Platform for optimizing photovoltaic consumption

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***Abstract*—This project aims to support the development and optimization of Intelligent Environments by simulating and analyzing user behaviors within these environments. Intelligent Environments leverage technology and artificial intelligence to enhance human experiences, requiring Today, we live in a world where it is essential to have all the necessary information available at the right time and in the right place. Applications, associated with different devices such as smartphones and computers, have brought this information into our hands.**

In that way, this project aims to develop a platform for maximizing photovoltaic use, which helps to improve energy consumption through photovoltaic panels. The platform will manage a heat pump considering the energy generated by the photovoltaic panels, control consumption and see the current temperature. The project have used two technologies known in the field of home automation, namely node-red and mqtt, which will facilitate the connection, in order to control and obtain information from the devices.

The platform will control the heat pump through the mqtt protocol using node-red. Using the application home assistant we show several graphs with information on energy consumption, heat pump temperature, the outside temperature and other information.

***Index Terms*—node-red, home-assistant, mqtt**

I. Introduction

In an era where sustainable energy solutions are gaining importance, this project aims to revolutionize the utilization of solar energy systems by maximizing efficiency and optimizing energy consumption.

Solar power, derived from photovoltaic (PV) systems, has emerged as a clean and renewable energy source with immense potential. However, harnessing the full benefits of solar energy requires intelligent management of both generation and consumption. This is where this platform steps in [2].

This project is designed to provide individuals, businesses, and communities with an innovative and user-friendly interface that empowers them to monitor, analyze, and optimize their photovoltaic consumption. By integrating advanced technologies and intelligent algorithms, this platform offers a comprehensive solution for maximizing the value and impact of solar energy installations [3].

With the ability to seamlessly connect to smart meters, weather forecasting data, and energy storage systems, this platform enables real-time monitoring and control of energy flows. This empowers users to make informed decisions about energy consumption patterns, maximize self-consumption of solar power, and minimize reliance on the traditional power grid.

One of the key features of this platform is demand-response capabilities, which allow users to dynamically adjust their energy usage based on factors such as electricity demand, available solar generation, and grid conditions. By intelligently managing energy demand in response to changing circumstances, users can optimize their consumption and reduce both costs and environmental impact [6].

This platform also includes energy storage management, enabling users to efficiently store excess solar energy for later use. By intelligently controlling energy flows and storage, this platform ensures that energy is utilized effectively and intelligently, avoiding wastage and enhancing overall system efficiency.

Furthermore, this platform offers smart load balancing, which optimizes the distribution of energy within a user's premises. By intelligently managing and prioritizing energy consumption across various devices and appliances, users can avoid overloads, minimize energy wastage, and achieve an optimal balance between comfort, convenience, and sustainability.

Nowadays the electricity service is available to anyone, being an indispensable good for human beings to carry out their tasks. The collapse in the financial sector, precarious work, the increase in taxes are some of the main factors that influence the economic power of the consumer.

One of the options for most people starts with reducing the use of electrical equipment that consume more energy or even replacing it with equipment with a efficient energy class. In this way, families nowadays have the need to control their consumption in order to better monetize their needs.

With this in mind, this project is focused on people who want to better manage energy efficiency in their homes, as this will benefit from saving time, consequently reducing costs and increasing efficiency. The objectives are above all, adapt and facilitate the visualizing consumption and most of all reduce the energy consumption, to achieve a better energy use and a lower cost.

In this project, we have developed a platform, which allows the interconnection between the different actuators (heat pumps, fan coils, etc.) and the inverter associated with the photovoltaic system, in that way it is possible in the controller device, to carry out all the necessary management between energy production and actuators in an automatic and autonomous way [7].

Also has been created a module for the Home Assistant open source automation platform that will show the relative information of the different actuators and the photovoltaic inverter.

II. State of the Art

Before developing any type of project, it is essential to study the applications already developed in this field in order to be able to develop a more advantageous product.

A. Similar projects review

In this way, a survey of applications developed at university level was carried out, and at table I are the projects analyzed with the name and acronym.

