Development of an Alternative Battery Charging for Remotely Piloted Aircraft Location System Based on Photovoltaic Cells

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Abstract. Remotely piloted aircraft (RPA) has proven to be an important tool for environmental research, natural disaster monitoring and safety promotion. This equipment is quite versatile, but eventually there are intercurrences that lead to accidents. In these cases, the GPS system associated with RPA navigation provides information necessary for its rescue. When this system becomes inactive due to lack of electrical energy, the recovery of the equipment is very complicated or impracticable. In this work we present the initial results of the development of a conditioning circuit of the energy generated by the PC (Photovoltaic Cells) for charging the battery responsible for the GPS of the RPA.

1. Introduction

The use of remotely piloted aircraft (RPA) or drones in research activities has increased according as technological evolution, making it financially attractive. Recently, surveys ranging from vegetation monitoring and atmospheric data collection [1] to analysis of areas affected by natural disasters [2] evidence of the scientific interest in this tool. Other examples of applications of RPAs can be find in the literature [3]. However, some challenges related to autonomy and recovery of RPAs deserve special attention.

In a normal flight, several problems can occur. Since batteries power these devices, commonly with 25 minutes of autonomy, falls are a constant concern. In these cases, a GPS (Global Position System) device that can, during navigation, assists in the flight and indicate the region of the fall, allowing the drone recovery. However, a RPA battery charges the GPS, and its short duration may interfere an affective recovery effort.

In the face of this problem, this work proposes the implementation of an alternative energy generation system bases on Thin Film Solar Cells (TFSC) for an extra battery, exclusively responsible for power supply the drone GPS system (developed in this laboratory). Therefore, it is expected that even in an event of an accident with the main battery depletion, the positioning system will remain active, sending information of the drone coordinates, thus enabling the rescue of the device.

2. Methods

The solar cells are coupled to the outer structure of the drone to capture solar irradiation. The circuit developed in this work will be coupled inside the drone and will be responsible for providing
stable voltage levels and protecting the overvoltage and overcurrent battery. The figure 1 below represents a basic outline of how the entire system will look.

![Figure 1. Project flow chart.](image)

In order to characterize all the components necessary for the implementation of the GPS power system, experimental tests were carried out on the battery and photovoltaic cells of the system. In this way, it is possible to know and ratify some electrical parameters of interest such as, maximum electric voltage generated, time of loading and discharging of the battery. In addition, a complementary electronic circuit was developed and tested to integrate the generation and storage of the electric power of the proposed system. The characterization of the system components (2.1.1 and 2.1.2) and the description of the developed electronic circuit (2.2) is described below.

### 2.1.1 – Battery Characterization

In order to estimate the GPS autonomy time, the battery model used was ZIPPY COMPACT 500 25C Series, 3 cells with 11,1V, 500mAh.

Two tests were performed with two different batteries (same model), a 75 Ω resistor was coupled to simulate the resistance of the electronic circuit of the GPS. As a precaution, a digital multimeter (± 0,5% + 3d) was used in order to the battery did not discharge below a minimum limit specified by the manufacturer, since below this level, the battery could be damaged and a power resistor to resist picking and dissipating the charge in the form of thermal energy.

### 2.1.2 – Solar Cells Characterization

The weight and flexibility of Thin Film Solar Cell (TFSC) were determinant for its use in this work. In a drone, adding weight can compromise aerodynamics, while its flexibility ensures a better use of the drone area. The TFSC are based on materials that strongly absorb sunlight so that the cells can be very thin (1µm – 3µm) [4].

To verify the information provided by the manufacturer, a first laboratory test was performed in order to obtain the Current vs. Voltage curve. The measurements were carried out in semiconductor analyzing equipment, varying the voltage at equal intervals, under a light with irradiance of 1,000 fixed sun. Once the parameters provided by the manufacturer were confirmed, the photovoltaic cells were characterized under real operating conditions (under sunlight). The tests were carried out on the campus of the Pontifical Catholic University of Rio de Janeiro (PUC Rio), located in the neighborhood of Gávea, Rio de Janeiro. This test was performed at 13:00 hours (Brasília time), with temperature around 30°C. With the aid of a multimeter, the current was measured for a resistance of 100 Ω and the open circuit voltage.

