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Producing electricity on board a ship in motion or stationary using photovoltaic panels

Nicolae-Silviu POPA, Mihai-Octavian POPESCU

Electrical Engineering Department
University POLITEHNICA of Bucharest
Bucharest, Romania
nicolaesilviu13@gmail.com

Vlad MOCANU, Mircea TÂRHOACĂ Ciprian POPA

Electrical Engineering Department
University POLITEHNICA of Bucharest
Bucharest, Romania

Abstract: ***A very important pillar for the world economy is the transport sector. Nowadays, about 80% of freight transport has been done by sea. Besides the recognized economic efficiency, ships are, unfortunately, an important sources of marine environment pollution. It is well known that the IMO is permanently concerned in maritime safety and many measures have been shown to be successful in reducing ship-sourced pollution. But it is not enough, new solutions must be found, and the answer can come from the direction of green energies (electricity produced from renewable sources). On board ships can be used as renewable energy sources wind energy or solar energy. Solar energy is easier to use because photovoltaic panels can be mounted on board the ship to produce electricity (however, provided that the photovoltaic panels do not increase the ship's forward resistance or reduce its manoeuvrability). Studies have shown that offshore wind energy is much more efficient than a ship-mounted wind turbine because an on-board wind turbine greatly reduces a ship's speed and manoeuvrability. The authors of the paper proposed to study the production of electrical energy obtained with the help of photovoltaic panels on board a ship in motion and stationary. The ship marched in the Mediterranean Sea for two months.***

Keywords—USB 6008, LabView, resistors, data acquisition, renewable energy sources, photovoltaic panels.

I. INTRODUCTION

It is known that photovoltaic panels capture light energy (from the Sun) and convert it into electricity. This aspect makes a considerable contribution to combating atmospheric pollution with CO2.[1]–[5] The energy balance according to the The National Energy Regulatory Authority shows that in November 2022, the electricity required by Romania produced from renewable sources was 61% (electricity production using PV system was 7.6%).[6] This aspect is reported in table 1.

TABLE I. TABLE 1 - ELECTRICITY PRODUCED IN NOVEMBER

No.	Production type	Value [%]	
		Value [MW]	Value [%]
1.	Hydro	6641.94	36.3
2.	Coal	3092.2	16.9
3.	Wind power	3014.91	16.5
4.	Hydrocarbons	2615.92	14.3
5.	Nuclear	1413	7.7
6.	Solar	1393.14	7.6
7.	Biomass	106.896	0.6
8.	Biogas	21.357	-
9.	Waste	6.03	-
10.	Waste heat	4.1	-
11.	Geothermal	0.05	-
12.	Total	**18309.543**	100

Another important factor that led to the development of technology to produce electricity from renewable energy sources is represented by the increase in the costs of conventionally produced energy (coal, hydrocarbons, etc.)

The current geopolitical situation has led to price increases in all sectors of the economy, but the energy and food sectors have been severely affected by recent events. Added to this aspect is the massive pollution faced by humanity these days. To reduce costs and reduce pollution, renewable energy sources represent a reliable and efficient variety.[7]–[9] The transport industry is also suffering from high costs. About 80% of the world's freight transport is done by ships, and the engines and generators of the ships are diesel engines. This fact significantly raises the level of pollution worldwide.[10]–[12]

A realistic and reliable alternative is represented by the installation of photovoltaic panels on board ships and the use of the resulting electricity to supply small and medium-sized consumers (GPS, ECDIS, Radar, radio equipment, etc.)[13]–[15]. This paper presents an experiment that took place on board the Training ship 'Mircea' for 2 months in the Black Sea and the Mediterranean Sea (This experiment is based on a study carried out in 2013[16]), first the installation on board of 3 photovoltaic panels and the data acquisition related to the voltage produced and the power consumed.

II. EXPERIMENTAL PLATFORMS

A. Hardware part.

To carry out this experiment, the following were used: power resistors (figure 1), 3 photovoltaic panels with a power of 10W (figure 2) and the USB 6008 data acquisition board (figure 4).

