[1] 21th International Conference on Renewable Energies and Power Quality (ICREPQ'23)

Madrid (Spain), 24th to 26th May 2023
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.21, July 2023

IoT-Internet of Things in Floating Solar Photovoltaic Systems

Paulo Vargas[1,] and AntónioValente[1,2]

[1] Department of Engineering University of Trás-os-Montes and Alto Douro

[2] INESC TEC—INESC Technology and Science, 4200-465 Porto, Portugal

al70216@alunos.utad.pt, avalente@utad.pt

Abstract. New technical solutions are beginning to emerge, of which the Floating Solar Photovoltaic (FSPV) systems, is a promising new technology growing rapidly in the recent years. Portugal is a good example in Europe with several facilities of this type. For a correct management of these systems, and to have significant data, it is necessary to have a reliable communication system, based on a Global System for Mobile Communications, adequate protocols to communicate and save the data for later analyses. This study aims to develop a climate data acquisition system to be placed next to an FSPV system installed on a farm next to the Douro River. This system is installed in a box over the water surface. To allow comparison of temperature variations over the water surface with the temperature (*offshore*) another box with similar sensors is placed on land *(onshore*). With the data collected by these two systems is possible to compare the temperature data in two boxes, installed in these different locations, to analyse the influence of the water mirror on the photovoltaic cell efficiency.

Keywords. Internet of Thinks, FSPV systems, photovoltaic energy productions

1. Introduction

New technical solutions and strategies are beginning to emerge, of which Floating Solar Photovoltaic (FSPV) systems are part. In this framework, southern European countries have excellent climate conditions for reinforcing the use of solar energy. There are several national and global goals to achieve, PNEC-2030[1] and RNC-2050[2]. Several studies have already been carried out in this field, of which the references [3], [4] are an example, where the authors show the effectiveness that FSPV have and the important role that they have to achieve these national goals. In the research assess the existing Portuguese potential for floating photovoltaic systems and its integration in the power grid. The authors carry out a study to evaluate the technical and economic conditions of a FSPV system[3] that may be installed in the Gouvães dam reservoir, in the Tâmega River. Effectively, carbon neutrality by 2050 presents one opportunity to Portugal, based on a democratic and fair model territorial cohesion that boost wealth generation and efficient use of resources[5] , Fig. 1, presents the utilization of energy renewables in horizon 2030. One the same line, the Portuguese main driver [2] for renewable energy horizon 2030, defines concert goals, especially for the Electricity and consummation of the economy, decentralized production, research and innovation in new technologies.

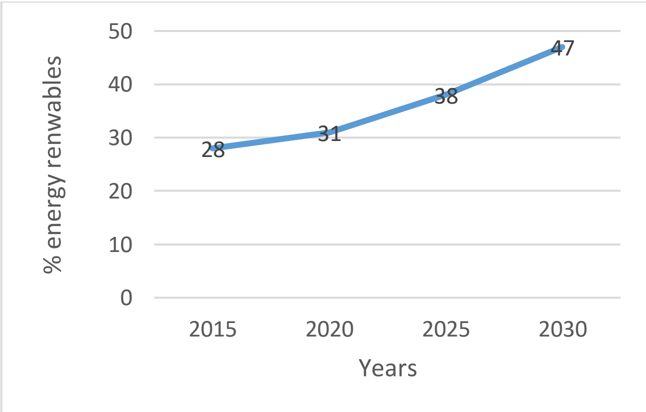

Fig . 1. Half energy renwables in horizon 2030.

A-Floating systems

In Portugal, in the North, for example, Alto Rabagão [6], is one the example, Fig. 2. Another project is located in Alqueva Dam, Fig. 3, this FPSV project, is a power plane, located in Dam reservoirs, consist in 840 PV panels with an area of 250 $m^{2.}$ And an installed capacity of 220 kWh with an annual production of around 300 MWh[7]. At the end of 2019, EDIA (Alqueva Development and Infrastructure Company) completed the construction of two FSPV of 1 MW each for self-consumption at the lake and Cuba-Este pumping stations, near Alqueva hydro power plant. The production of these units will be largely absorbed by the pumping units installed there. This project comprises the installations of 10 floating PV power plants, Fig. 3, with a total installed capacity of 50 MWp and will occupy an area of about 50 hectares over the water. With an estimated production of 90 GWh/year, the energy obtained from all these PV plants would be enough to supply about 2/3 of entire population of low Alentejo region. To achieve the objectives defined in PNEC-2030[1] and achieve carbon neutrality, several projects are underway to install FSPV System in dams and lakes from Portugal.

