MANAGEMENT OF PHOTOVOLTAIC SOLAR ENERGY IN A MINIDRONE

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ABSTRACT

In this work, the operating principle of a system used to manage the energy embedded in a quad rotor minidrone was studied. For the hardware aspects, the energy management system was designed with MATLAB/SIMULINK. A "calculator" model that manages on-board energy has been developed. Simulations have been made and it has been found that with this calculator, the exploitation of on-board energy is managed optimally.

Keywords: *on-board energy, energy management, quadrirotor minidrone, control card, photovoltaic solar energy, calculator.*

INTRODUCTION

Since the dawn of time, Man has been concerned about finding the source of energy to meet his needs. Following this thirst for discovery, several inventions have been made if we only cite electricity which is the pillar of all modern evolutions. But often the problem for researchers is how to design an energy conservation object with a large storage capacity but a small size.

In the areas of new technology, and particularly in embedded systems, the problem is significant. Indeed, for an on-board system like the drone, finding an optimal solution to the constraints imposed by weight, performance and the amount of energy to embark is always a challenge.

The use of drones to support economic development is more than necessary. Aware that the use of drones is of paramount importance despite the complexity of implementation, in this brief we try to make our contribution to make possible the use of more efficient drones by managing the electric energy on board in order to increase the autonomous flight.

1. BASIC PRINCIPLE OF THE ENERGY MANAGEMENT SYSTEM

Several studies have already been carried out on the design of a model of a minidrone for several different uses.

But the problem that arises so far is how to optimize the on-board energy source used during the flight of the minidrone?

The basic principle of this on-board energy management control card is to manage the two types of energy source: solar panel and battery *(Fig-1)*. The goal is to use more of the energy provided by the solar panel, in order to reduce the number of batteries used to minimize clutter and weight.

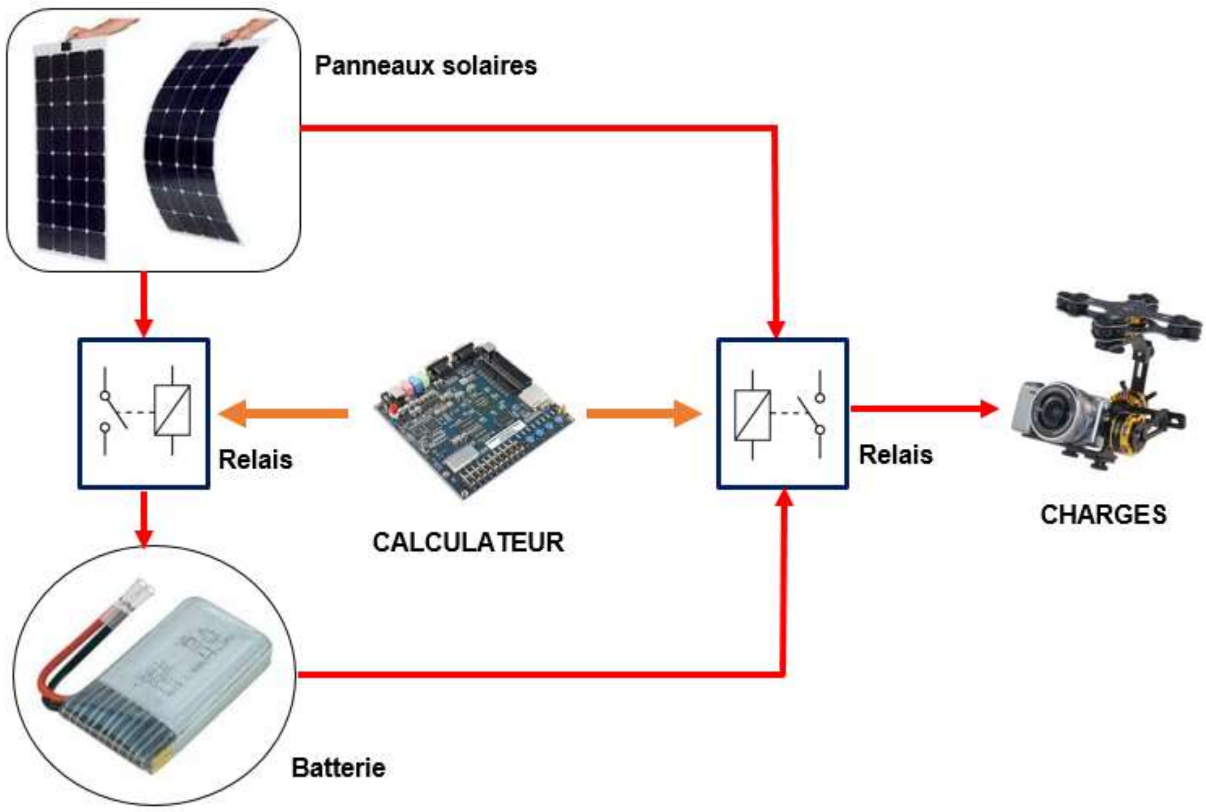

Fig-1 : Basic principle of the system

1.1. Prototype of minidrone architecture

In our studies, we will use the model presented in the reference [7]. The architecture of the minidrone is represented at *Fig-2*.