Power resistors - these elements had the purpose of consuming the power produced by the panels, but also to realize the voltage divider, because the USB 6008 board can measure a maximum of 10V (DC), the voltage divider was needed.

Photovoltaic panels[17] - 3 photovoltaic panels were installed on board the ship (port - left side, starboard - right and on the command deck – figure 3) with the specifications shown in table 2.

Fig. 2 – Photovoltaic panel

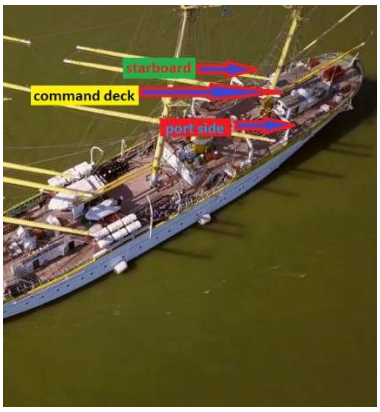

Fig. 3. – Organizing the panels on board

TABLE II. CHARACTERISTICS OF THE SOLAR PANEL

No.	Characteristic	Value
1.	Maximum Power (P_{max})	10 Wp
2.	Power Tolerance Range (%)	±3%
3.	Open Circuit Voltage	22.3V
4.	Maximum Power Voltage (V_{mp})	18V
5.	Short Circuit Current I_{sc}	0.6 A
6.	Maximum Power Current (Imp)	0.56A

USB 6008 data acquisition board - The NI USB-6008 (Part Number: 779051-01, 191039C-02) is a Bus-Powered Multifunction I/O Device. There are eight single-ended or four differential USB 6008 analog input channels, two USB 6008 analog output channels, and 12 digital input/output channels. The USB 6008 National Instruments can perform both multiple and single analog-to-digital conversions of an infinite or fixed number of samples. A FIFO buffer keeps the data held during acquisitions through analog inputs to ensure that no samples are lost. The USB 6008 is run using the NIDAQmx driver software which is compatible with software packages or application development environments (ADEs) such as LabVIEW, LabWindows/CVI, Measurement Studio, or LabVIEW SignalExpress.[18]

Fig. 4 – USB 608

B. Software part

The LabVIew program was chosen for this experiment. This program is produced by National Instruments. This program allows the data acquisition and the creation of a database in real time. LabVIEW is systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights.[19]. Figure 5 shows the structure of the LabView program for this experiment.

DAQ Assistant Expres VI (Figure 6) - Contains samples to write to the task. data is an output for measurement tasks and an input for analog and digital output tasks. data does not appear for counter output tasks.[20]

