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A GREED AND SELF-POWERED LIFE RAFT FOR SEAFARERS

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Abstract: *The renewable energy systems are widely use, starting with powering the NASA's satellites and ending with standalone water pumping systems. There are grid connected and off grid renewable energy systems, from the level of GW power to the level of a few KW installed power. This article presents an idea which tries to implement the renewable energy systems where is more applicable, where there is a desperate need for electric energy and this one is definitely missing. An application of this kind is the implementation of PV modules on board of life rafts. A simulation in PVsyst of a self-powered life raft is presented.*

Key words: *life raft, PV panels, PVsyst;*

INTRODUCTION

Life without electrical energy is not an option for modern people, more than that, for many of us is an unimaginable scenario. But, there are people who don't have access to a modern life, and the main reason is that they are isolated and too far away from an electric grid. The cost for connection them to the electric grid is, most of the time, to high and involves many resources and time. That is why is more practical to develop a local electrical generation point, a small off-grid system. In this situation the cost-benefits percent, projected for a long period of time, is favorable for renewable energy systems than to classical generators or connection to national grid option. Otherwise, the use of renewable energy systems have not a competitive price in the battle with classical ones yet. Only the intervention of national energetic policy can accelerate the rate of renewable energy implementation. An important policy with this purpose, EU 20/20/20 directive and its new versions, was developed by European Union and has more steps to be implemented, you can read more in[1] or in [2]–[4].

Another hard to believe situation is that your electrical energy provider will stop working for a long period of time, right in the moment you need electricity more than ever. What would you say about that?! But what if I tell you that every time you go onboard of a vessel you are very close to this situation?! Would you consider to have with you one or more alternative different from the classical one?! The good part is that in our days is very easy to implement an alternative or additional solution for classical electrical energy system in many domains. In this case, the scope of safety will excuse the price of implementation and the cost/benefits ratio is useless.

This article is mainly dedicated for IMO (International Maritime Organization) followers but can be a source of inspiration for everybody who lives or works in an isolated place. The first time when we wrote an article about the implementation of renewable energy systems onboard of vessels was a few years ago and it was about an INMARSAT Communication Equipment Supplied By an Off-Grid Solar PV System[5]. This time we realized a scenario in which the seafarers need to abandon the ship and embark in 8 personslife rafts. Accordingly to BBC news article [6] the record for the longest survived period of time in a life raft is hold by Poon Lim, 133 days in 1942. Another presented case isfor a family who spent 38 days in a life raft after their yacht sank, and the examples can continue. If we keep in mind that the life raft is designed to keep the survivors in life for a **short time**, until the SAR (Search And Rescue) activities succeed, it is clear that the life raft needs to be redesigned.

In [6]Tipton says survivors have a "hierarchy of needs":

- Air
- Viable circulation in the body
- Suitable temperature
- Fluid
- Food

Based on these logical things we developed a new type of life raft which use renewable energy system to assure the basic needs and uninterruptible operation of communication and SAR equipment (VHF radio station, EPIRB or PLB, SART).

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The article contains information about life raft, typical emergency pack, proposed equipment to be implemented on board of life raft, and a simulation in PVsyst of an off grid PV system installed on a life raft.

SOLAS AND LIFE RAFT

The SOLAS convention is considered one of the most important international treaties referring to the safety of ships at sea. It has been first adopted in 1914 after the Titanic tragedy, then it had new versions in 1929, 1948 and 1960. Its aim is to set the standards for ships construction, equipping and exploitation in safe conditions. The current SOLAS Convention includes articles that establish general obligations, amendment procedure, followed by an annex divided into 14 chapters, this article focusing on chapter 3 – Measures and equipment for saving lives at sea.

The liferafts are mainly composed of a platform and a cover which must protect the survivors inside from the weather at sea.

There are two kinds of rafts:

- Inflatable rafts
- Rigid life rafts

All liferafts must withstand weathering for 30 days afloat in any sea state conditions.

IMPLEMENTATION OF PV PANELS ON LIFERAFTS

Today, solar panels are widely used in various types of environments, from urban areas to villages, fields, serving the same purpose: supplying electricity. It may be also met on different types of ships of different sizes and shapes, but not on liferafts, yet.

For ensuring the prolonged functionality of the equipment onboard the rafts (EPIRB, VHF, SART and others), the easiest renewable energy source to apply is the solar energy.

Onboard the rafts there are equipment that will signal an emergency and then the position of the hazard so the authorities can locate the area where to search and rescue. There is one flaw: battery lifetime is limited. The life rafts ensure minimalistic surviving conditions, usually enough to save the lives of those inside, but it can be for sure improved by adding some other equipment.

