ENERGETIC OPTIMIZATION AND ENVIRONMENTAL PROTECTION BY USING SOLAR ENERGY ON SECURITY PONTOONS ON THE DANUBE

Ph.D. Eng. Corneliu Critescu[1]
Ph.D. Eng. Radu Rădoi[2]
Ph.D. Eng. Catalin Dumitrescu[3]
Ph. D. Student Eng Liliana Dumitrescu[4]
[1, 2, 3, 4] Hydraulics and Pneumatics Research Institute INOE 2000-IHP, Romania

ABSTRACT

The renewable energy resources available to Romania create favorable conditions for their use both to reduce the consumption of classic fuel based on hydrocarbons and to reduce their negative impact on the environment.

The first part of the paper presents the technical solutions adopted for the capture, storage and use of thermal and photovoltaic solar energy as well as for the implementation of these systems in the specific spaces available, ensuring the proper functioning of human crewed pontoons for the accomplishment of the missions specific

In the second part of the article, a number of issues are presented emerged and solved during the commissioning of the combined / hybrid system,of use, at the same time, of classical/chemical energy and renewable solar thermal and photovoltaic energy, in order to optimize and improve energy efficiency. Finally, favorable conclusions are presented on the use and possibility of generalizing the use of the systems presented.

Keywords: *Renewable energy, energy conversion, combined energy systems, hybrid energy systems, solar energy, pontoon*

INTRODUCTION

Monitoring and securing of traffic on the Danube, especially in the border area, requires the use/location of floating pontoons (Figure 1) necessary to live of gendarmerie crews responsible for coastguard operations. Ensuring the security service implies adequate living conditions that require the availability of adequate energy sources.

In current practice, the pontoons are powered by generating sets where the electric generator is driven by a thermal motor, usually a diesel engine, which uses diesel as primary chemical energy.

In this situation, the reduction of pollutants in the Danube area at present, until their elimination in the near future, becomes an immediate goal of action, for which adequate technical solutions, implemented, tested and validated must be identified.

The specific objective of the researches was to establish technical solutions for the use of solar renewable energy [1], [2], in order to reduce the classical energy consumption and to protect the environment, applicable in the conditions specific to the river pontoons.

The general objective of the research is that, after the development of a combined / hybrid system for the use of solar thermal and photovoltaic renewable energy, to be extensed/generalized of this system to the entire flotilla of existing pontoons in Romania, as well as to create the posibility, that on the commercial bases, to ofer to all partners interested in these systems.

Fig. 1 Surveillance pontoon

METHODOLOGY

If all the equipment on the surveillance pontoon in Danube Delta would be in operation it would consume an aggregate power of 15 kW. Depending on operating conditions (day, night, surveillance) and certain coefficients of simultaneity, the power consumption can vary between 1.5 kW and 7.5 kW maximum. The average consumption of 10 kW Diesel Genset fitted to the pontoon is 2.8 liters per hour and in the maximum load consumes 3.7 liters per hour. Diesel fuel consumption varies between 30 and 80 liters per day. Electricity consumption for domestic hot water boiler is 7.2 kWh / 24 h. The average power consumed by the equipments on the pontoon is 5.5 kW. In order to optimize energy consumption has been set as a target, the reduction of the energy produced by the diesel genset with 20 % [3]. Thus 1.1 kw must be obtained with solar panels both in sunny days and in less sunny days in the winter. For this, two technical solutions have been established for obtaining domestic hot water and one for obtaining electricity. Electricity consumption of the domestic hot water boiler is reduced by the use of thermal solar panels. The functional schemes of the two installations comprising two solar thermal panels, an array of photovoltaic panels and equipment for the conversion and storage of solar energy.

Group of thermal solar panels

The electric boiler is replaced by a solar thermal boiler that allows heating of water both by electricity or by coil heat exchanger. For this, 2 thermal solar panels with 10 vacuum tubes and a solar station were installed. The features of one solar panel are: peak output (G=1000W/m², $\eta 0$): 1 kW, maximum pressure: 6 bar, tubes number: 10, heat loss coeff.: <0.8 W/m^2 °C, absorbtion surface: 0,8 m^2.

