AN EXPERIMENTAL STUDY ON THE PERFORMANCE OFMANUFACTURED SOLAR POWERED UNMANNED AERIAL VEHICLE (UAV)

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Abstract: Developing aerial technologies allows researchers to find better solutions for the flying performance of unmanned aerial vehicles (UAV's). In addition to this, renewable energy technologies are getting more convenient day-by-day. Among renewables, solar power is generally the best way to produce clean and sustainable energy. In this experimental study, an UAV is developed by supplying from materials available in the marketplace. This quadcopter UAV has a GPS unit, Arduino microcontroller circuit with gyro-magnetic sensors, four motors with drivers, four propellers and one RF receiver with remote controller. In this paper, it is aimed to see the effect of directly connected PV (Photovoltaic) module to the battery system of the vehicle on its performance. Performance tests are realized with and without the PV module. Statistical analysis is performed with the voltage values from the experiments. Finally, the results are illustrated, compared and disccussed.

Keywords: Unmanned Aerial Vehicle, Solar, PV, Charging, Statistical Analysis

INTRODUCTION

Unmanned aerial vehicles are now widely used in many areas. It is available for use in monitoring, defense systems, trade, electrical malfunction, even in agricultural irrigation. It saves people time and money. While performing all these features, it takes the energy from the battery on it. These batteries mostly come from li-ion, li-pol battery types. Vehicles that are of great importance for being light due to being an aircraft are trying to keep the battery dimensions as small as possible. This situation causes less flying time duration. In order to increase this flying time, there are many studies.

Lin et al. (2014) developed a monitoring system to observe the energy tracking in solar powered UAV [1]. The output power of UAV solar panels reaches 481.12W. The calculated output power of 513.70W based on the aircraft attitude through software simulation is in line with the theoretical value. The accuracy and reliability of the energy monitoring system is verified.To increase the durability flight capacity of the solar-powered IMA, Lee et al. (2015) optimize the flight path by controlling the flight height and using the potential of gravity through control of the aircraft attitude[2]. The energy model includes sun position, aerodynamic behavior and aerodynamic characteristics, and the effect of air height and atmospheric transmission is considered according to flight altitude change.

The application of the solar-powered flight to unmanned aerial vehicles (UAVs) powered by small-scale solar energy has seen infrequent research activity and is only partially explored. The use of solar energy as an energy source allows multi-day flight by extending the over-24-hour flight times of smaller UAV's carrying heavier, more powerful sensor loads[3]. Morton et al. (2015) focuses on the latest developments made by the Distributed Robots Center on a four-meter flanked solar UAV designed for low-altitude air detection applications. Emphasized in this article, solar energy system and body performance measurements, aircraft, drive and electronic equipment design as well as experiments are directions.

Oettershagen et al. (2016) presents the design of the AtlantikSolar UAV, powered by small-scale, manually operated solar power, and summarizes flight results for the 28-hour uninterrupted solar energy demonstration of Atlantiksolar's energetic continuous flight capability and offers flight-based model verification[4]. The performance and appearance of energy margins that can be offered on a continuous basis with UAV technology working with solar energy today. Ruben D'Sa et al. (2016) presents an improvement in solar powered UAV robot design with a modular aircraft, hybrid drive system optimization and solar energy electronics [5]. This robot is produced for the independent testing of two prototypes, fixed-wing and four-rotor aircraft.

In addition to the solar UAV studies in the literature [6]–[8], this study focused on designing an economical solar powered UAV and the performance test of this vehicle. Firstly, the structure step of the UAV is explained. Neither an MPPT (maximum power point tracking) algorithm nor a DC-DC converter is not used in this principal design to test the results. Solar panels are connected to the system directly. Voltage changes are observed with and without solar panels and compared in the results section.

In this study, an unmanned vehicle is built to imptove the fly duration of the vehicle a PV system is

positioned on a suitable place of the vehicle. The vehicle and the conducted solar module is introduced in Section 2. The meterials, built process and control mechanisms of the vheicle are also demonstrated in this section. The results are provided and discussed in Section 3. Finally the conclussion of the study is summurized at the last section.