There are already photovoltaic panels that are not stiff and could be included in the fabric of the rafts cover to be able to bring extra energy on board.

Next (Figure 1), there is a design of how the panels could be mounted on the raft, created in PVsyst5.The article continues with the results of the simulation that calculated the amount of solar energy generated using PV panels on a life raft.

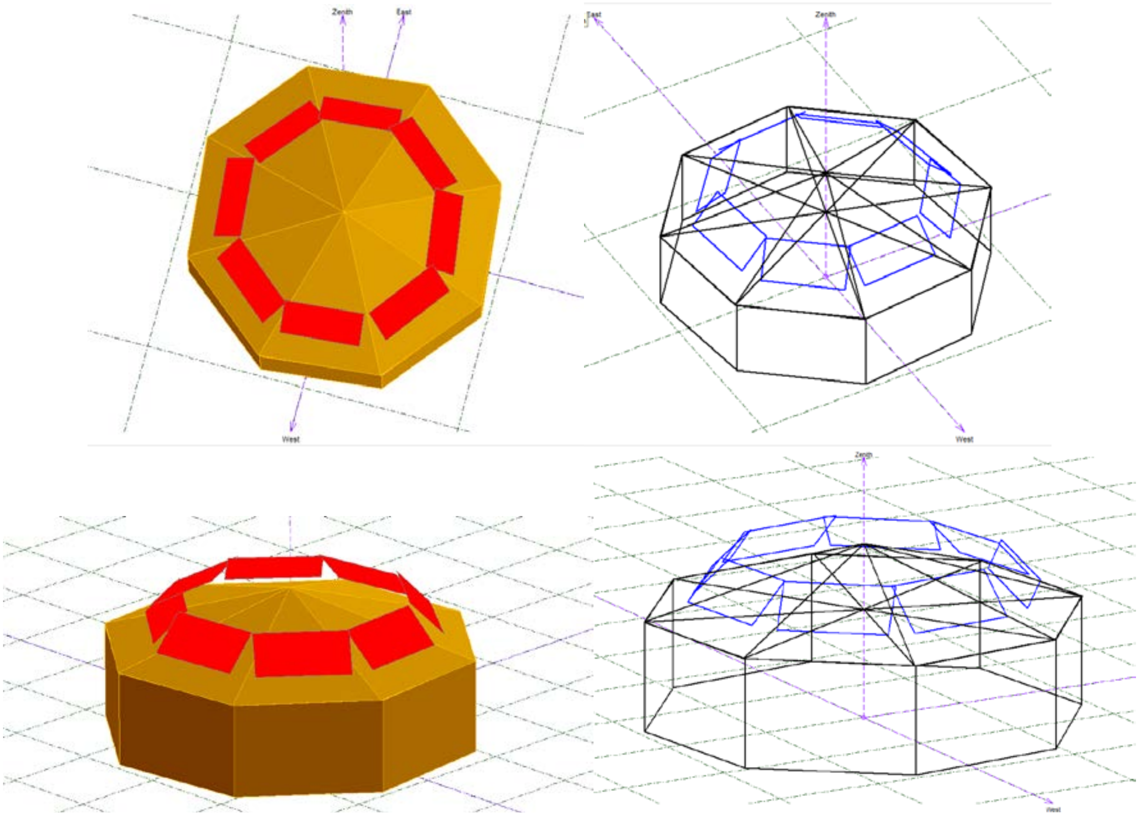

Figure1.Photovoltaic panels mounted on a liferaft in PVsyst5

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DESCRIPTION OF MATHEMATIC MODEL USED IN SIMULATION

For describing the functioning of a PV module, the program uses the model with a single diode Shockley (defined for a single cell)[7]–[12].

The generalization of this model implies that are the cells are identical. A more sophisticated model which implicates two different diodes is being used for very accurate designs for a single cell.

This model is suitable describing cSi, but needs adapting to reproduce the way thin-film modules behave.

The mathematical expression that PVsyst uses is resulted from calculations after introducing shunt and series resistances:

$$I = I_{ph} - I_0 \cdot \left[e^{\frac{q \cdot (V + I \cdot R_s)}{N_{cs} \cdot \gamma \cdot K_B \cdot T}} - 1 \right] - \frac{V + I \cdot R_s}{R_{sh}} \qquad (1)$$

Where:
I= current generated by module [A];
V= the voltage at the terminals of the module [V];
I_{ph}= photocurrent [A] proportional to irradiation G, and a correction depending of T;
I_0 = inverse saturation current depends on the temperature [A];
R_s = series resistance [ohm];
R_{sh} = shunt resistance [ohm];
q = electron charge = 1,602 • E-19 Coulomb;
K_B = Boltzmann's constant = 1.381 E-23 J / K;
γ = quality factor of the diode, usually between 1 and 2;
N_{cs} = Number of cells in series;
T = actual temperature of the cells [Kelvin].