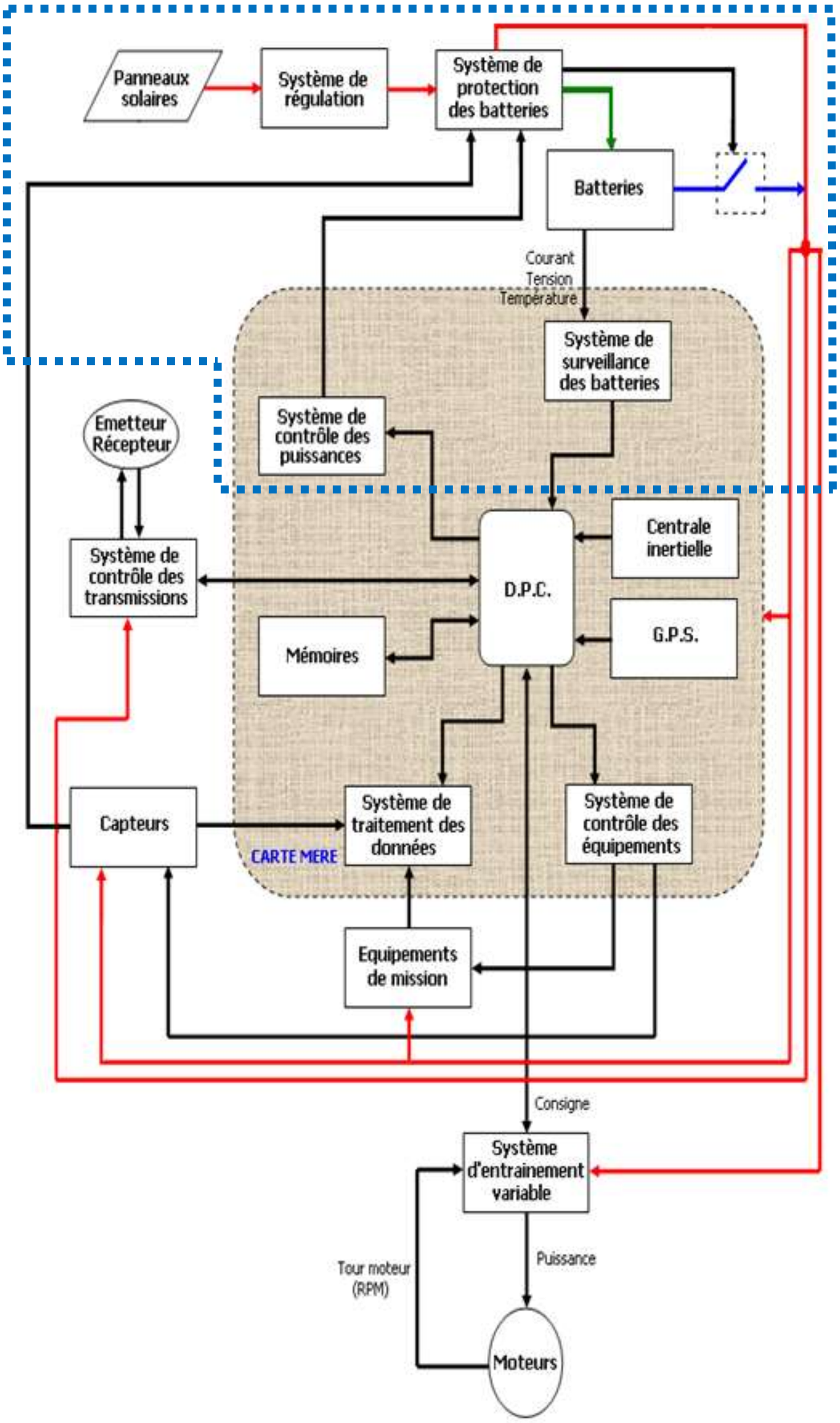

Fig-2 : Global architecture of the minidrone studied [7]

1.2. Control card synopsis for energy management:

As the *Fig-2* illustrates, a few changes have been made to improve integral energy management.

a. Implementation of the monitoring module

Three monitoring modules have been installed to monitor in real time, respectively:

- The power provided by the solar panel,
- Battery charge state,
- The energy power provided by energy sources,
- and the energy power required by the minidrone.

b. Using a temperature sensor

A temperature sensor is used so that the regulator can calculate the battery life of the solar panel based on it.

c. Relay use

Two relays controlled by the "CALCULATOR" are then used to choose the type of energy source requested.