Fig. 2 . FSPV System in Dam Rabagão

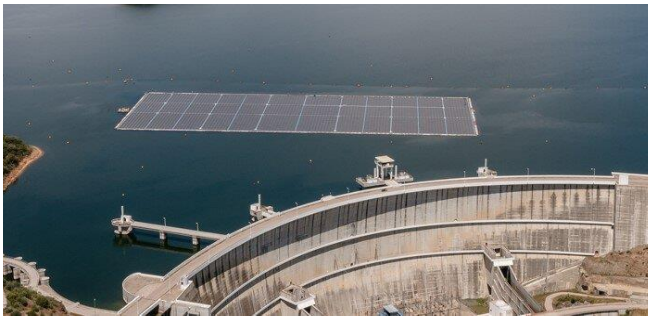

Fig. 3. FSPV System in Dam Alqueva

2. Theoretical concepts

The sun is the only energy source on Earth that varies with latitude and cloud layer, with an annual average value of about 15,3x10^{8} Cal/m2, and equivalent to about 40000 kW of energy available per inhabitant [8] . Using solar energy to produce part of the energy we consume seems to be a good bet, since in general the world is increasingly dependent on electricity. The Internet of Things (***IoT***) was used as a remote monitoring systems to obtain the data from: intensity of Current, voltage, consumption power, temperature, humidity, and light intensity[9]. A Lora WAN IoT, consists of sensors modules with wireless transmission[10] using the LoRaWAN protocol communicating every 15 min, a gateway connected to The Things Network through a GSM/LTE connection and a server with a time-series database. The LoRaWAN[11] for data transmission , is a protocol with low consumption, small and easy for programming [10]. It is low cost, easy to install, easy maintain, low consumptions and communicates wireless trough a Long Rang Wide Area Network LoRaWAN [12], as show in Fig.4

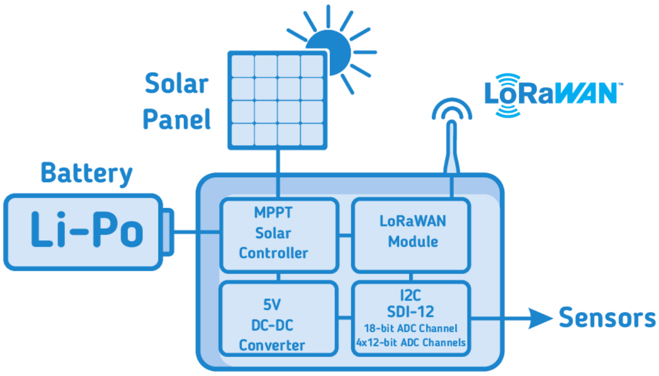

Fig. 4. LoRaWAN System Node

3. Case study

In this section a case study will be presented consisting in installation a prototype of FSPV, installed in a lake in Quinta do Crasto Douro River [13], with two locations relatively close together, one *offshore* in the middle of the lake, and another similar sensors located near, *onshore*, in land and use the appropriate protocol to communication LoRaWAN[11]

A-Electronic system

The system offshore, is installed in a box of material, plastic and waterproof to protect the electronic components, Fig. 5, inside the box, with groups of sensors BME680[14] (temperature and atmospheric pressure), with the sensors connected to each module, and lithium-ion batteries that proved total at 4600mAh, of capacity, and another sensors systems located near, show in Fig.6. To avoid the greenhouse effect, the systems are in direct contact with the atmosphere through a hole in the box, and has an antenna to communicate via internet. The prototype system is attached to a floating material that is fixed to the banks through anchors, fixed at two points in the land near the lake.

Fig. 5. The FSPV system prototype (offshore)

Fig .6. The system (onshore)

B-Data visualization

After data acquisition, we can already be seen the data in (https://thingspeak.com/channels/1807749/private_show), by MATLAB[15] and data can be exported to Excel (CSV) to analyses in MATLAB Of the available variables, in the following analyses we will focus on the temperature collected since we aim to verify if the water mirror influences the energy production. In the following graph we have a sample of values collected during a week in July 2022, it is sampling that properly treated will give precious indications about trend values and defined a relationship about the influence the mirror water in the efficiency the PV and the global FSPV-System.