Photocurrent varies with irradiation and temperature: it may be determined by the values given for reference conditions (Gref, Tref):

$$I_{ph} = \frac{G}{G_{ref}} \cdot \left[I_{ph\,ref} + muISC \cdot \left(T - T_{ref} \right) \right] \qquad (2)$$

Where:
G and Gref = actual irradiation and of reference [W / m²];
T and T ref = actual temperature and of reference of the cell [°K];
muISC = temperature coefficient of the photocurrent.

Reverse saturation current of the diode varies with temperature as in the formula below:

$$I_0 = I_{0\,ref} \cdot \frac{T}{T_{ref}} \cdot 3 \cdot e^{\frac{q \cdot E_{Gap}}{\gamma \cdot K_B} \left(\frac{1}{T_{ref}} - \frac{1}{T} \right)} \qquad (3)$$

Where:
E_{Gap} = energy band for the material (1.12 eV for crystalline Si, 1.03 eV for CIS, 1.7 eV for amorphous Si, 1.5 eV for CdTe)

DEFINING THE CONSUMER

Defining consumption is a step as important as the simulation of the energy produced by photovoltaic panels. Consumption dictates the dimensioning of the system. Another important aspect is the additional space that elements will occupy. In this regard, it was intended to minimize the number of added items such as batteries, the most bulky and heavy components of the system. Consequently, in the absence of batteries, the system will operate mainly in daylight, then, as much as the accumulators of the equipment allow. Equipment on board the rafts that will benefit the energy from the panels are: fresh water maker, the EPIRB, VHF station with battery and SART, when and if their batteries do not last enough. In the future, additional equipment might be added which are absent at the moment because of the lack of energy. For the present situation it resulted an average consumption of 66 W, with a daily consumption of 1.58kW.

FINAL RESULTS OF THE SIMULATION

Final results should outline clearly how much renewable energy we have at disposal, how much of this energy we can capture using the panels and how much of it we use.

The simulation has been made for 1998 because the free license of the software allows only this year. And there have been made eight simulations, one for each PV panel located on the liferaft in the following orientations: 0°, 45°, 90°, 135°, 180°, -45°(225°), -90 °(270°) and -135 ° (315°).

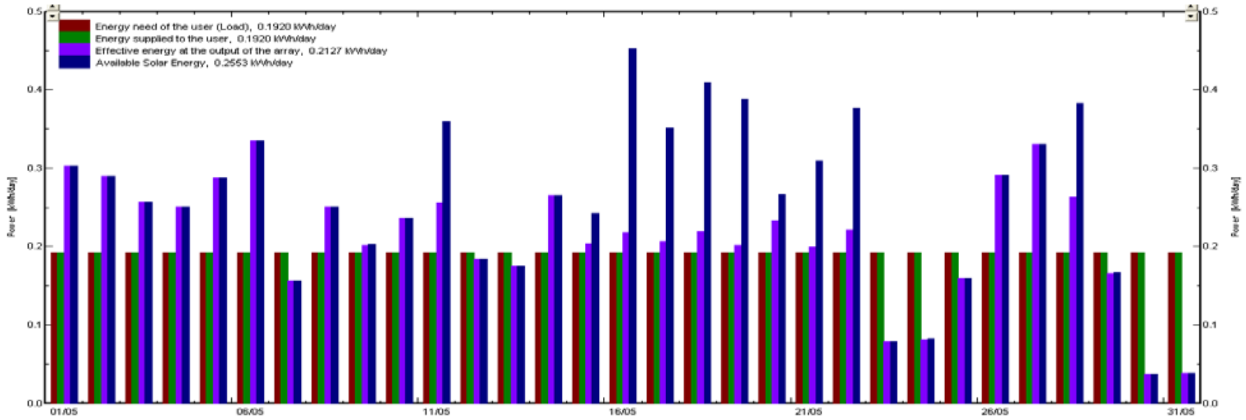

Figure 2. An example of graphic results of simulation for 45° azimuth

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	EArray kWh	EUnused kWh	E Avail kWh	E Load kWh	E User kWh
May	6.595	1.321	7.916	5.952	5.952

