Volume XXIII 2020
ISSUE no.1
MBNA Publishing House Constanta 2020

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

Charging floating bases for marine unmanned aerial drone

To cite this article: Vlad Mocanu, Petrica Popov and Vasile Dobref, Scientific Bulletin of Naval Academy, Vol. XXIII 2020, pg.116-121.

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-20-I1-015

Charging floating bases for marine unmanned aerial drone

V Mocanu[1], P Popov[2], V Dobref[3]

[1]Eng, Naval Academy “Mircea cel Bătrân”, Constanța, RO
[2]Lecturer PhD, Naval Academy “Mircea cel Bătrân”, Constanța, RO
[3]Professor PhD eng , Naval Academy “Mircea cel Bătrân”, Constanța, RO

E-mail: m.vladmocanu@gmail.com

Abstract. In this paper, the authors present new ways of using drones in the marine and offshore environments. The article includes the presentation of the main constructive electrical elements of a marine floating buoy, which play the role of charging base for an unmanned aerial drone. Also, are highlighted the main losses of the system’s components, what should have been taken into account when choosing the size of such an independent energy source, as well as the main steps for energy source design.

Keywords: wireless charging, marine environment

1. Introduction

In technological terms, a drone is an unmanned flying vehicle; but in formal activities, the drones are known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UASes). Overall, a drone is a software-controlled flying robot that can fly autonomously or remotely controlled.

A purpose for using drones is the reduced human safety risk of UAS compared to that of conventionally piloted aircraft, but some tasks can be exclusively made by drones. In this paper the focus will be on multicopter drones (figure 1 –A), which have some advantages against plane drones (figure 1 –B); but there are also hybrid drones as a combination between planes and helicopters (figure 1 –C).

Figure 1. Type of drones [1][2]

In the Maritime and Offshore industry, drones can be used for many purposes [4]. It is a cost-effective alternative to shipping documents, spare parts, medicine or different samples from ships to shore departments and return. Also, drones can take air and water samples to prevent and identify pollution from inner harbor and oil terminals. A close domain of marine industry where drones can be used is the sea weather forecasting, thus UAV collects pressure, temperature and relative humidity data from different altitudes. Drones can also be closely related to humans, so they can be used for offshore *search and rescue* missions or as a lifeguard on Black Sea beaches. Of course, these intelligent robots can prevent poaching and smuggling, defending our borders.

In all these cases, the unmanned aerial vehicles need an independent charging base, which is preferably to be as close as possible to the place of action, due to its limited autonomy of flying.

2. Charging floating base-Experimental set-up and results

Floating bases have to be independent power systems because they will be anchored in offshore areas, therefore, wired power bases are not the most reliable option due to the high costs of installation. Considering the circumstances, independent bases need independent energy sources such as photovoltaic panels or small wind turbine preferably VAWT (Vertical-Axis Wind Turbines). Because of the limited space on the floating bases, the efficiency of energy sources has to be as high as possible.

Although photovoltaic panels produce energy only during the daytime, they are more stable being preferred to the detriment of the wind turbine. Photovoltaic panels convert solar radiation into electrical energy through the photovoltaic effect. The photovoltaic cells (PVCs) architecture is based on the union of two semiconductors with different electron concentration; type n materials (semiconductors with an excess of electrons) or type p materials (semiconductors with an excess of positive charges), though in both cases the material is electronically neutral [5].

PVCs that have been developed up to date can be classified into 4 categories [5]:

- silicon technologies, monocrystalline and polycrystalline, based on gallium arsenide (GaAs);
- amorphous silicon (a-Si) and microcrystalline silicon (μc-Si) thin films solar cells;
- nanocrystalline thin films;
- inorganics and organics.

Monocrystalline and polycrystalline silicon technologies are the most used cells due to their reasonably high efficiencies, albeit are relatively expensive to produce (~90% of the current PVC market) [5]. The best record lab cell efficiency reported is 24.7% for mono-crystalline and 20.3% for multi-crystalline silicon wafer-based technology [6], [7].

Table 1. Best efficiencies reported for the different types of solar cell [7]

Cell type	Highest reported efficiency for small area cells produced in the laboratory	Highest reported module efficiency
c-Si (crystalline Si)	24.7% (UNSW, PERL)	22.7% (UNSW/Gochermann)
Multi-c-Si	20.3% (FhG-ISE)	15.3% (Sandia/HEM)
a-Si: H, amorphous Si	10.1% (Kaneka), N.B. single junction	Triple junction. Stabilized efficiency ¼ 10.4%

The solar efficiency η is given by [7]:

$$\eta = V_{OC} I_{SC} FF / P \tag{1}$$

where: V_{OC}- open-circuit voltage (the voltage generated when the load resistance is infinite), I_{SC}- is the short circuit current (the current generated when the load resistance is zero), FF- fill factor (defined to be the ratio of the maximum power generated by the cell divided by $V_{OC} I_{SC}$, is a measure of the quality of a solar cell), P-solar power.