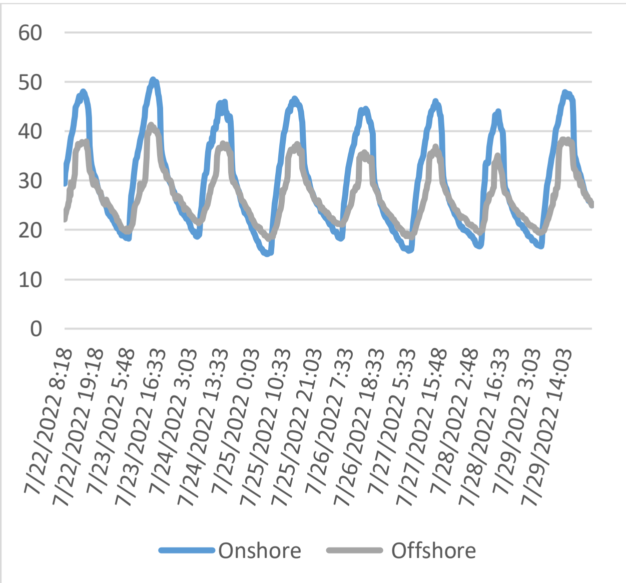

Fig. 7. Temperature in onshore/offshore º C

C-Data analysis

For better compliance and analysis of the results show in Fig. 7, the values of temperature in land (*onshore)* and lake (*offshore*), regarding the data collected, in the next table 1, a summary table is presented with the values of the minimum and maximum for the temperature, in the two systems of sensors, values collected on the same period of time. Considering the sample of available values, during days of the month July 2022, hot and sunny days, which are a good example for the production of PV systems, the values registered in the sensors installed *onshore* in a place close to *offshore oscillate* between the values, 22 ºC, at 8h18m, system start-up, the values grown to a maximum value 37 ºC. A variable to display the difference between maximum and minimum temperatures over the main time periods, recorded at the two points, by analyzing the values verify that the lake system present less temperature oscillation absolute values, with temperature more elevate in same periods of the day, see the values in the Table I, for example on the 22 of July Land temperature= 18ºC against a Lake temperature = 17ºC, the amplitude is above -1.44ºC, and more examples are shown in the Table I. It is possible to show that the water mirror where the systems is floating in lake, influences the temperatures values in the installed system and that this temperature difference affects the energy productions of the systems and shows that the FSPV System perform better than is equivalent on land, additionally in case of large-scale solar system, the increases in production will be significant.

Table I – Temperature in land, lake and thermal amplitude

Time	Onshore ºC	Offshore ºC	Amp. º C
7/22/2022 8:18	29.33	22.09	7.24
7/22/2022 13:33	46.59	37.23	9.36
7/23/2022 6:18	18,25	19.69	-1.44
7/23/2022 14:33	50.27	40.88	9.39
7/24/2022 6:18	18.99	21.54	-2.55
7/24/2022 14:48	45.94	36.85	9.09
7/25/2022 6:03	15.32	18.71	-3.39
7/25/2022 15:18	45.8	37.47	8.21
7/26/2022 5:48	18.26	21.09	-2.83
7/26/2022 16:18	41.92	34.37	7.55
7/27/2022 6:03	15.88	18.85	-2.97
7/27/2022 15:03	45.14	35.25	9.89
7/28/2022 5:48	16.68	19.34	-2.66
7/28/2022 15:18	44.06	34.2	9.86
7/29/2022 6:18	16.7	19.58	-2.88
7/29/2022 15:48	47.5	37.62	9.88

D- Influence of water mirror on the photovoltaic cell efficiency

In this section we talk about the influence between the temperature in the two locations with the two different points (*onshore/offshore)* and characterize the relationship between temperature and yield of the FSPV systems.

For a good definition, is necessary to study the influence of the temperature of the optimal production of the photovoltaic cell, there are papers where this topic is addressed [16] [17].The solar temperature incidence on the PV is a factor with influence in the efficiency [18] of the system.