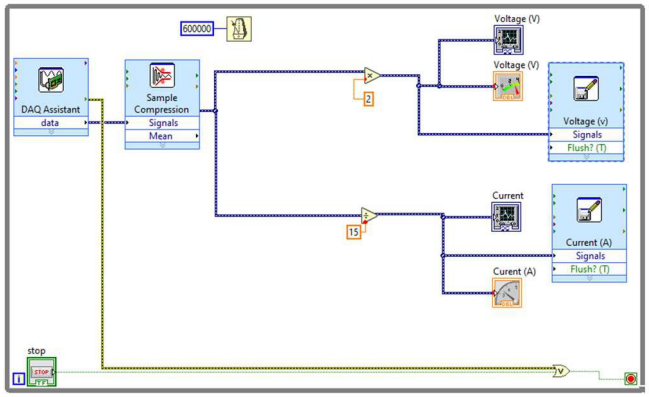

Fig 5.a – Block diagram

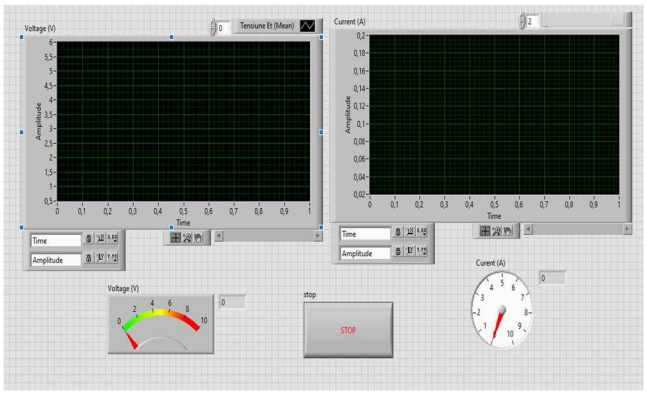

Fig. 5.b – Front panel

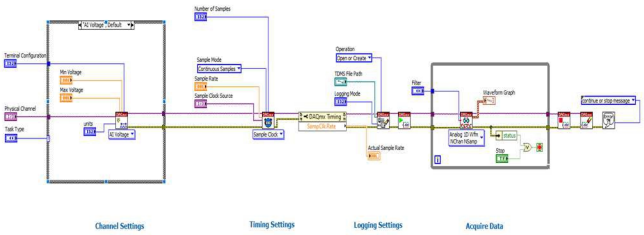

Fig. 6 – DAQ assistant Express VI construction

Sample Compression Express VI - Acquires a large number of data points and compresses the data points into a smaller number of points.[20]

Wait Until Next - Waits until the value of the millisecond timer becomes a multiple of the specified millisecond multiple. Use this function to synchronize activities.[20]

Waveform Graphs - The waveform graph displays one or more plots of evenly sampled measurements. The waveform graph plots only single-valued functions, as in y = f(x), with points evenly distributed along the x-axis, such as acquired time-varying waveforms. The following front panel shows an example of a waveform graph.[20]

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Numeric Controls and Indicators - Use numeric controls and indicators on the front panel to enter and display numeric data in LabVIEW applications.[20]

Write To Measurement File Express VI - Contains the description of the measurement file. LabVIEW appends the text you enter in this text box to the header of the file. This text box is unavailable when you select the Microsoft Excel (.xlsx)[20]

While loop - Repeats the code within its sub diagram until a specific condition occurs. A While Loop always executes at least one time.[20]

III. EXPERIMENTAL PART

A. *Circuit analysis*

The specifications of the panel say that it can provide a power of 10Wp at a voltage of 18V, with a current of 560mA. For this hypothesis it is necessary to dimension the circuit and find out the resistance to have the expected effect.

$$\begin{cases} U = I \cdot R \\ P = I \cdot U \end{cases} \rightarrow P = I^2 \cdot R \quad (1)$$

For this case:

$$\begin{cases} U = 18V \\ P = 10Wp \\ I = 0{,}56A \end{cases} \quad (2)$$

Substituting the values from relation (2) in relation (1), it is obtained:

$$P = I^2 \cdot R \rightarrow R = \frac{P}{I^2} = \frac{10Wp}{(0{,}56)^2 A} = 31.88\Omega \approx 32\Omega \quad (3)$$

At a resistance of 32 Ω, in conditions of high brightness, the voltage at the terminals is 18V, it is necessary to create a voltage divider, because the USB 6008 measures a maximum of 10V (Figure 7).[18]

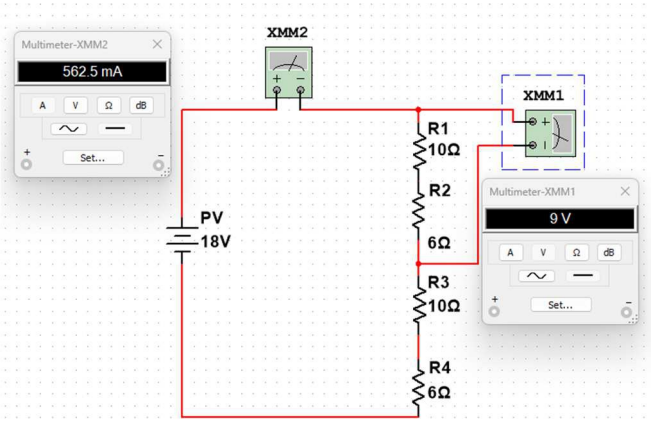

Fig. 7 - Circuit diagram with voltage divider – *NI Multisim 14.1*

B. *Data acquisition and energy production*

Training ship 'Mircea' performed a training march of approximately 2 months, on the route: Constanta - Augusta - Genova - Valencia - Valetta - Alexandria – Constanta. During the training march, the energy production and consumption was monitored for the 3 photovoltaic panels mounted on board.