Table 1. An example of numeric results of simulation for 45° azimuth

Averageper dayof a month	Energy available (EAvail) kWh	Energy at the output of the array (EArray) kWh	Necessary energy for consumer (E load) kWh	Used energy (E User) kWh	Unused energy (EUnused) kWh
0°	258.7	214.2	192.0	192.0	44.5
45°	255.4	212.7	192.0	192.0	42.6
90°	228.6	209.9	192.0	192.0	18.7
135°	197.5	197.4	192.0	192.0	0.1
180°	189.0	188.9	192.0	192.0	0.1
-45°	262.3	213.2	192.0	192.0	49.0
-90°	234.4	211.0	192.0	192.0	23.3
-135°	201.9	201.8	192.0	192.0	0.1
Total	1827.7	1649.1			178.5

Table 2. Numeric results of simulations for all PV panels installed on life raft for one month

Comparing panels to each other is noted that the total available power, which varies backwards from the 0° to 180° orientation, the available energy system output is between 82-99.9% of the total available. However, the output power compared with the previous panel was kept close, decreasing to 12% thus obtaining similar values. The most ineffective position was found to be in the 180% orientation.

The highest rate, of available-produced energy, 99.9% was at 3 of 8 panels: the orientations 135 °, -90 ° and -135 °. Of course, the raft will have movements while being on the water, and these results will vary, but the most important aspect of the simulation result is that the energy requirements were always met and there hasn`t been found any lacking energy. This proves the efficiency of the panels on the liferaft. Besides this, the average amount of energy obtained in one day has a significant value of 1.6491 kWh.

The panels used during the simulation according to the manufacturer promise an efficiency of 12%, as well as the flexible panels that would be required on the liferaft. The amount of the 8 panels surface is 4m^2. After a simple calculation, knowing that under standard test conditions we use 1000w / m ^ 2 and Romania has 4 hours of solar energy per day, we have the following results:

$$E_{availRomania}\text{=4h*1000W/}m^2\text{= 4kWh/}m^2\text{/day} \quad (4)$$

$$E_{produced} = \frac{1.6kWh}{day}/4m^2 \quad (5)$$

$$E_{\frac{produced}{m^2}}/day = 0.4\frac{kWh}{m^2}\text{/day} \quad (6)$$

$$\text{Efficiency: } \frac{0.4 \times 100}{4} = 10\% \quad (7)$$

This result suggests that at sea, instead of a panel efficiency of 12% we will get a 10%. This is considered a very good result, the loss not being significant. The following Table presents the efficiencies of each panel separately, reported to the maximum energy obtained.

Orien-tation	(EArray) Daily average [Wh]	Energy efficiency related to 0° azimuth	PV panel efficiency related factory specs.
0°	214.2	100.00%	10.7%
45°	212.7	99.30%	10.6%
90°	209.9	97.99%	10.4%
135°	197.4	92.16%	9.9%
180°	188.9	88.19%	9.4%
-45°	213.2	99.53%	10.7%
-90°	211.0	98.51%	10.6%
-135°	201.8	94.21%	10.1%
Total	1649.1 Wh	96%	10%

Table 3. PV panels efficiency

It is being proposed a formula for the energy produced on board the liferaft:

$$E_{STC}\text{= 1000 Wh/}m^2 \quad (8)$$

$$S_{HD}\text{=4h/day} \quad (9)$$

$$\Rightarrow \quad I_{ROM/zi}\text{= 4000 Wh/day*}m^2 \quad (10)$$

And

$$E_{prod.PV12\%} = \frac{12}{100}\text{*4000= 480 Wh/day*}m^2 \quad (11)$$

But:

$$E_{prodPVonboard} = \frac{10}{100}\text{*4000= 400 Wh/day*}m^2 = \text{= 83\% of } E_{prod.PV12\%} \quad (12)$$

⇨ formula:

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$$E_{prod.onboard.} = E_{STC} * S_{HD} * \eta * M * A * n, \quad (13)$$

where:

- E_{STC} – energy in standard test conditions [W]
- S_{HD} - solar hour daily [h]
- η – panel efficiency by factory
- M - Moldovan® coeficient= 83% (simulated result)
- A – panel surface PV/ unit
- n – number of panels

CONCLUSIONS

The paper proposes the implementation of photovoltaic panels on liferafts as a way to achieve a renewable energy source that will generate electricity for the equipment on board a liferaft, necessary for search and rescue operations (SART, EPIRB, VHF station with batteries and fresh water maker), or new equipment that might be implemented from now due to the presence of a source of electricity on board. The latter can increase the chances of survival of the occupants of the raft, can increase comfort and in some cases, save lives.

In short, simulations were performed using the program PVsyst for photovoltaic panels placed around the raft, and calculations were performed for each orientation from 45 to 45 degrees obtaining encouraging results.

Also, it has been proposed a formula, by which, knowing some elements, you can find out the amount of solar energy available for usage in any part of the world.

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