In the location of the pontoon global annual irradiation is 1500…1700 kWh/m^2 (Figure 2) [4]. For calculations, an average value of 1600 kWh/m^2 was taken. Taking into account the effective surface and efficiency, it is obtained that over a year, 1 m^2 of thermal panel produces an energy of 1600 kWh/m^2 ·0,75 = 1200 kWh/m^2 , and during one day will produce 1200 kWh / 365 days = 3,29 kWh / day / m^2 .

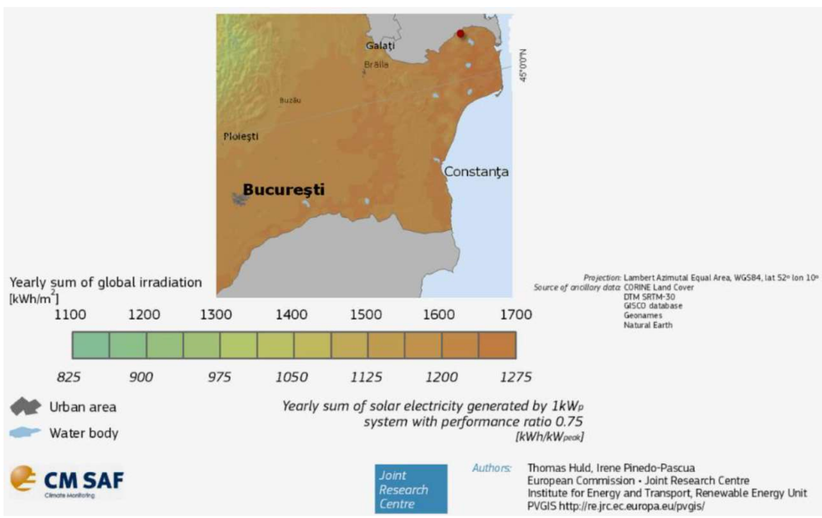

Fig. 2 Global irradiation and solar electricity potential for SE Romania [4]

Fig. 3 Surveillance pontoon endowed with solar energy solutions

In the calculation methodology of small solar thermal system provided by ESTIF [5], are given values for losses and efficiency for different applications (Table 1).

Table 1

Application	Pipe Losses in% of Collector Output	Extra Tank Losses in % of CollectorOutput	Boiler Efficiency in %	Boiler Stand-by Losses in % of CollectorOutput
Domestic hotwater DHW Boiler Back-up	10%	5%	85%	15%
Domestic hotwater DHW Electric Back-up	10%	5%	100%	0%

Considering the summed surface of the two panels, the energy produced by the thermal panels system in one day will be: 1,6 m^2 · 3,29 kWh / day / m^2 = 5,264 kWh.

To find out the energy transferred to the cold water through the coil heat exchanger in the boiler was considered a 85% overall transfer efficiency and it results $E_{tr} = 5{,}264\ kWh \cdot 0.85 = 4.47\ kWh$.

Energy requirement for boiler water heating is given by the formula

$$Q = m \cdot c \cdot \Delta T \qquad [1]$$

where m – volume of the boiler: 0,08 m^3; c – heat capacity of water: 1,16 kWh/m^3K;

ΔT – temperature difference – hot water and cold water temperature: 40 K

$$Q = 0{,}08 \cdot 1{,}16 \cdot 40 = 3{,}712\ kWh$$

Thus, it follows that the energy production of solar panels cover the energy requirement for heating water in the boiler, even providing a surplus of energy. With the help of solar thermal panels, the energy consumed by the electric boiler is reduced by 62%.

European Solar Thermal Industry Federation proposes a simple calculation methodology to determine the energy yield of small thermal systems which is based on a few selected parameters and the assumption of a constant mean temperature in the collector [5].

For the installation of solar panels on the roof of the pontoon, some structures attached to the roof of the pontoon were designed. The mode of installation of the solar panels on the roof of the pontoon can be seen in Figure 4.