DETAILS EXPERIMENTAL

2.1. Materials and Procedures

It is a difficult job to supply a balance for a UAV to let it fly on the air, properly. However, thanks to the developed technology, it is possible to find optimized parts for an UAV on the market. Among those in this study one of the manufacturers products are chosen and obtained. It is aimed to conduct solar energy on the UAV. By this way it is aimed to get the vehicle on the air longer compared with the vehicle without PV.Light and strengthen plastic materials are chosen for the body of the UAV. Balanced and light weight is very significant for an air vehicle. Construction step of the vehicle is shown in Fig. 1.

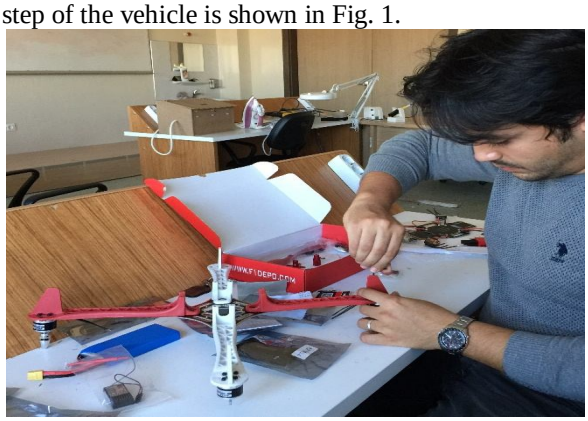

Fig. 1. Construction phase of UAV

Complete version of the UAV is shown in Fig. 2. As seen from the figure, the UAV has a four propellers, quadcopter. Gyro sensors are in the control circuit and the round GPS sensor is standing on a stick on the UAV. Developable UAV has arms with holes to stick some other equipment for being light. To energize the UAV, 11.1 V 3000 mAh Li-Pol battery is selected due to its light weight and high current potential.

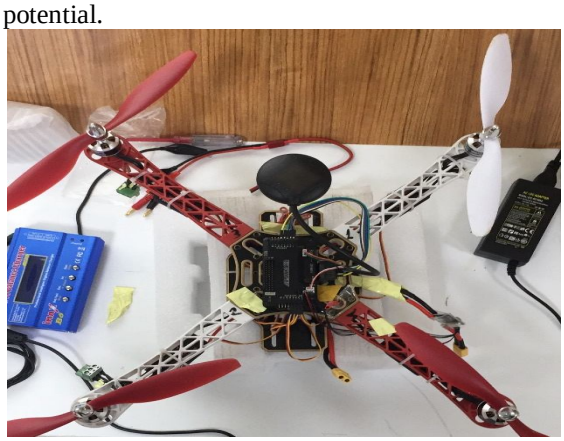

Fig. 2. Final Version of UAV without PV panels

2.2. UAV Controller System

Being an Arduino Mega based control card, Arducopter(APM 2.6) is chosen to control the flight system of the UAV. APM is an Arduino Mega based control card. The card has ATmega2560 microcontroller and ATmega32u2 microcontroller for USB-Serial conversion. In addition to microcontrollers, sensors such as the accelerometer, gyroscope, barometer and magnetometer required for autonomous motion are also integrated on the card. The required ESC and servo connections for the vehicle are located on the card. Ready connectors for external sensor and telemetry connections are located on the card. It is an easy-to-find equipment and relatively cheaper one in the marketplace. The control scheme of the UAV is illustrated in the Fig.3.

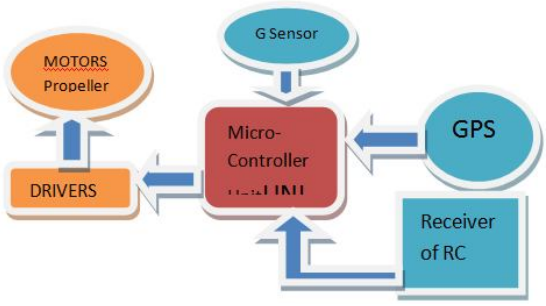

Fig. 3. Control Scheme of the UAV with IO's

2.3. Solar Power Integration

In this experimental study, two 1 W, 6 V, 105x66 mm size solar panels are used to support the Li-Po battery. They connected in series together and parallel to the battery of the UAV. Under good solar radiation such as 1000 W/m², it gives nearly 12,8 V totally. This voltage is adequate to charge the 11,1 V Li-Po battery. Two arms are selected to put these PV's.