Thus, one can use directly, either the energy provided by the solar panels or the energy stored in the batteries. In the worst-case scenario, both are exploited.

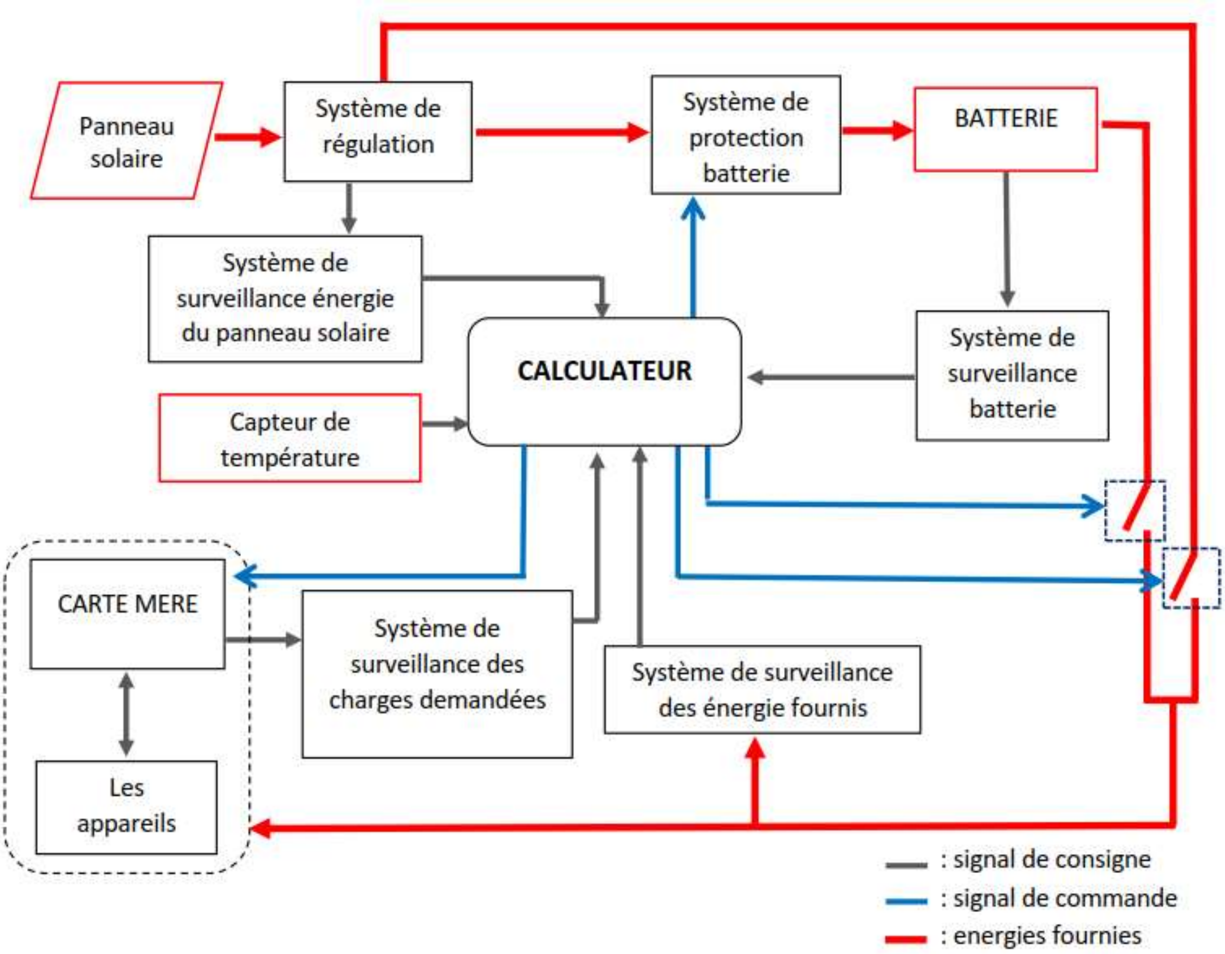

Fig-3 : Embedded Energy Management Map Synoptics

2. Simulation of the on-board energy management system

2.1. Introducing models

a. Solar panel

In total, the solar panel is composed of 60 cells,with a parameter under MATLAB-SIMULINK:

The results of the simulations obtained are similar to the ideal characteristic of the solar panel according to the illumination of the sun *(Fig-4.)*.