Fig. 4 Solar panels and mounting rails on the roof of the pontoon

Area of photovoltaic panels

For the photovoltaic panels dimensioning, is needed the amount of electrical energy to be supplied by photovoltaic panels in one day so that to reduce the diesel genset consumption by 20% thus 5,5 kW ·24 h · 0,2 = 26,4 kWh. In order to achieve a 27 kWh average production capacity over a year, 30 photovoltaic panels of 265 W are needed.

For storage of electricity, 12 batteries are used with the following characteristics: voltage U = 12 V, capacity C = 220 Ah. The energy stored by them is E = U [V]· C [Ah] · 12 = 12 V · 220 Ah · 12 = 31680 Wh.

In order to obtain 1000 discharge cycles specific to gel batteries, the battery discharge depth must be limited to 40%. Then the available battery energy is Eb = 31,68 kWh · 40 % = 12,67 kWh. Under these conditions, the essential equipment that consumes 1,1 kW can be powered from batteries ~ 11 hours (12,67 kWh / 1,1 kW).

The performances of the photovoltaic system were simulated with an on-line tool made available by PVGIS [6], [7] (Fig. 5).

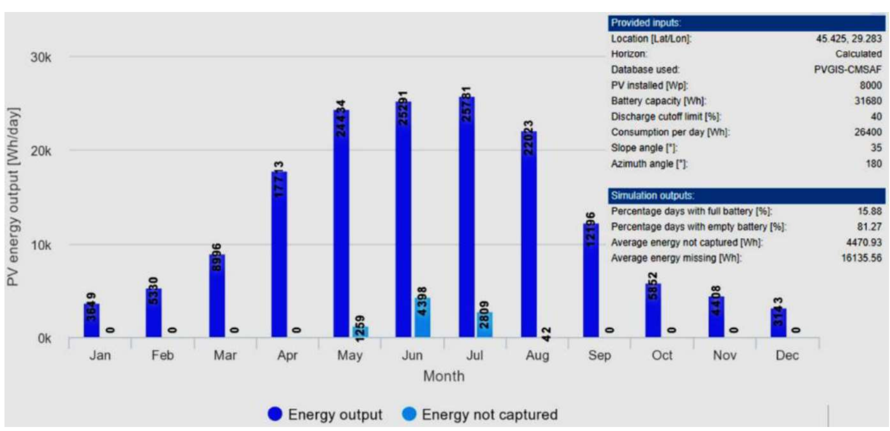

Fig. 5 Performance of off-grid PV: PV energy output © PVGIS, 2017 [5]

For batteries charging is used a charger model SmartSolar 250/100, and for energy management and for DC/AC conversion is used a unitQuattro 48/8000. Quattro unit contains an inverter and has a function for switching energy sources (grid, genset, solar). Both units are produced by the company Victron Energy (Figure 6a). For boiler water heating is used a closed loop system with a solar station that circulates a mixture of water with antifreeze from the solar collector to the heat exchanger inside the boiler (Figure 6b).

a b

Fig. 6 Equipments installed on board of the pontoon

RESULTS

Statistics on the consumption and production of the solar installation were obtained through VRM Victron Energy Portal [8]. The equipments are connected to the internet via a Venus GX unit. At the site of the pontoon, the internet was provided with an LTE modem.

Figure 7 shows the energy consumed over a day from the grid (genset), battery and solar. It can be seen that solar energy is available after sunrise at 6 AM and is interrupted when the supplied electricity is too weak after 15:30. If the energy supplied by the solar system during certain periods (mostly in the summer) can not be consumed or stored in batteries, the system can be configured to deliver energy to the grid. By installing a bi-directional meter can be reduced the cost of the invoices paid to the electricity supplier.

