Decision Support System for Adherence to the White Tariff

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Abstract: The existence of different tariff modalities for charging the electricity sector in Brazil, if applied assertively in the user's consumption reality, can mitigate the negative effects that energy charges have on everyday life. Thus, the proposed work deals with the development of an intelligent measurement system for the consumption of energy by the consumer's home appliances and he will have access to his pattern of energy use throughout the day, through a web network and mobile platform. According to the tariff values available by ANEEL (National Electric Energy Agency), the user will be able to define, based on his consumption history, the adoption of the conventional tariff or the white tariff. It is important to consider that the white tariff has differentiated prices at certain times of the day, having its highest rate at peak times. These hours represent a range of hours in which the highest energy consumption occurs during the day, usually set to three hours per day and not valid on weekends and holidays. Please note that peak times vary by region. In this way, the system will act in parallel with the energy concessionaires and will take into account the interests of energy users.

1 INTRODUCTION

Brazil has a high hydric potential, and this contributes, to a considerable extent, to the fact that the country's energy production model is mostly comprised of hydroelectric plants. Despite the great energy potential, it is remarkable that it has one of the highest electricity tariffs in the world (Bem et al., 2023).

To understand what is involved in the Brazilian electricity bill, it can be noted that it is defined by the purchase of energy, transmission, and distribution fees, as well as sectorial charges and taxes (ANEEL, 2022a).

In the context of tariff issues, it should be noted the differences in tariffs charged according to residential, industrial, commercial, rural, and public power classes, and their respective subclasses. These classes are inserted in tariff groups that have specific tariff modalities. These groups are defined by: Group A, which consists of consumer units with voltage connection greater than or equal to 2.3 kV or units served by an underground system with voltage less than 2.3 kV; and Group B, consisting of consumer units with voltage connection less than 2.3 kV. (ANEEL, 2021). There is also a group of other accessors, composed of distributors and generating plants, as presented in (ANEEL, 2022b).

Focusing in Group B, it has subgroups that include the residential, rural, and other classes, besides public lighting, and its tariff modalities are defined by Conventional Monomial and White Tariff (ANEEL, 2022b). The conventional tariff consists of a single value regardless of the time of day, while the White Tariff is determined by consumption over three periods of the day: On-Peak, Intermediate, and Off-Peak. Comparing these rates to the conventional model, the price in off-peak hours is lower than the conventional rate values, while in the intermediate and on-peak hours the prices are higher in (da Silva et al., 2018). It is worth noting that the White Hourly mode does not include the low-income residential class and pub-

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lic lighting, according to (ANEEL, 2022b).

In this context, it is proposed the development of a low-cost smart meter, through which the user will identify their pattern of electricity consumption and will be able to define which tariff modality to adopt. This product consists of a combination of hardware, which measures the electrical energy consumed, stores the information, and sends it to a database; and software, which gives the user the power to monitor their consumption in real-time and visualize, in an intuitive way, the most appropriate tariff modality given their history of energy demand.

In general, the objective of the proposed work is to build an intelligent meter that can capture the user's consumption data, which will be visualized by the energy consumer, and enable him to define the tariff mode that applies to his context, based on his consumption pattern. The product to be created will observe the behavior of each user and indicate whether it is viable for him to change his energy bill to the White Tariff or continue with the Conventional Tariff, according to the hours of highest and lowest consumption and their respective values in kWh. Each user will have all the information via Wi-Fi such as exaggerated consumption alerts, suggesting the shutting off of some equipment, the amount of kWh consumed in the month, and a comparison to the year and guarantee that the White Tariff or the Conventional Tariff is the most viable. In this way, if the user opts to adopt the White Tariff, he will limit his consumption to the hours when the tariff value is lower. This project also benefits utility companies, considering the reduction of energy consumption during on-peak hours and mitigating overloads in the grid.

Paper organization: Section 2 presents the background of the proposal, through a brief literature review. Section 3 cites the Research Methodology adopted to carry out the presented decision support system. Section 4 details the development phase of the project. Section 5 presents the preliminary results, Section 6 discusses the final considerations and possible future works, followed by the acknowledgments references.

2 LITERATURE REVIEW

Considering the tariff scope, the consumer has the possibility to define which mode to adopt for his consumption pattern. Technologies such as certain smart meters can assist the user in this matter. J. P. Lima (2019) developed an energy measurement system linked to the ability to analyze the best tariff mode that fits the consumption pattern of the low-voltage user (Lima, 2019). To build the meter, a resistive circuit and an H11AA1 optocoupler were used for the voltage measurement, and the STC013 sensor for the current measurement. The ESP8266 microcontroller was used to process the data obtained and send the information to the database via Wi-Fi. Furthermore, an Android application was built, where the user can visualize his consumption and obtain a comparison of it when applying the conventional and hourly white tariff modalities. It is worth mentioning that the developed meter has its application open for two-phase and three-phase systems.