TABLE I
SIMILAR PROJECTS.

Project name	Acronym
Maximizing the energy use of photovoltaic panels	MAEPF
Use of photovoltaic-integrated solar heat pump system in Hong Kong	PPISHP
IoT Platform for Energy Sustainability in University Campuses	IOTPES

Next these three projects are described.

1) MAEPF: This project has the objective of future application in a 10 kW photovoltaic power plant, examined in the most efficient way to operate a solar tracker considering available local radiation, the operating temperature of the panels and losses due to electrical consumption. For this, a methodology was developed to calculate solar energy on surfaces, through solar position and atmospheric transmissibility, and a photovoltaic panel modeling purely as a function of radiation and temperature [1].

2) PPISHP: Most buildings in Hong Kong are served with water heaters for hot water supply. With the high aspiration to quality of life, the increase in demand for hot water has contributed in part to the growing use of energy in the city in recent decades. An integrated photovoltaic solar heat pump (PV-SAHP) system, which can be seen as a scientific fusion of photovoltaic/thermal and solar assistant heat pump technology, is proposed here as a sustainable alternative. Numerical analysis was performed using a dynamic simulation model and TMY meteorological data from Hong Kong. It was verified that the proposed system with R-134a is capable of reaching an average annual COP of 5.93 and photovoltaic output efficiency of 12.1%; the energy output is therefore considerably higher than the conventional heat pump plus side-by-side photovoltaic system. Within a year, the PV-SAHP system performs best in summer time when the average monthly COP can reach six or more. So its application potential in Hong Kong is good [2].

3) IOTPES: University campuses are usually made up of large buildings responsible for high energy demand, and are also important as demonstration sites for new technologies and systems. This project presents the results of achieving energy sustainability in a set of four buildings that make up the School of Telecommunications Engineering at the Polytechnic University of Madrid. In the project, after characterizing the consumption of university buildings for a whole year, different options are presented to achieve a more sustainable use of energy, considering the integration of renewable generation sources, namely photovoltaic generation, and the monitoring and control of energy demand. electricity. To ensure the implementation of monitoring and desired control, an internet of things (IoT) platform based on wireless sensor network (WSN) infrastructure was designed and installed. This platform supports an intelligent system to control heating, ventilation, air conditioning (HVAC) and lighting systems in buildings. In addition, the work presents the developed IoT-based platform, as well the implemented services. As a result, the project illustrates how providing the appropriate technology to existing old buildings can contribute to the goal of transforming these buildings into near-zero energy buildings (nZEB) at low cost [3].

III. Materials and Methods

After a study of the necessary technologies for the development of the application, together with the collection of information from the existing research as a guideline for its development.

It was concluded that it was crucial to define the steps for the application development, as well to understand the studied protocols utilization. To start, the following functional requirements were defined:

- Get outside temperature;
- Access the indoor temperature;
- Obtain the production of the photovoltaic panels;
- Turning the heat pump on at sunrise and off at sunset;
- Turn on the heat pump if there are low precipitation levels;
- Turn off the heat pump if there are very low energy production levels;

A. Node-Red automation

Automation in Node-Red is only allowed through the interconnection between the different actuators (heat pumps, fan coils, etc.) and the information from the photovoltaic inverter present in the house, so that the controller device can carry out all the necessary management between consumption and actuators automatically and autonomously. In Fig. 1 it is possible to visualize a diagram of the automation of the heat pump.

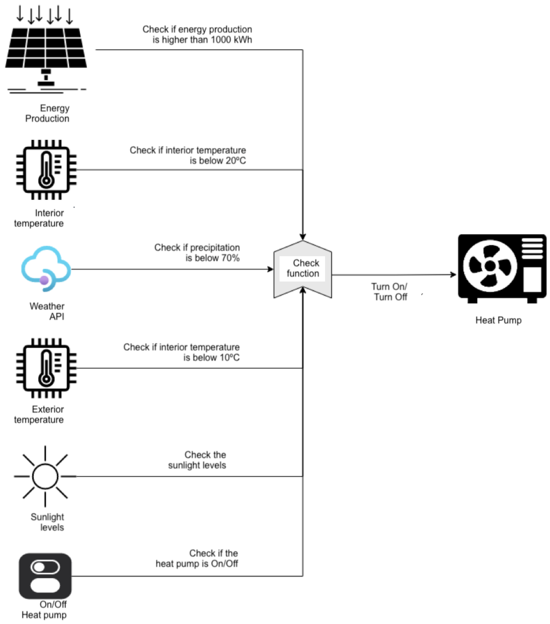

Fig. 1. Node-Red automation.