4. Energy production

In this section a case study presented is about of the calculated energy production of the systems installed in the two different point: the data temperature *onshore* and *offshore*. In the Fig.10, presented the evolution of the temperature *onshore / offshore*, in a typical day. To obtained the energy balance were important to knew that the climatic conditions, namely the solar radiance that was obtain from European Commission [19].

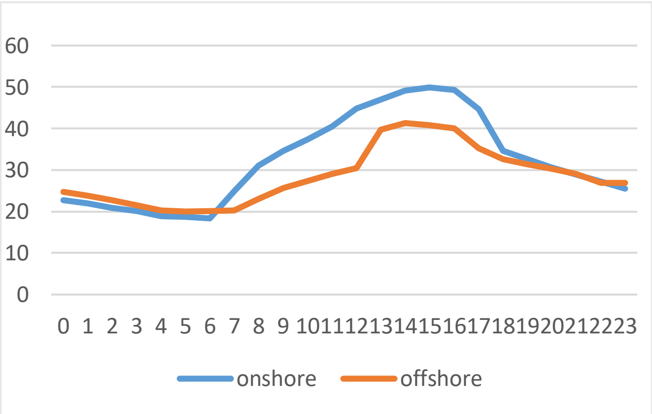

Fig. 10. Evolution of temperature onshore/offshore

The photovoltaic solar panel chosen for the PV system is the Panasonic N340, whose main characteristics are shown in Table I

Table I. Panasonic N340 Technical specifications

Model	VBHN340SA17
Rated Power (Pmax)	340W
Maximum Power Voltage (Vpm)	59.7V
Maximum Power Current (lpm)	5.70A
Open Circuit Voltage (Voc)	71.3V
Short Circuit Current (Isc)	6.13A
Temperature (normal operating)	44°C
NOCT	44.0°C
Length	1,59 m
Width	1,053 m

A- Energy production onshore/offshore

In the Fig**.** 11, presented the production of the system in *onshore/offshore*, with the values of temperature in the two different scenarios. Next, the formulas[18] that were use to calculate Imax(1), the maxim power (2), energy production (3) and the cell temperature(4).

$$Imax = \frac{G}{Gr} * I^{t}max \qquad (1)$$

Imax- Maximum current (A)
G- Radiation (W/m^2)

$$P_{max} = V_{max} I_{max} \qquad (2)$$

Pmax-Maximum power (W)
Vmax-Maximum voltage (V)
Imax- Current intensity (A)

$$E = \eta_{inv} \sum_{i=1}^{n} P_{max}(G,T)\Delta t_i \qquad (3)$$

E- Energy (Wh)
$\boldsymbol{\eta_{inv}}$ – Perfomance (%)
$\boldsymbol{P_{max}(G,T)}$ - Maximum power depending on the incident radiation and temperature (W)
$\boldsymbol{\Delta t_i}$ – Time interval considered

$$\theta c = \theta a + \frac{G(NOCT-20)}{800} \qquad (4)$$

θc-Cell temperature, ºC
θa- Ambient temperature ºc
G-Incident radiation (W/m^2)
NOCT- Normal operating temperature (ºC)

B-Energy balance

In the Fig. 11, presents the power evolution onshore/offshore, by the comparative analyses of the two locals where the production are different.

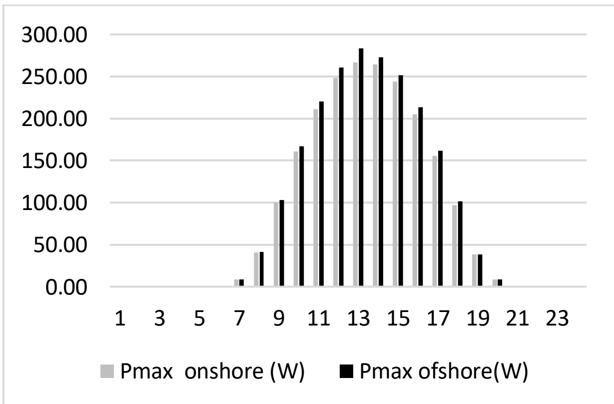

Fig. 11. Evolution energy production onshore/offshore

In the Table II, presents the global production in the two systems: *offshore; onshore*. In resume, the Global energy production, in this typical day, in *offshore* system is 4.1 % higher than the system *onshore.*

Table II. Global energy production

Energy production/day	Onshore	Offshore	Variation (%)
KWh	2049.34	2133.22	4.1

5. Conclusion

The realization of this work was a good challenge, which allowed the integration of different areas of knowledge, Floating Solar Photovoltaic (FSPV), electronic, protocol communication, LoRaWAN, and energy production. In resume can affirmed in this typical day the production in *offshore* is more elevate 4.1 %, than the system in *onshor*e, because the water mirror in the lake has an influence in the temperature and performance of the photovoltaic cell efficiency.