Since the period was very long, it is not possible to load the chart for the entire duration of the march, because it is too loaded with data and it would not be possible to read it. Figure 8 shows the data obtained for 7 days.

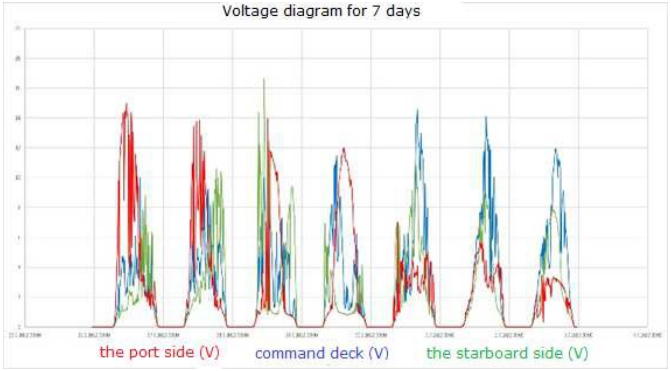

Fig. 8 – Voltage diagram

Figure 9 shows June 26, 2022. on this day the cloudiness had a value of 3-4 (0 clear sky, 8 - sky completely covered with clouds)

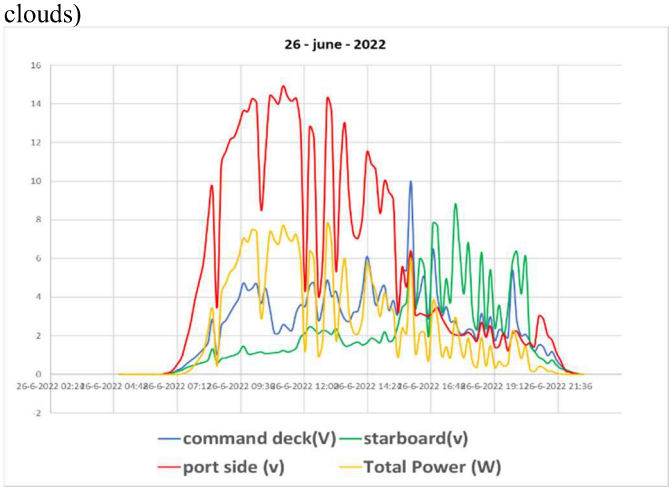

Fig. 9 – Voltage and power diagram – June 26, 2022

Figure 10 shows June 27, 2022. On this day the cloudiness had a value of 3 (0 clear sky, 8 - sky completely covered with clouds).

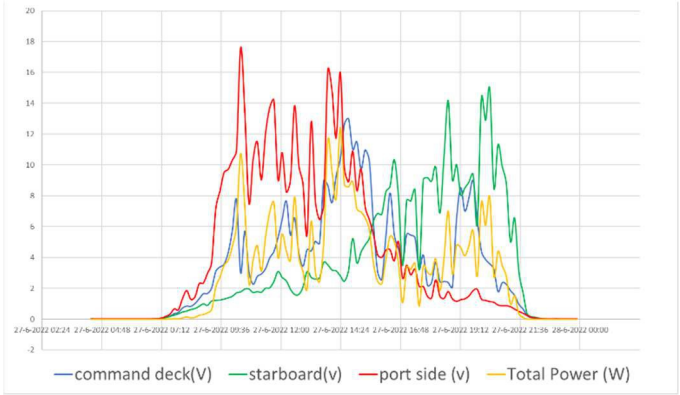

Fig. 10 -Voltage and power diagram – June 27, 2022

IV. DATA ANALYSIS

In this subchapter, the data obtained every day of the week presented in subchapter 3 are analyzed. This week was chosen for analysis because weather conditions were among the most varied. The analyzed data have as time interval 07.00AM - 09.00PM for each day (from the moment when the panels started the production of electricity, until the moment when

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they no longer benefited from sufficient light for the production electricity).