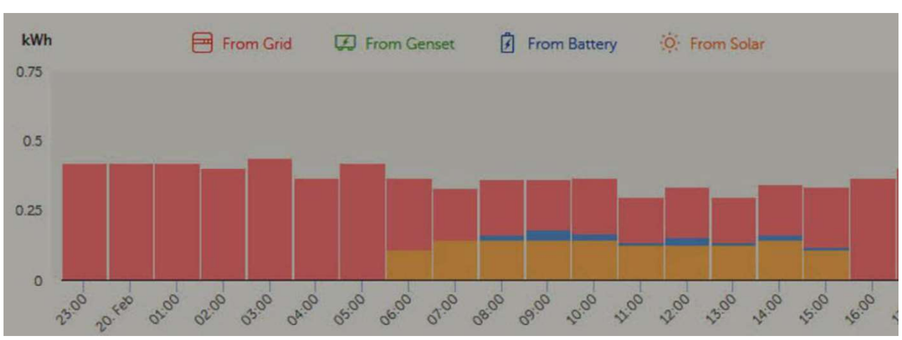

Fig. 7 - Energy consumption [8]

Figure 8 shows the variation in photovoltaic energy production over a day. The diagram shows the large variation in production due to atmospheric conditions (variable sky due to clouds or fog).

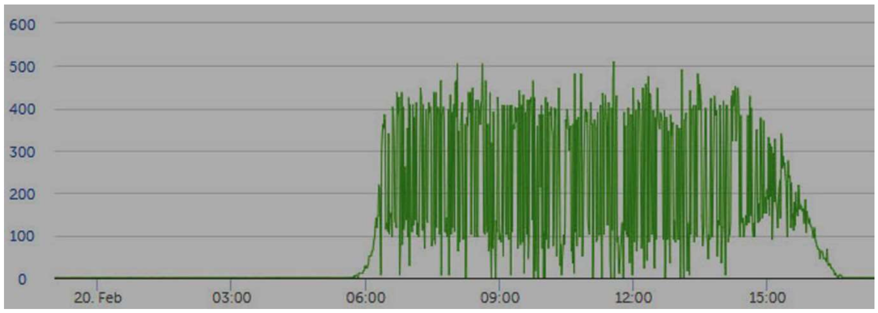

Fig. 8 - PV Yield [W] [8]

Figure 9 shows how is used the energy produced by photovoltaic panels on the pontoon as long as the sun is in the sky. One part is used to charge the batteries, and most of it is used directly for consumption.

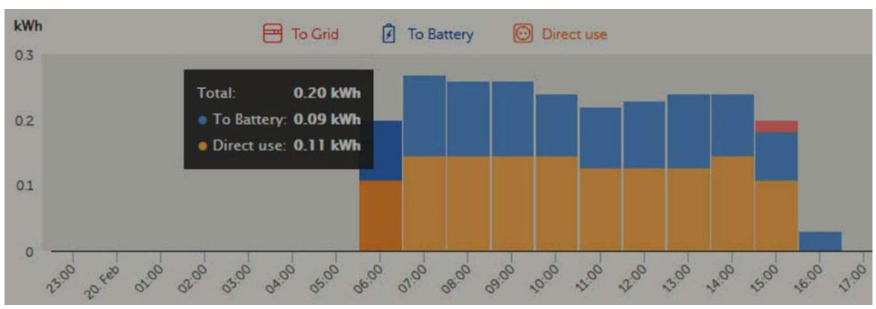

Fig. 9 - Solar consumption [8]

Figure 10 shows consumption over the course of a few days since mid-February. Solar production is not high, which is justified by the period in which the data were recorded. For February 17, consumption was 84% from grid, 1% from battery and 15% from solar.