RESULTS AND DISCUSSION

3.1. Testing the Battery Performance

With a portable digital oscilloscope, the solar powered UAV is tested under the sun as shown in the Fig. 4. Same starting voltage, 11,3 V, is set on the battery charge process. Time duration is determined as 20 minutes equally for each experiments.Scope is set to collect 333 data per minute.

Experiments are occurred on the earth without propellers because same conditions should be provided. In case of flight test, providing completely same conditions are not very possible in the outdoor and GPS unit doesn't work very suitable to hold the UAV in the same position. Every motion requires energy. In the future studies, these experiments should be done during the flightwith better GPS solutions and nearly same weather conditions. This study aims to see the effect of directly connection of PV to the battery.



Fig. 4. Voltage Drop Comparison of solar powered and normal UAV

System voltages are measured for each experiments and saved to compare the PV panel effect and drawn in the Fig. 5. According to cloud situation, PV panel voltage is waving sometimes. This causes more losses for the total energy. The experiments are occurred at the noon under 1000 W/m² solar radiation approximately.

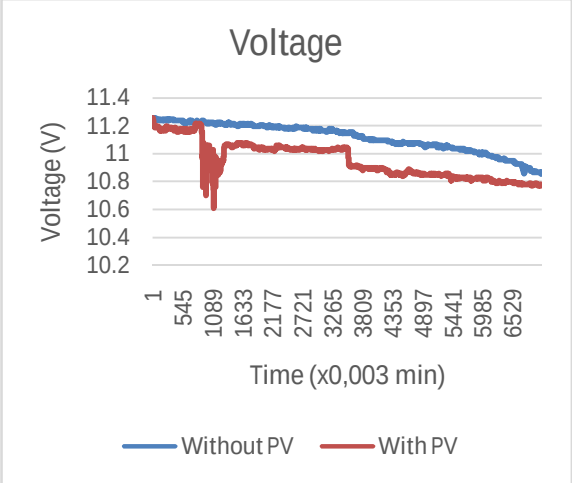

Fig. 5. Voltage Drop Comparison of solar powered and normal UAV

3.2. Statistical Values of Voltages

There are some statistical values shown in Table 1. Standart deviation and variance values show that battery voltage of the vehicle with PV change more than without PV usedvehicle.Minimum value gives us the last (end) voltage of the experiment. Maximum voltages should be the same because of the procedure. According to mean value and the median of the voltages, UAV without PV has higher voltages.

Table 1. Statistical Values of Voltages

	Standart Dev.	*Variance*	*Min*	*Max*	*Average*	*Median*
With PV	0,13	0,02	10,61	11,26	10,96	10,91
Without PV	0,10	0,01	10,86	11,26	11,12	11,16

CONCLUSIONS

This study presents the construction phase of a solar powered UAV and its voltage test under the sun. In this study, PV panels are connected to the battery voltage directly. It is economical way instead of buying power electronic circuits and also it is lighter way for the weight control. However it is obtained that, using the PV without a control unit has important disadvantages such as; voltage drop under the load and life reducing effect for the batteries. Therefore it is critical to use control units in case PV is positioned on the UAV. Otherwise due to the atmospherical effects such a sudden cloud occurance, the voltage of the PV decrease dramatically. Hence, the PV starts to behave as a load for the battery. The results claim that a DC-DC converter with maximum power point tracker (MPPT) is very necessary to have better results. Testing the performance of the PV powered UAV including a DC-DC converter with MPPT algorithm and testing different MPPT algorithms can be regarded as future studies.

ACKNOWLEDGMENTS

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