The API used in the project supports the subscription service for meteorological and oceanographic data produced at IPMA. With this application programming interface (API), IPMA provides users with a way to access a set of data, which can be integrated into an application, the API provides, among other data, forecast data associated with places (cities) in JSON format.

Forecast data are obtained automatically through statistical processing of forecasts from two numerical models (ECMWF and AROME), being updated twice a day, namely at 00UTC (available as a rule from 10:00 am) and 12UTC (available at rule from 20:00) [8].

Next, at Fig. 2 it is possible to visualize the initial mockups of the project, which contain several charts with information on energy consumption, the temperature of the heat pump and the outside temperature.

In Fig. 3 it is possible to visualize a network map with produced energy, consumption energy, battery status, energy injected in the network and consumed from the network.

And at Fig. 4 it is possible to visualize a char with the same information.

B. Implementation

To help develop the application for the photovoltaic platform, a flow was created through the implementation of code in node-red.

Next, it will be detailed the flows that will be used to obtain information from the devices, sensors, photovoltaic inverter and the outside temperature to receive all the data in the

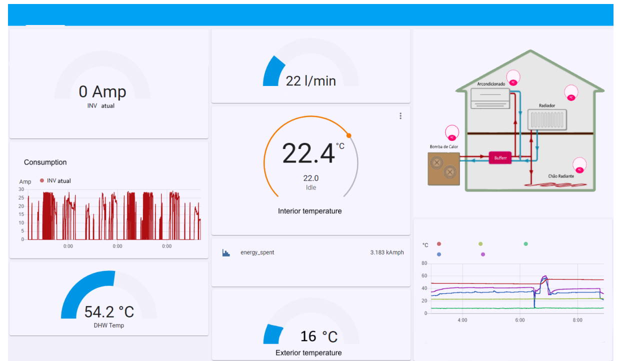

Fig. 2. Mockup Home Assistant.

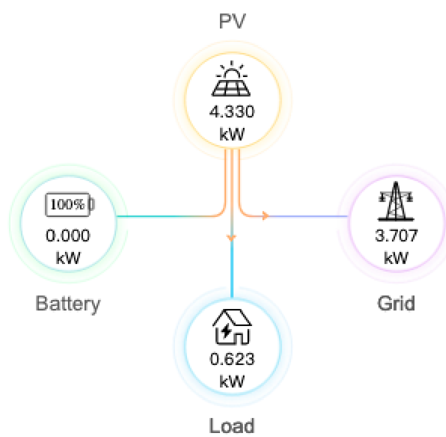

Fig. 3. Inverter Dashboard.

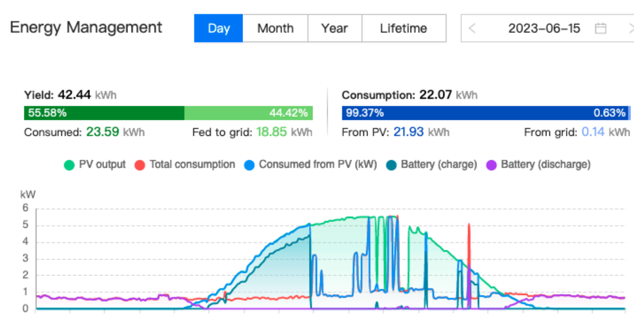

Fig. 4. Inverter information chart.

function and decide what will be the behavior to adopt by the heat pump.