In addition to this theme, F. Brito and D. Dias developed a system capable of simulating, based on user consumption, which tariff mode best suits the context. Such a system is constituted by the single-phase digital meter PZEM-016, which, from a TTL to RS-485 converter, communicated with an Esp32 microcontroller. This has attributes such as Dual Core and Wi-Fi module, which contributed to the processing of functions simultaneously as well as the ease of sending data to the cloud. In this way, the energy measurement data was sent by the Esp32 to the Firebase database, where it was stored. For the consumer to visualize the information, an Android application was developed, which also generated comparison reports between white and conventional tariffs based on the consumption of the user (de Souza Dias and Brito, 2021).

3 METHODOLOGY

The White Tariff has three different values throughout the day. The periods are determined by ANEEL for each distributor and the energy users that have their consumption concentrated in the off-peak hours will benefit from this tariff mode instead of the conventional one (Luciano et al., 2021). Thus, the proposed system helps the user to understand his consumption pattern and adhere to the tariff that suits his pattern.

As mentioned, it is understood that there are already systems that have been developed with the same purpose. However, it is worth highlighting the difference between the proposed system and its benefits for the public to which it is intended. Thus, narrowing the comparisons to facilitate the analysis, the project of F. Brito and D. Dias, despite its advantageous application, does not have a system to store consumption readings before sending the information to the database (de Souza Dias and Brito, 2021). The proposed system has this attribute with the intention of not losing the captured data in case of internet connection failure. Furthermore, the interface proposal developed is more intuitive for the user, allowing for a more pleasant experience while using the system. Therefore, it is understood that user usability is extremely important. Furthermore, the system presented by the authors uses the white tariff simulation, and, for this, the user needs to inform the value of the tariffs in effect. The product in question will provide data from the distributors based on the values displayed by ANEEL. It is worth noting that the system developed defines on-peak, off-peak, and intermediate schedules according to the variation presented by region, according to the distributors, and in agreement with ANEEL.

Making a comparison with the system of J. P. Lima, in (Lima, 2019), numerous characteristics are close to the proposed work, such as the development of an open meter for two-phase and three-phase systems; a system that has consumption reading storage to avoid data loss due to internet connection failures and through which the user does not need to inform the tariff values to obtain the invoice simulation. However, attributes that define the differential of the product proposed in this work stands out. The meter can make the first connection with software via Bluetooth so that the consumer can enter his Wi-Fi user and password, through which the next connections will be made. In addition, the processor used presents greater applications within the expected goal and the interface is, in fact, extremely intuitive and easy to use.

In this way, considering the objective of the smart meter and the tariff context in which it will be introduced, it is understood that its insertion in the residential energy consumer scenario at a low-cost will offer knowledge about tariffs better applied to the consumer's circumstances and more autonomy to the user to make decisions related to his consumption. To fulfill these purposes, the project was based on the development of hardware, software, and the integration between both.

4 DEVELOPMENT

Regarding the hardware development, the system modeling was done so that it was possible to visualize and understand all the functionalities that needed to be inserted in the expected product. Then, a prototype was built that was able to perform the measurement of electric power consumption, store the readings locally, and send them to a database. The data sensing and processing system considers the accuracy, efficiency, and low cost that the product aims to achieve. The design of the meter was elaborated in such a way that it could be installed in a suitable place for its operation, such as the home's main switchboard. Its design was also conceived to be well seen and attractive to the user.

A schematic of the segments involved in the hardware and the connection to the software is shown in Figure 1.

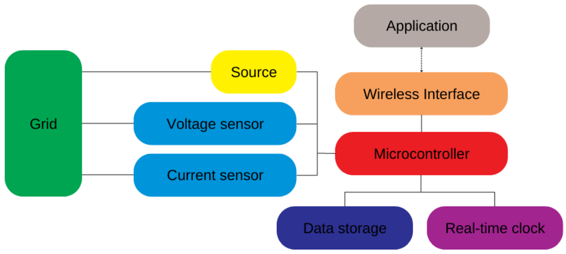

Figure 1: Project outline.

The smart meter will be connected to the electrical grid of the residence and will take readings of electrical current and voltage. This data will be processed by a microcontroller. As mentioned, the system has data storage that helps to preserve the data in case of power failure. The real-time clock ensures the accuracy of the time in which the readings are taken. Considering that the white tariff has its value changed depending on periods of the day, it is important to correctly record the time of the measurements. In addition, the hardware and software connection is made via a wireless interface.

The hardware circuit was built on a test board and several tests were made to analyze whether the prototype's behavior meets the expected goals. Among these tests, we can cite: the accuracy of the current and voltage readings on specific loads, the storage of data in case of internet connection failure, and the reaction of the system to certain disturbances.

Concerning the software, the consumer has access to the data through a mobile application and using the web, platforms developed in a way that is easy to handle and intuitive to use because the usability of the system is the focus of the development. Visually, the user monitors the energy consumption by his home appliances and has access to the billed values of energy consumed, based on the tariffs determined by the attending utility and the White Tariff schedules defined by the same in agreement with ANEEL. It is worth noting that the White Tariff schedule changes depending on the region, and this factor is considered by the system.

The use case diagram of the software system is shown in Figure 2.