Analyzed data will be:

- Effective energy at the output (aver)
- Current (aver)
- Voltage (aver)

A. June 26, 2022

On this day the cloudiness had a value of 3-4 (0 clear sky, 8 - sky completely covered with clouds). Figure 11 shows the voltage-power diagram for this day.

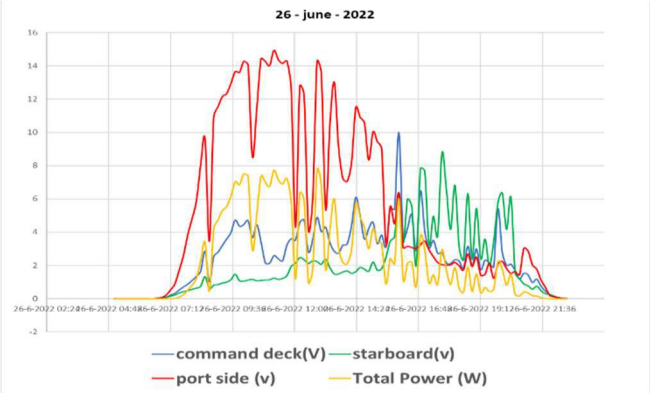

Fig.11 – Voltage and power diagram – June 26, 2022

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.0422\ kWh/day \\ Current = 0.2444\ Ah \\ Voltage = 12.3524\ V \end{cases}$$

B. June 27, 2022

On this day the cloudiness had a value of 2-3 (0 clear sky, 8 - sky completely covered with clouds). Figure 12 shows the voltage-power diagram for this day.

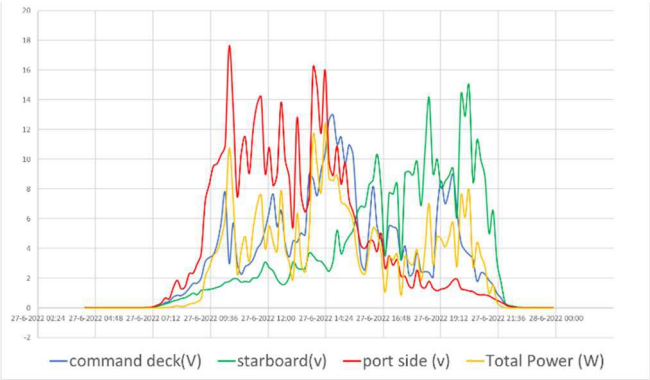

Fig.12 – Voltage and power diagram – June 27, 2022

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.0606\ kWh/day \\ Current = 0.2717\ Ah \\ Voltage = 15.9293\ V \end{cases}$$

C. June 28, 2022

On this day the cloudiness had a value of 3 (0 clear sky, 8 - sky completely covered with clouds). Figure 13 shows the voltage-power diagram for this day.

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.0466\ kWh/day \\ Current = 0.2490\ Ah \\ Voltage = 13.195\ V \end{cases}$$

D. June 29, 2022

On this day the cloudiness had a value of 4 (0 clear sky, 8 - sky completely covered with clouds). Figure 14 shows the voltage-power diagram for this day.

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.0383\ kWh/day \\ Current = 0.2328\ Ah \\ Voltage = 11.7754\ V \end{cases}$$