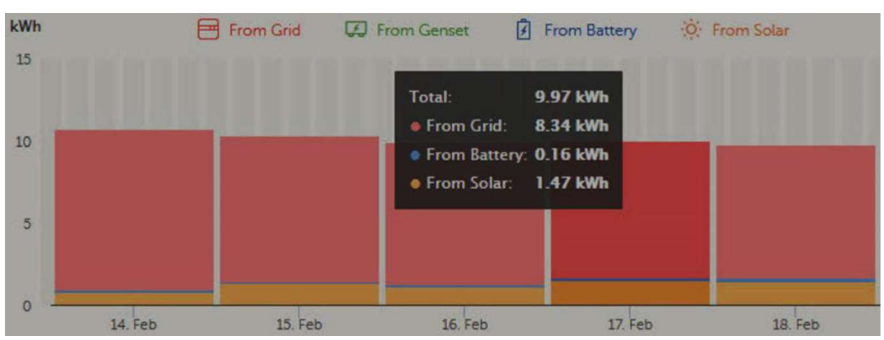

Fig. 10 - Daily consumption [8]

In Figure 11 there are diagrams of battery voltage variation and variation of charging current from the solar charger. In the period when the solar charger is active, it is noticeable that the battery voltage is higher. The load current varies as the intensity of the solar radiation that reaches the surface of the solar panels varies.

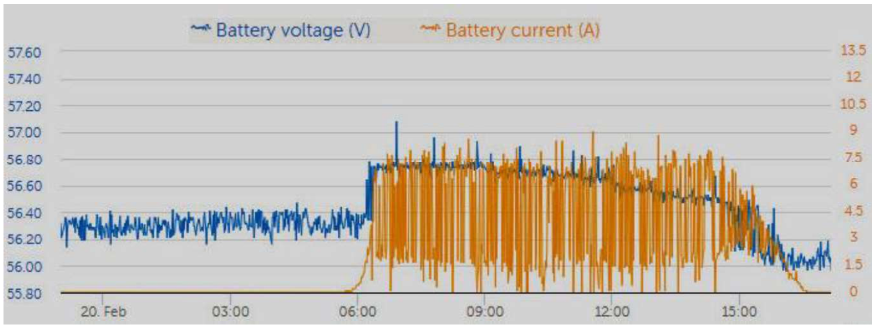

Fig. 11 – Variation of battery voltage and charging current [8]

CONCLUSION

The technical solution, adopted and developed by the INOE 2000-IHP Institute in Romania, proved to be in line with the specific requirements of pontoons operation, in terms of reducing the consumption of classical fuel and reducing the negative impact on the environment.

The 30 photovoltaic panels and two solar thermal panels ensure the reduction of fuel consumption for the generator (or energy from grid where it is available) according to the proposed target (20%), in the summer months production is even higher than consumption.

If at night the electricity consumption was high and in the morning the batteries drop below the set threshold (40%), the diesel genset will automatically start operating until the sun rises and become operational the solar power. After the solar power resumes, the genset stops automatically.

The system can be remotely monitored via the internet connection and the VRM Victron Energy Portal.

The technical solutions adopted have a strong generalizing character, and after a real-time testing period, actions / activities will be initiated to generalize the tested technical solutions.

REFERENCES

[1] Bostan I., Dulgheru V., Sobor I., Bostan V., Sochireanu A. Renewable Energy Conversion Systems – Wind, Solar, Hydraulic (Sisteme de conversie a energiilor regenerabile – eoliană, solară, hidraulică), Book, ISBN: 978-995-63-076-4 ,Tehnica-Info Publishing House, Chișinău / Moldova Republic, 2017;

[2] Bostan I., Bostan V., Dulgheru V., Sobor I., Secrieru N., et al., Elaboration of autonomous irrigation systems integrated with photovoltaic, International Conference HERVEX, Romania, 2017, pp. 297-307;

[3] Cristescu C., Dumitrescu C., Dulgheru V., Popescu T.C., Increasing energy efficiency and optimizing the operation of systems that produce clean energy from renewable sources (Creşterea eficienței energetice şi optimizarea funcționării sistemelor care produc energie curată din surse regenerabile), Hidraulica Magazine, ISSN 1453-7303, Romania, No.3/2017, pp.62-73,;

[4] http://re.jrc.ec.europa.eu/pvg_download/map_index.html#!

[5]www.estif.org/fileadmin/estif/content/policies/downloads/Simple_Calculation.pdf

[6] http://www.leonics.com/support/article2_14j/articles2_14j_en.php

[7] http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVP

[8] https://vrm.victronenergy.com/installation.