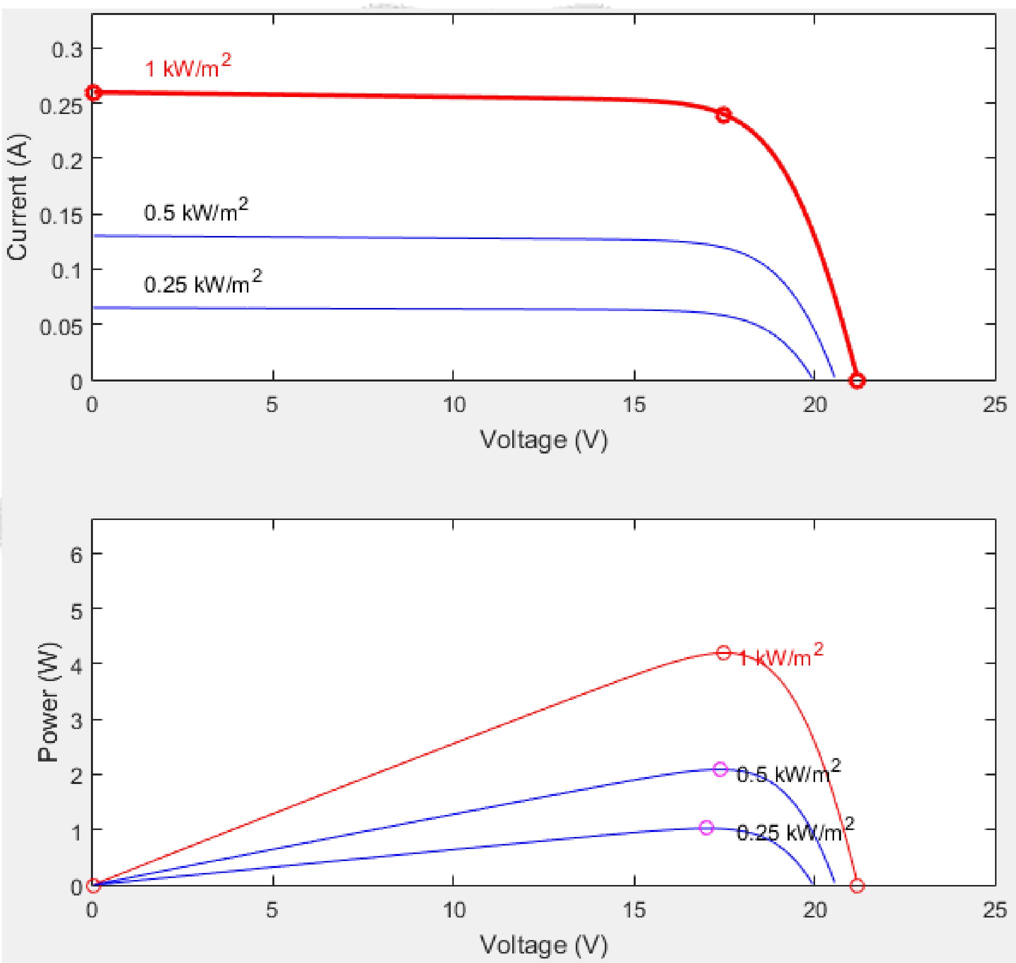

Fig-4 : Feature of the solar panel based on the lighting

b. Battery and charging circuit

i. Introducing the model

Before simulating the entire system, a simulation was performed to be able to visualize the state of the battery according to the charge of the solar panel.

The 9V and 12Ah battery, which is 70% charged, powers a 450W charge. The solar panel is then used to charge the battery during its activity *(Fig-5)*.