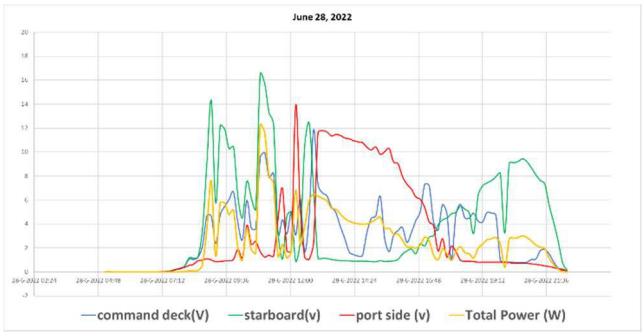

Fig. 13 – Voltage and power diagram – June 28, 2022

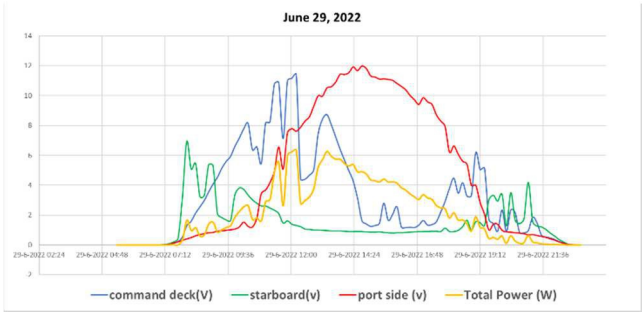

Fig. 14 – Voltage and power diagram – June 29, 2022

E. June 30, 2022

On this day the cloudiness had a value of 4-5 (0 clear sky, 8 - sky completely covered with clouds). Figure 15 shows the voltage-power diagram for this day.

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.03865\ kWh/day \\ Current = 0.2131\ Ah \\ Voltage = 12.9506\ V \end{cases}$$

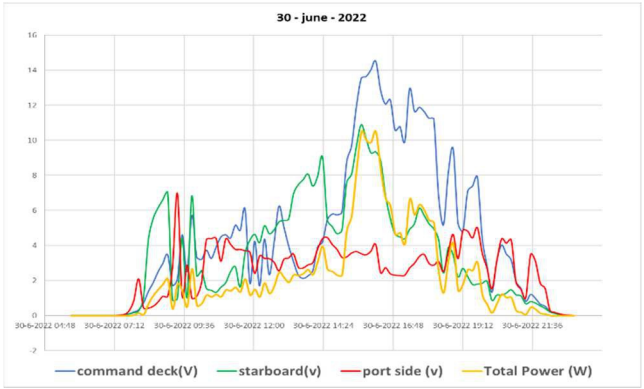

Fig. 15 – Voltage and power diagram – June 30, 2022

F. July 1, 2022

On this day the cloudiness had a value of 1-2. Voltage and power diagram – Figure 16.

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.08099\ kWh/day \\ Current = 0.2969\ Ah \\ Voltage = 17.9897\ V \end{cases}$$

On this day the ship performed training maneuvers for rescuing the man from the sea. Although the degree of cloudiness is low, the variation of the ship's course can be seen in the graph below, through the voltage fluctuations. However, this day was the most productive of the entire analyzed period.

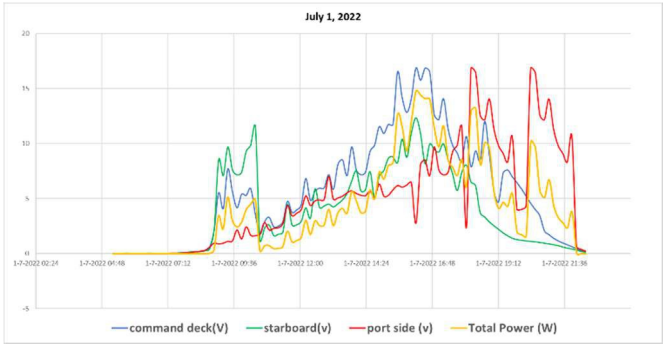

Fig. 16 – Voltage and power diagram – July 1, 2022

G. July 2, 2022

On this day the cloudiness had a value of 4-5. Voltage and power diagram – Figure 17.

Date obtained:

$$\begin{cases} Effective\ energy\ at\ the\ output = 0.035847\ kWh/day \\ Current = 0.1707\ Ah \\ Voltage = 14.9987\ V \end{cases}$$

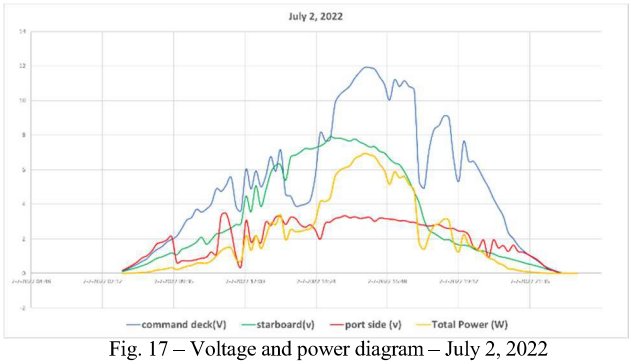

Fig. 17 – Voltage and power diagram – July 2, 2022

V. COMPARISON OF ANALYZED DATA

In this paper, the production of electricity with the help of photovoltaic panels, on board a ship, for the duration of 7 days was analyzed. Figure 18 and table 3 show the values obtained from the experiment.