Charging system. In the authors' opinion the most suitable charging system is wireless charging due to the following advantages:

- charging wires elimination;
- creating a watertight structure of both the floating power base and the drone;
- removing electrical contact defects due to salinity and impurities;
- higher tolerance of drone landing precise point;
- does not require maintenance;
- improved aerodynamic drone design;
- compatible with other drones with a wireless charging system.

This system has the disadvantages of increased losses produced by energy transmission and it makes the drone mass a little bigger.

3. Sizing the energy system of the base according to drone energy requirements

3.1 The power specifications of a professional drone:

Battery Type: LiPo 6S
Battery capacity: 4500 mAh-4.5Ah
Battery voltage: 22.2 $V_{d.c.}$
Battery energy=4.5Ah * 22.2 $V_{d.c.}$=99.9 Wh
Power consumed for one charging≈125 W
Power consumed for 4 charges/day =4*125W≈496W/24h

This means that the battery could theoretically supply 99.9 W for an hour. However, the consumer is never really able to take all the power from a battery, as once the voltage drops, the battery requirements will no longer be able to power the load [8].

3.2 Wireless power charging efficiency

Radiofrequency technology utilizes radio frequencies (RF) to charge a device, but charging can be accomplished through other different technologies: inductive and magnetic resonant.

The performance of a wireless charger can be determined by using the overall efficiency parameter which is defined as [9]:

$$\eta = \frac{D.C.\ output\ power}{RF\ input\ power} \tag{2}$$

it depends on many parameters such as transmit power, frequency band, operation voltage, and load impedance (figure 1).

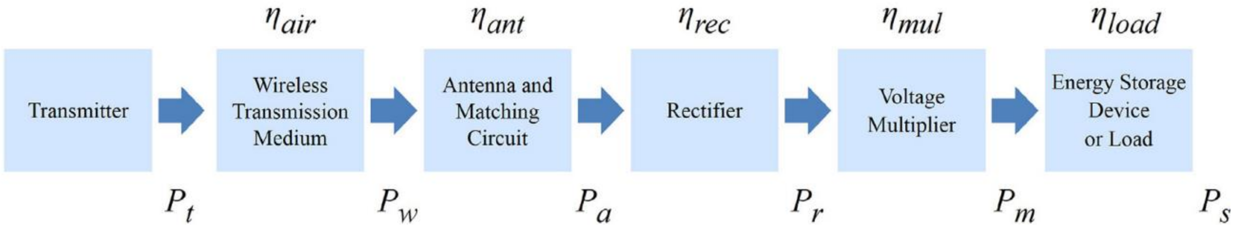

Figure 2. The efficiency parameters of RF energy blocks constituting the overall efficiency [9]

In this project, η_{air} shows changes in parameters because of the marine environment modification through the variation of temperature, humidity, pressure, salinity. Air is the wireless transmission medium between the transmitting and harvesting antennas in free space. The receiving antenna is the harvesting antenna for RF energy. The efficiency η_{air} can be formulated as [9]:

$$\eta_{air} = \frac{P_w}{P_t} \quad (3)$$

where: P_w- wireless transmission medium output power, P_t- transmitted power.

The Department of Energy's Oak Ridge National Laboratory (ORNL) upgraded its previous 20 kW wireless charging system to 120 kW, and through a new design and a silicon carbide power electronic device, it was able to achieve 97% efficiency. Demonstration of the new system was done at a 6-inch (15.2 cm) air gap, which means that electric cars could recharge almost as efficiently as in the case of wired charging [10]. In this paper was chosen a 65% efficiency.

For the previews drone specifications, the power consumed for 4 charges per day =4*125W≈496W/24h, adding a 35% wireless losses, the total power consumed for four charges per day with the losses added will be: 35%*496W/24h+496W/24h≈670W/24h.

This energy comes from battery storage, which is charged by photovoltaic panels.

3.3 Battery storage

670W/24h≈28W/h- is the batteries consumption, so we need the equivalent of 24 batteries with 28Wh power capacity (power available in watt-hours). Due to the 4 charging cycles of drone we can distribute energy in four batteries, with the available power in watt-hours: 670W:4≈168Wh.

It has been supposed that the wireless charger is running on 12$V_{d.c.}$, therefore, the batteries configuration will be:

- capacity for one battery measured in Amp Hours:168Wh:12$V_{d.c.}$=14Ah
- voltage: 12$V_{d.c.}$
- power: 168W.

3.4 Charge Controller or Voltage Regulator

This is an essential element of the solar system, it controls the charge input of batteries, stops overcharging and prevents the solar panel from pulling power from the battery during the night.

The efficiency of the charger controller is around 80% [11], so:
670W/24h +20%*670W/24h=804W/24h – the requirement energy at this point.

3.5 The power of the photovoltaic panel

It must be considered other losses:

- losses due to dust, snow and the atmosphere salinity which can cover the photovoltaic panel with a thin layer of salt (2-10%),
- D.C. cables losses (1 to 3 %),
- A.C. cables losses (1 to 3 %),
- Temperature losses (5% to 20%).