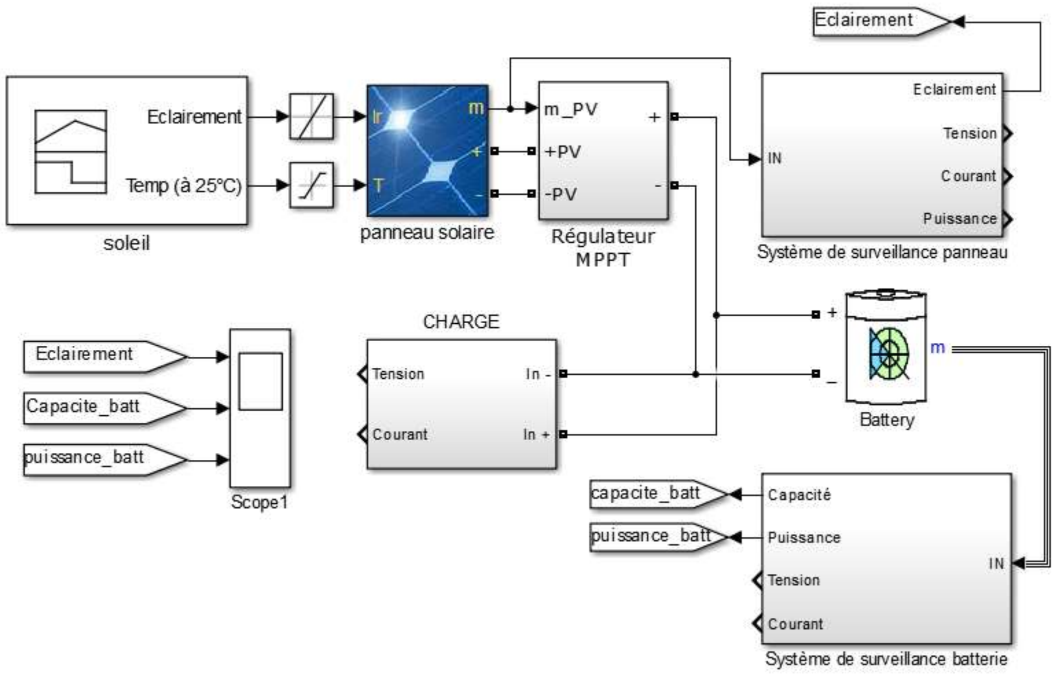

Fig-5: Synoptic battery charger

ii. Battery charger test

After the simulation, we got the curves of the *Fig-6*.

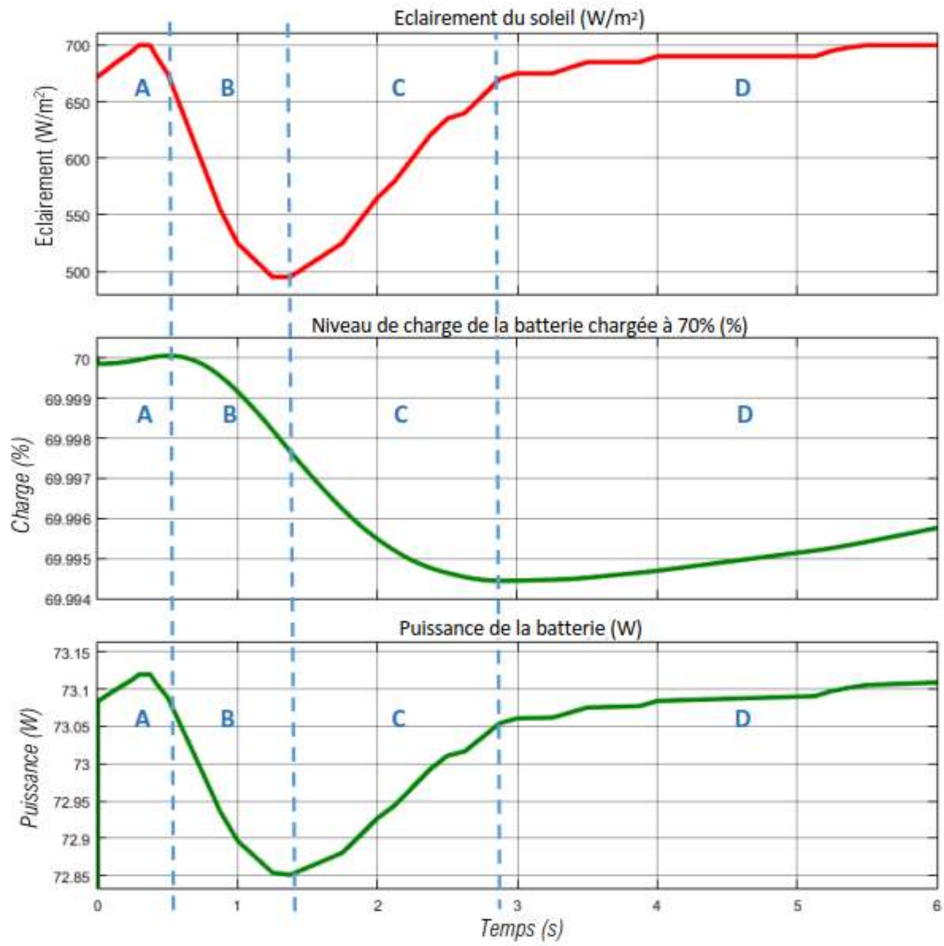

Fig-6: The pace of the battery charge based on illumination

Based on these curves, the battery charge level varies with the sun's illumination.

iii. Interpretations of the simulation

- ***Zone A***

According to the curve, the battery capacity gradually increases thanks to the energy provided by the solar panel. Similarly, the power provided by the battery is more or less stable.

- ***Zone B***

The illumination drops sharply to reach the value of 500 W/m^2. We notice directly that the battery power drops. Battery capacity decreases at the same time.

- **Zone C**

After reaching the value of 500 W/m^2, the illumination increases exponentially to a value close to 700 W/m^2. Battery power increases the same and battery capacity begins to stabilize.

- **Zone D**

The illumination stagnates, as well as the power of the battery. On the other hand, the battery capacity increases gradually.

We can conclude at first, that the battery power varies almost the same pace as the illumination of the sun on the solar panel, contrary to its capacity. During the decrease in illumination, its capacity gradually decreases, but the illumination must reach a higher and stable value in order to initiate battery charging.