Acknowledgement

Special thanks to Quinta do Crasto for providing the space and help in carrying out this research.

References

[1] "PNEC - 2030 Portuguese main drive for renewable energy horizon 2030."

[2] "RNC2050", Accessed: Feb. 18, 2023. [Online]. Available: https://descarbonizar2050.apambiente.pt/

[3] J. V. P. Baptista, "Portuguese national potential for floating photovoltaic systems: a case study," presented at the IEEE International Conference on Environement and Eletrical Engineering. doi: Proceedings - 2020 IEEE International Conference on Environment and Electrical 10.1109/EEEIC/ICPSEurope49358.2020.9160790.

[4] J. Baptista, P. Vargas, and J. R. Ferreira, "A techno-economic analysis of floating photovoltaic systems, for southern European countries," *Renew. Energy Power Qual. J.*, vol. 19, pp. 57–62, Sep. 2021, doi: 10.24084/repqj19.214.

[5] Ministry of Economy, "PNAC-2030, Electricity sector in Portugal on the 2020-30 horizon." 2019.

[6] "APE-Portuguese Environmental Agency, 2010." [Online]. Available: https://apambiente.pt/

[7] "Inauguration of Solar Photovoltaic Power Station at the Pisões dam." Jul. 06, 2017. Accessed: Mar. 08, 2023. [Online]. Available: https://www.cm-montalegre.pt/pages/819?news_id=3596

[8] "A synthesis of the days, "Production of electrical energy from renewable sources, 2010."

[9] "Design and Development of Real-Time Data Acquisition of Photovoltaic Panel Parameters via IoT," *NTU J. Renew. Energy "*, 2022.

[10] António Valente, "A LoRaWAN IoT System for Smart Agriculture for Vine Water," *Agriculture*, p. p.5/17, Dec. 2022.

[11] "What Is LoRaWAN? Long Range Wide Area Networks Explained." EMnfy. [Online]. Available: https://www.emnify.com/iot-glossary/lorawan.

[12] Antonio Valente, Sérgio Silva, Salviano Soares, "Low-Cost LoRaWAN Node for Agro-Intelligence IoT." Jun. 12, 2020. [Online]. Available: https://doi.org/10.3390/electronics9060987

[13] "Quinta do Crasto,." [Online]. Available: "https://www.quintadocrasto.pt/

[14] "Guide for BME680 Environmental Sensor with Arduino (Gas, Temperature, Humidity, Pressure)." Accessed: Mar. 14, 2023. [Online]. Available: https://randomnerdtutorials.com/bme680-sensor-arduino-gas-temperature-humidity-pressure/

[15] "MATLAB2023Rb, 'Thingspeak,' 10 01 2023." Accessed: Jan. 10, 2023. [Online]. Available: https://thingspeak.com/channels/1807749/shared_view

[16] David L. King, Jay A. Kratochvil,and William E. Boyson, "Temperature Coeficient For PV Modules," *26th IEEE PhotovoltaicSpecialists Conf. Sept. 29-Oct. 3 1997 Anaheim Calif.*.

[17] David L. King, Jay A. Kratochvil, and William E. Boyson and Sandia National Laboratories, Albuquerque, NM, "Temperature coefficients for PV modules and arrays: measurement methods, and resultsT."

[18] José Manuel Ribeiro Baptista, Raul Morais dos santos, "Fundamentals of Photovoltaic Solar Energy; 5-dimensioning of photovoltaic systems." Didactics-Applied Sciences 383, UTAD, Jan. 2010.

[19] "Photovoltaic Geographical Information System." Accessed: Mar. 11, 2023. [Online]. Available: https://re.jrc.ec.europa.eu/pvg_tools/en/#DR