1) Weather API: In Fig. 5 it is possible to visualize the flow used to receive atmospheric information, a weather-free API was used to obtain the probability of precipitation. In this part of the flow, the program will make a request to the API for information on the probability of precipitation and send the information (Probability of Precipitation) to the function that checks if the precipitation is less than 70%.

2) Interior temperature: In Fig. 6 it is possible to visualize the flow used to receive the outside temperature information. A

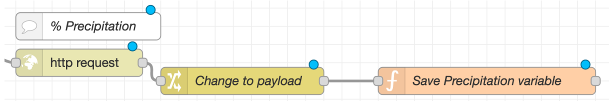

Fig. 5. Node - Weather API.

temperature sensor was used to obtain the current temperature in the house as we need this information to know if it is at the ideal temperature, or if not to turn on the heat pump to increase the temperature value.

The program will receive the temperature sensor value, then it will check if the temperature is below 20ºC (example of ideal temperature). If this is true, turn on the heat pump as it has not yet reached the ideal temperature.

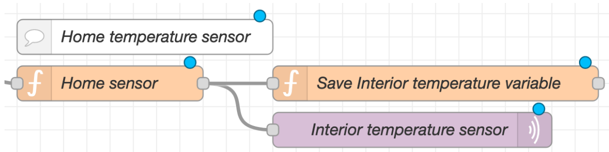

Fig. 6. Node - Interior temperature.

3) Exterior temperature: In Fig. 7 it is possible to visualize the flow used to receive exterior temperature information.

A temperature node from the Home Assistant itself was used to obtain the outside current temperature, as that information is needed to know if it is cold, or if not to turn on the heat pump to increase it.

The program will receive the temperature sensor value, then it will check if it is below the temperature (10ºC). If this is true, turn on the heat pump, if not, turn off the heat pump.

Fig. 7. Node - Exterior temperature.

4) Energy production: At Fig. 8 it is possible to visualize the flow used to obtain information from the photovoltaic inverter. The platform will receive this information, which is the production value in kWh and which will be used to see if the production is above 1000 kWh.

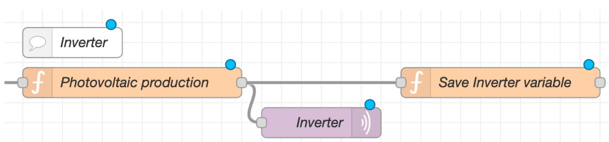

Fig. 8. Node - Energy production.

5) Heat pump: In Fig. 9 it is possible to visualize the flow used to turn the heat pump on and off. In the following flow, the function will check if it advantageous for turning on the heat pump, it will also check if it is active and if it is to turn it off or on, it will carry out this process automatically in 50 minutes.

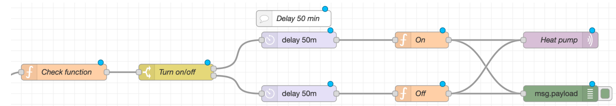

Fig. 9. Node - Heat pump.

6) Heat pump temperature sensor: In Fig. 10 it is possible to visualize the flow that serves to receive temperature information from the heat pump, we also use the MQTT protocol to send that information to the Home Assistant and in that way show it to the user.

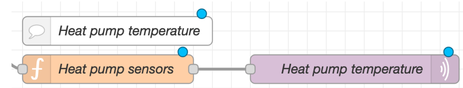

Fig. 10. Node - Heat pump temperature sensor.

7) Sunlight levels: To receive the information of the sunlight levels, is used the node in Fig. 11 to turn off the heat pump if there is no sun, as there will no longer be any photovoltaic production.

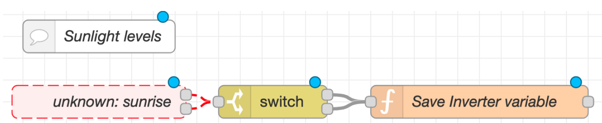

Fig. 11. Node - Sunlight levels.

8) On/Off: In Fig. 12 it is possible to visualize the flow that serves to receive information from the Home Assistant to turn the heat pump on and off, for that is used the MQTT protocol that will send the status "On" or "Off" to the check function and for the heat pump.