3. SIMULATION OF THE ON-BOARD ENERGY MANAGEMENT SYSTEM

In the simulation of the system, the illumination is given by a predefined signal and the power required by a constant source

3.1. The constituents of the calculator

The power management card that we later call the "calculator" collects all the information produced by the four monitoring systems (S1, S2, S3) using the ports of*entry, including*:

$T_{p:}$ *the voltage of the solar panel,*
$C_{p:}$ *the current provided by the solar panel,*
$P_{p:}$ *the total power of the solar panel,*
$CH_{b:}$ *the battery charge level,*

T_f: *the voltage of energy sources,*

C_f: *the current supplied by energy sources,*

P_f: *the voltage provided by energy sources,*

P_d: *the power requested,*

E_{cl}: *lighting level.*

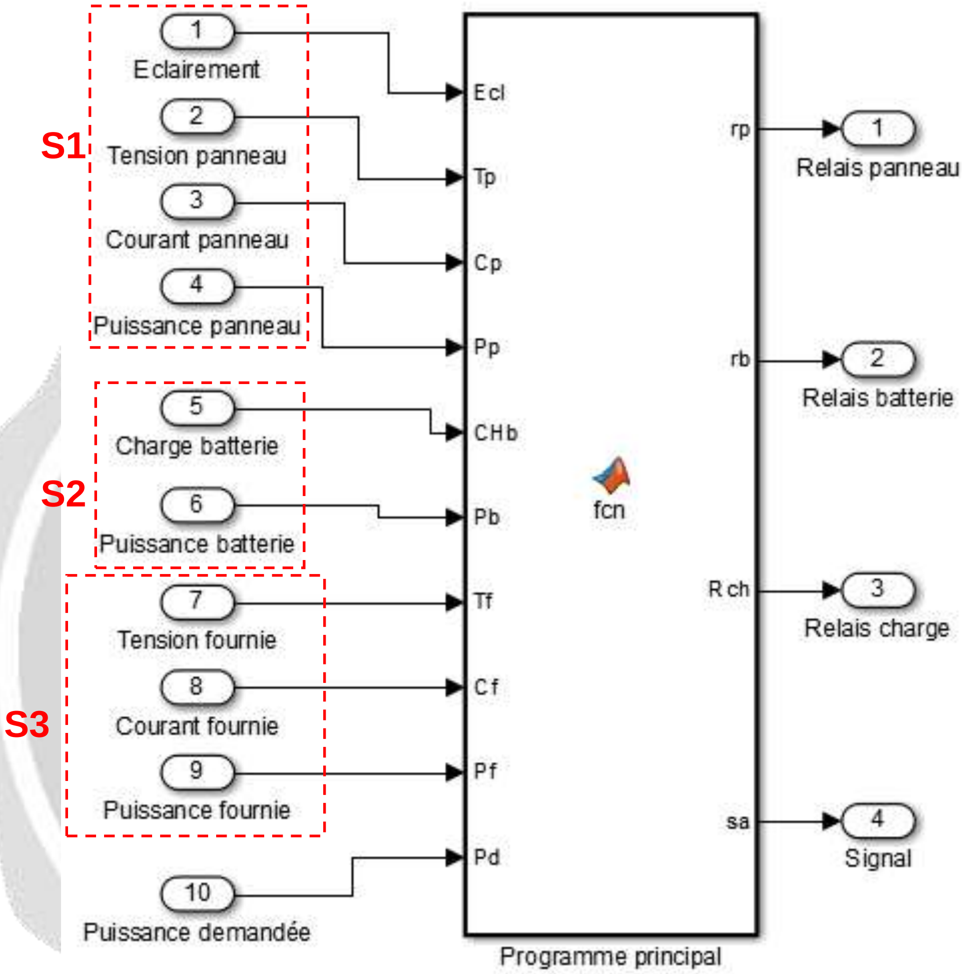

Fig-7 : The components of the CALCULATOR

Some formulas are used to obtain information for battery protection.

i. Energy available in the battery

The actual energy supplied by a battery is the product of its voltage by the number of ampere hour stored:

$$E_{réelle} = U.C$$

with

***$E_{réelle}$* :** *actual capacity provided by the battery, in Wh*

***U* :** *Actual battery voltage, V.*

***C* :** *Actual battery capacity,in Ah. (C=i.t)*

Tghe net energy of the battery : $E_{nette} = U_{nette}.C_{nette}$

Therefore, the energy available in the battery is obtained by : $E_{disponible} = E_{reelle} - E_{nette}$

ii. Battery charge time

A battery is characterized by its voltage and capacity. In this case, the battery charge time is calculated according to the formula:

$$T = k\left(\frac{C}{I}\right)$$

with:

k: *the constant charge of the battery (k - 1.2 to 2),*

C: *Battery capacity, in mAh,*

I: *Intensity of the charger (current provided by the solar panel), in mA.*

iii. Battery discharge time

A battery must not be discharged or risk destruction. In general, the discharge rate of a battery should not go beyond 60% to 80% of a battery's capacity. For example, for a 10Ah battery, at a discharge rate of 70%, the useful capacity is therefore 10Ahx0.7-7Ah. Hence the theoretical time to discharge the battery is obtained by:

$$T = \frac{C}{I}$$

with:

C: *the useful capacity of the battery (60% to 80% of its capacity),*

I: *the intensity delivered by the battery.*

For the simulations, we will take into consideration the parameters presented in the reference [7], namely:

- Engine rotation speed (max) : 600 $rad.s^{-1}$ ou 5 714,285 rmp,
- Engine rated power : 450W or 0,61 ch,
- Minidrone's cruising speed : 10 $m.s^{-1}$,
- Maximum altitude : 1 500m.

3.2. Simulation results

a. Simulation No.1

In this first simulation, we consider the following parameters:

- Battery: 100% charged,
- demanding power: 150W.

Fig-8 represents the results:

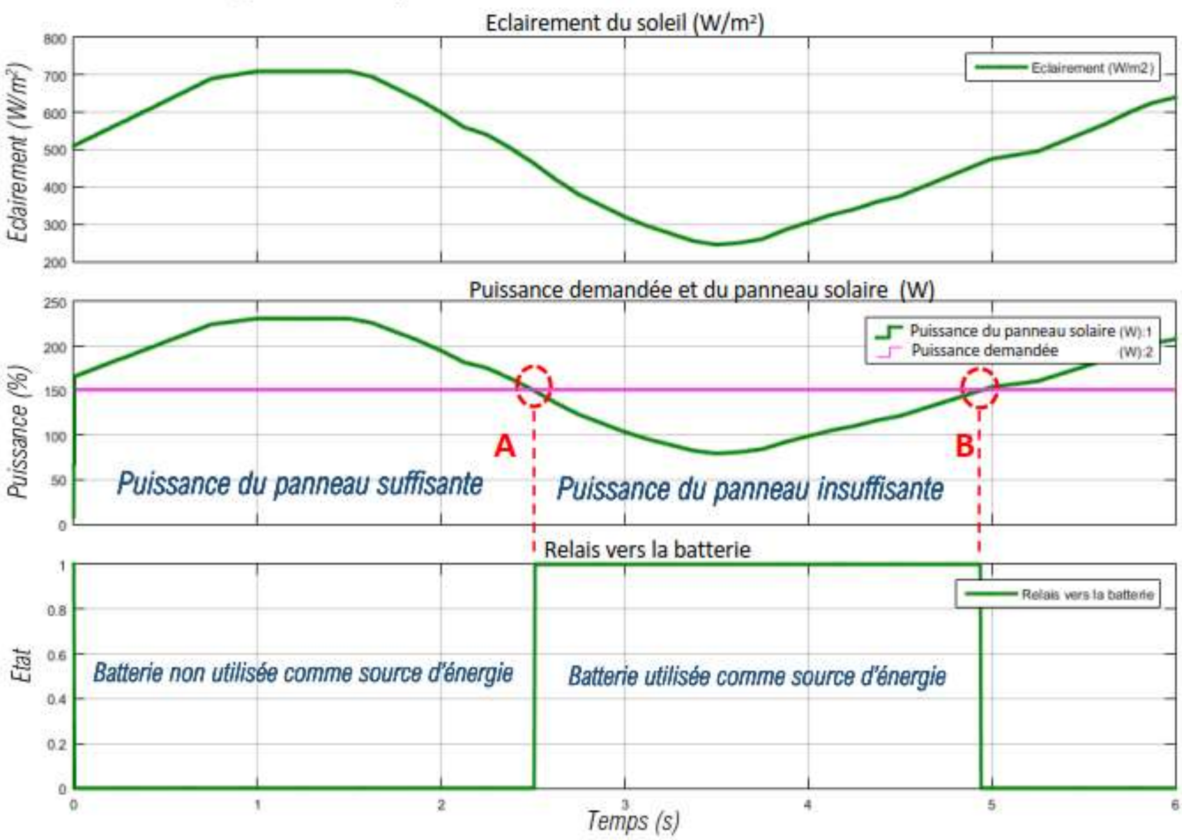

Fig-8 : Simulation with a 100% charged battery and 150W power demand

According to the figure, the system meets the requirements. Because the battery is charged and the power of the solar panel is greater than the required power, the energy of the solar panel is then the only energy source used.

Once the power of the solar panel is less than that requested, then the "calculator" activates the "relay" to the battery. The battery and solar panel work together to meet demand. Once the panel power is sufficient to power the charge, the main program disables the "relay" to the battery. These two critical points are represented by *fig-8* points A and B.

b. Simulation No.2

In the second simulation, the parameters considered are:

- battery: 99% in the process of charging,
- demanding power: 450W.