From the losses considered before, it can be made an average of 20% loses which will be added to the last power consumed (804W/24h), so: 20%*804W/24h+804W/24h =965W/24h

An important element for the photovoltaic panels dimensioning is the sun shining hours per day (24h). Along the Romania coast, the average hours of sunshine are displayed in the following table [12].

Tabel 2. Constanta – Sunshine

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours	3	4	5	6	9	9	11	10	8	5	3	3

The darkest scenario should be considered, 3 sunshine hours/day, during the winter. With additional losses above mentioned, the photovoltaic panels should cover the need of 965W/24h power consumption, with 3 hours of energy production. This can be translated into 965W power produced by photovoltaic panels in 3 hours during a day (24h). Will be chosen 4 photovoltaic panels to mechanically balance the buoy, these 4 panels will have to produce 965W in 3 hours (the darkest scenario of sunshine).

Therefore, in 1 hour, one photovoltaic panel has to produce the following power: 965W:3 hours:4 panels≈81W.

It will be used a 100W monocrystalline solar panel with the following parameters (specified by a certain manufacturer):

-Rated Maximum Power: 100W
-Maximum Power Voltage: 18.0V
-Maximum Power Current: 5.56A
-Open Circuit Voltage: 22.5V
-Short Circuit Current: 6.00A
-Module Efficiency: 16.96%
-Power Tolerance (Positive): +5%
-NOCT (Normal Operating Cell Temperature): 45±2°c
-Temperature Coefficient of Pmax: -0.40%/°C
-Operating Temperature: -40°C to +85°C
-Series Fuse Rating: 15A
-Cell Type: Monocrystalline 156
-Dimensions (mm):670x880x30
-Weight(Kgs):7.00(approx).

In figure 3 is presented the system of Floating base for marine drone charging.

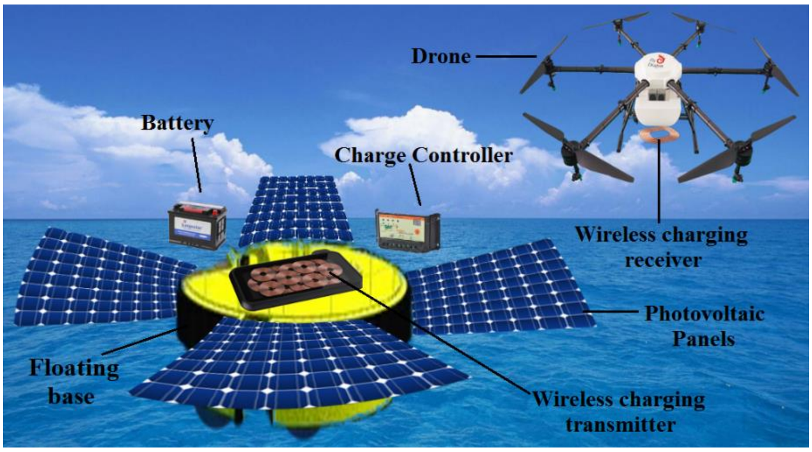

Figure 3. Floating base for marine drone charging

4. Conclusions

From the study presented in this paper, we can conclude that in the offshore or marine environment, a wireless charging system and an independent photovoltaic energy source are facing different environmental variables, which must be considered when designed the entire system.

Also, the sizing of the energy system is primary to start with the drone consumption requirement calculation and then, the efficiency of each process must be introduced.

References

[1]*** https://technikblog.ch/2015/04/high-end-multicopter-gepaart-mit-high-speed-4k-kamera/

[2]*** https://www.wired.com/2015/05/nasas-new-10-engine-drone-half-chopper-half-plane/

[3]***https://www.trendtimes.com/rc-predator-airplane-drone.html#

[4]***www.commercialuavnews.com

[5] **José Antonio Luceño-Sánchez, Ana María Díez-Pascual, Rafael Peña Capilla**, *Materials for Photovoltaics: State of Art and Recent Developments*, International Journal of Molecular Sciences, 23 February 2019

[6]*** Photovoltaics report, Prepared by Fraunhofer Institute for Solar Energy Systems, ISE with support of PSE GmbH Freiburg, 14 November 2019

[7] **R.W. Miles, K.M. Hynes, I. Forbes**, *Photovoltaic solar cells: An overview of state-of-the-art cell development and environmental issue,* Progress in Crystal Growth and Characterization of Materials, Volume 51, Issues 1–3, 2005, Pages 1-42

[8]***https://www.solartechnology.co.uk/

[9**] Mustafa Cansiz, Dogay Altinel, Gunes Karabulut Kurt** - *Efficiency in RF energy harvesting systems: A comprehensive review,* DOI: 10.1016/j.energy.2019.02.100

[10]*** https://insideevs.com/news/340478/120-kw-wireless-charging-proves-97-efficient/

[11]*** http://www.ti.com/

[12]*** https://www.climatestotravel.com/climate/romania#coast