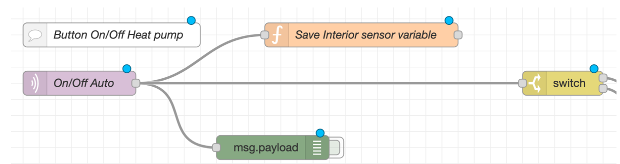

Fig. 12. Node - On/Off.

IV. Results

In Fig. 13 it is possible to see several charts with information of the energy consumption, the heat pump temperature, the outside temperature and it is also possible to see an image of the devices and their information in the house.

The information is obtained through the MQTT protocol, available through the device simulation.

Regarding the performance of the solution, we have preliminary results, which advance us a saving in the monthly bill in the order of 15%. Taking advantage of the heat pump operating

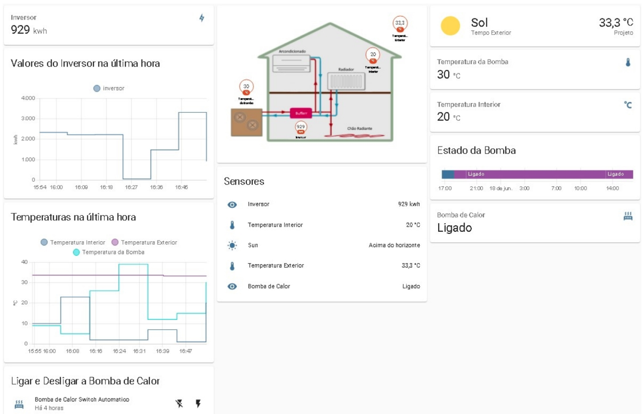

Fig. 13. Dashboard - Home Assistant.

only in periods of high photovoltaic production, which allows the pump to work completely free of charge.

This savings is significant, as this heating equipment is usually the equipment that consumes the most in a domestic environment. And that in the periods in which they are used, they represent in the order of 60 to 70% of the overall consumption of housing. Thus, the focus on optimizing the operation of this type of equipment must be continuous, to achieve the greater objective of more efficient and economical global consumption for users.

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V. Conclusions

In conclusion, the development of this project has yielded promising results in advancing the utilization and efficiency of solar energy systems. By leveraging cutting-edge technology and data analytics, this platform aims to maximize the benefits of photovoltaic generation while ensuring optimal energy consumption.

Through this project, we have successfully created a user-friendly interface that enables individuals, businesses, and communities to monitor and manage their solar energy production and consumption in real-time. This platform integrates with smart metering systems and weather forecasting data to provide accurate insights and recommendations for optimizing energy usage.

The platform offers several key features, including demand-response capabilities, energy storage management, and smart load balancing. These features empower users to make informed decisions regarding energy consumption, enabling them to leverage the full potential of their photovoltaic systems while minimizing grid dependency and reducing energy costs.

By intelligently allocating and prioritizing energy usage based on weather conditions, electricity demand, and individual preferences, this platform helps maximize self-consumption of solar energy. This not only reduces reliance on traditional grid power but also fosters greater energy independence and resilience in the face of potential disruptions.

Moreover, this project emphasizes the importance of energy efficiency as a core principle in sustainable energy management. By optimizing energy consumption patterns and avoiding wasteful practices, we can significantly enhance the overall performance and economic viability of photovoltaic systems.

The successful implementation of this project holds great potential for the widespread adoption of solar energy and the transition towards a greener future. By empowering users with real-time data and intelligent energy management tools, we believe this platform can contribute to substantial energy savings, lower carbon emissions, and a more sustainable energy landscape.

With this project, several work was done namely the project requirements were collected, the Home Assistant module was developed and the Node-Red flow was optimized in order to obtain better results.

Some issues were found during the development, due to the lack of different hardware (heat pumps, inverters) to obtain different results and to optimize the algorithms. As future work its intended to implement this project in different heat pumps and photovoltaic systems, to check its performance at different scenarios.

Acknowledgment

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