The *Fig-9* represents the results obtained:

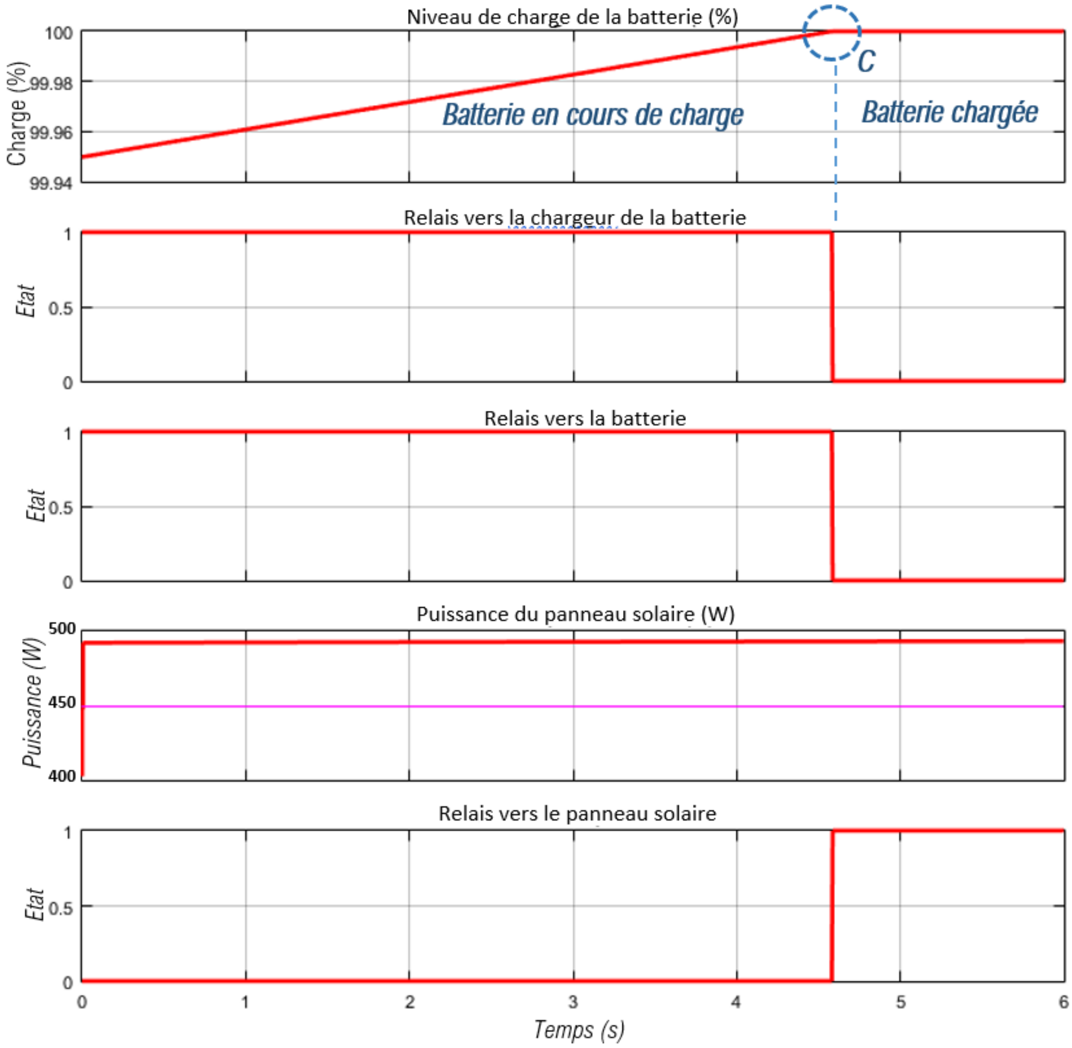

Fig-9 : Simulation with a battery being charged and a power demand of 450W

The battery is charged by the solar panel. However, the main energy source used is the battery, because the solar panel cannot provide sufficient energy.

While the battery is charging, it is the only energy source used. Once it reaches its maximum charge, the system disables the battery charging process and uses the solar panel as the only source of energy because its power is sufficient to support the requested charge (point C).

As a result, once the battery is charged, it will no longer be used unless the power of the solar panel is insufficient for the needs required by the minidrone.

4. CONCLUSION

On-board energy management improves the autonomy performance of embedded systems. Designing a system capable of managing this energy optimally, considering the constraints imposed by weight, is complex.

We studied the different processes of a software with existing lifecycle types as well as the testing and validation steps of a software. This has helped us to understand the different steps that need to be taken to eventually design our system.

Simulations were carried out to verify the results. We simulated the battery charge and then used a few models to implement the system that is used to manage the on-board energy. It has been concluded that the designed system is capable of managing on-board energy

5. REFERENCES

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