TABLE III. VALUES OBTAINED

Day	Voltage (V)	Current (Ah)	Power (Wp)	Effective energy (kWh/day)
1	12,3524	0,2444	3,0195	0.0422
2	15,9293	0,2717	4,3288	0,0606
3	13,1949	0,249	3,2868	0,0466
4	11,7754	0,2328	2,7421	0,0383
5	12,9506	0,2131	2,7608	0,0865
6	17,9897	0,2969	5,7855	0,0809
7	14,9987	0,1707	2,5605	0,0358

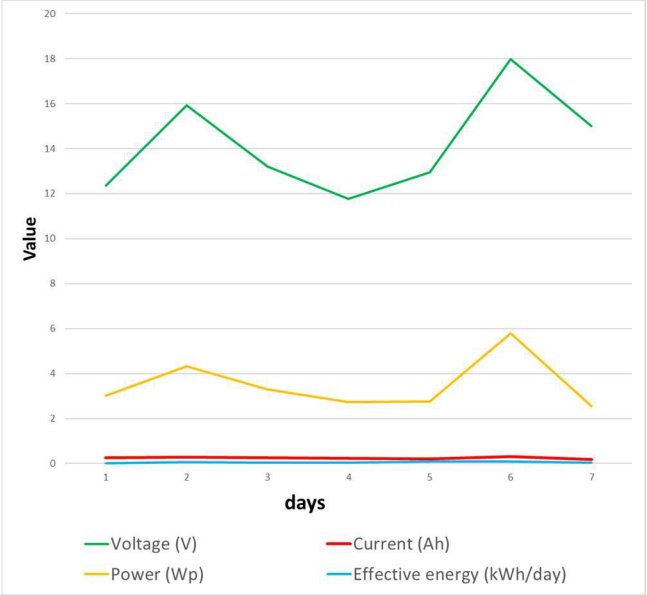

Fig. 18 – Values obtained.

Weather conditions (cloudiness, precipitation, fog, etc.) significantly influence the production of electricity, when we refer to photovoltaic panels.

However, it can be observed that the maneuvers performed by a ship influence the production of electricity. On the sixth day (July 1, 2022) the weather conditions were favorable to produce electricity on board using photovoltaic panels, but the execution of maneuvers (successive change of the ship's course) favored voltage fluctuations (the position of the panel in relation to the sun was changed).

VI. CONCLUSIONS

Photovoltaic panels can be a secondary source of electricity on board ships, for powering navigation or communication equipment. for the safety of the ship and crew it is necessary for a diesel generator to be the primary power source (at least at present). The diesel generator remains the main source of electricity on board a ship, as it does not depend on the cloudiness and the angle the ship makes in relation to the sun. There are very large electricity consumers on board the ship, so the electricity needs cannot be produced using photovoltaic panels.

The use of panels as a secondary source of electricity on board ships (worldwide) would help reduce CO2 pollution, as photovoltaic panels can supply electricity to small and medium-sized consumers on board ships. This would reduce the amount of electricity produced using diesel generators and therefore reduce the number of pollutants.

To further explore the potential of using photovoltaic panels on ships, we plan to repeat the experiment using panels with higher power. We will study the charging and discharging of Li-Ion batteries for storing the electrical energy generated by the panels and use this energy to power the equipment on board the ship. This will create a small network

consisting of a main source of electricity (diesel generator), a secondary source (photovoltaic panels), energy storage (Li-Ion batteries), voltage converter and inverter, and consumers (naval equipment).

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