A total of 10 photovoltaic cells were used. The tests occurred for different configurations of mixed arrangements (in series and in parallel) of the photovoltaic cells. In these tests the behavior of a string with 2 photovoltaic cells was tested under 4 different arrangements in parallel (2 strings in parallel, 3 strings in parallel, 4 strings in parallel and 5 strings in parallel).
2.2 - Developed Electronic Circuit

Since a voltage generated by the cells is not stable, we have created an electronic circuit. This circuit is also responsible for amplifying and controlling the voltage supplied by the photovoltaic cells, protects also the battery from over-voltage and over-current. In this way, this circuit works allowing the charging of the battery responsible for the GPS.

For the construction of this prototype, it was used electronic components such as resistors, operational amplifiers, transistors, regulators and voltage converters.

Figure 2 presents the schematic of the electronic circuit prototype developed for this work. This circuit aims to electrically protect the drone, as well as provide controlled levels of current and voltage for charging the battery responsible for the operation of the GPS.

![Figure 2. Illustration of the complementary electronic circuit](image)

In this prototype, the power supply (obtained by solar cells) requires a minimum voltage level of 4.5V to turn on the voltage converter. This converter amplifies the voltage supplied by the cells to 18V, but the current decreases proportionally according to the increase in voltage. Then, the voltage regulator (U3), the resistor (R2) and potentiometer (R8) were simulated the control of the Arduino (to be implemented in the future) and the operational amplifiers (U1A and U2B) are activated.

The resistors (R7, R4 and R6) serve to supply the 16V voltage at the output of the (U3) regulator, and the resistance (R3) provides the voltage drop which will serve as the reference voltage for the (U2B) amplifier. This circuit in turn will also be serving potential difference between the base and the collector of the transistor (Q1) so that the current flows in the charging direction of the battery.

The amplifier (U1A) serves to provide a control of battery charging depending on the input voltage of the Arduino (which a maximum of 5V). This amplifier (U1A) also has a 3-fold ratio with the amplifier (U2A). The amplifier (U2A) serves to inject a voltage at the base of the transistor, which will cause the potential difference involved between the base and the collector to provide the current flow to the collector of the transistor (Q1).

In the current stage of development of the project, it was desirable to have freedom to vary the voltage levels at the input of the circuit, to maximize the current supplied by the arrangement and to control the charging of the battery. Therefore, for safety reasons, it was decided not to use the battery during the tests due to the possibility of explosions. Thus, the battery was simulated by the potentiometer (R9).
3. Results
Table 1 shows the voltage and current measurements, with a fixed resistance of 100 Ω, obtained for the different arrangements of proposed photovoltaic cells, and carried out under conditions of exposure of direct solar radiation in the time of 13:00 hours, with average temperature with 30°C, in the city of Rio de Janeiro. In the table 2 are the results of the characterization of fully charged batteries, which are discharged up to a safety voltage of 9V.

| Arrangement | Voltage (V) | Current (mA) |
|-------------|-------------|--------------|
| 2 strings   | 8,12        | 48,00        |
| 3 strings   | 7,60        | 61,50        |
| 4 strings   | 7,70        | 62,00        |
| 5 strings   | 7,70        | 67,00        |

| Batteries | Initial Voltage (V) | Final Voltage (V) | Total Time (h) |
|-----------|---------------------|-------------------|----------------|
| First     | 12,6                | 9,0               | 02:01:00       |
| Second    | 12,6                | 9,0               | 02:00:00       |

4. Conclusion and Future Works
With the purpose of assembling an electronic circuit that can condition the levels of voltage and electric current generate by the photovoltaic cells to power the drone GPS, it was developed a prototype circuit. Ten thin film solar cells were tested in different mixed arrangements. It was observed that the arrangement that is presented better power generated was composed of five strings of two cells.

The present work was traced as a first step of a much bigger project, which the main goal is using solar cells to supply the drones owns circuit. But for this initial stage of the work, it was chosen to just build the electronic circuit.

The battery was not installed with this circuit for accident prevention. Thus, it will be necessary to do more security tests for the battery become part of the electronic circuit.

In the future, it is intended to conclude the Arduino circuit. Besides, it will be worked on further optimization tests of solar cells, in order to characterize different arrangements, install a battery to the circuit and finally, apply all on a drone device. Followed by this, there is a wish to start evaluate the possibility of keep the drone’s GPS active indefinitely.

References
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