effective solution for improving the performance of small scale UAV systems.

Parameter	Without Solar System	With Solar System	Observation
Flight Time (minutes)	12 min	~15 min	Increased endurance
Battery Voltage Drop	High	Lower	Slower discharge
Current Consumption	Higher	Reduced	Efficient usage
Power Source	Only Battery	Solar + Battery	Hybrid advantage
Charging During Flight	Not Possible	Possible	Continuous energy
Stability	Stable	Stable	No major impact
Weight (grams)	Lower	Slightly Higher	Acceptable increase
Efficiency	Limited	Improved	Better performance

V. CONCLUSION

This study presented the design and development of a hybrid solar powered unmanned aerial vehicle (UAV) intended to enhance flight endurance using renewable energy. The proposed system integrates photovoltaic (PV) cells with a battery-based energy storage unit to provide a continuous and reliable power supply during flight, thereby reducing reliance on conventional battery power.

An efficient charge controller (MPPT) system was incorporated to maximize the electrical energy extracted from the solar panels under varying environmental conditions. Experimental observations showed that the integration of solar energy significantly reduced the battery discharge rate while extending the overall flight duration of the UAV. Additionally, the inclusion of solar panels did not adversely affect the aerodynamic stability or operational performance of the aircraft.

The results indicate that hybrid solar assisted UAV systems offer a practical and cost-effective approach for improving the endurance of small scale unmanned aerial platforms. Future research may focus on improving photovoltaic efficiency, optimizing aircraft aerodynamic design and implementing advanced energy management techniques to further enhance system performance.

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