As can be seen, the software system is responsible for keeping and managing the account with user

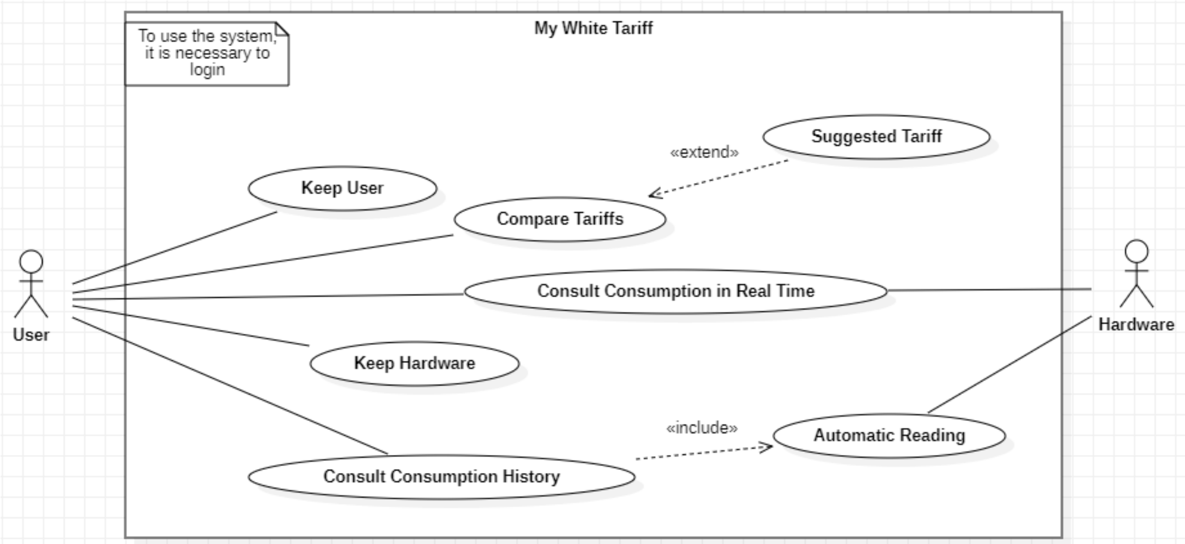

Figure 2: Software System Use Cases Diagram.

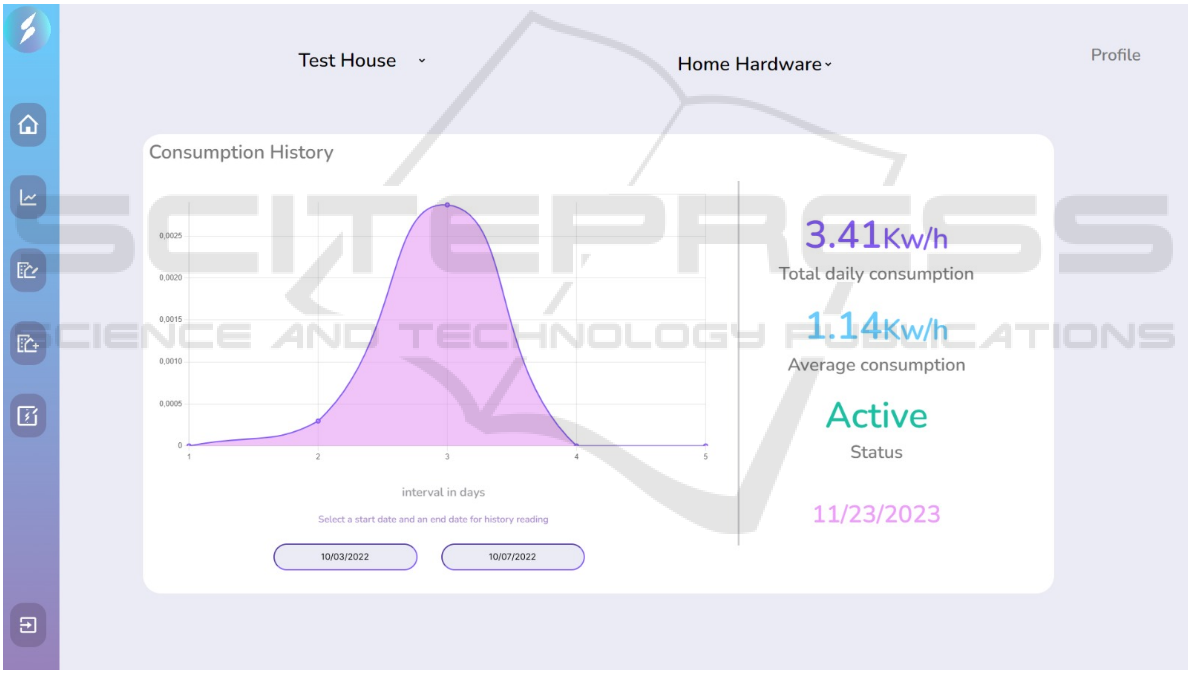

Figure 3: Web Platform Dashboard.

and hardware data, analyzing the energy consumption in real-time, and consulting the consumption history from the hardware connection, as well as comparing and suggesting the best tariff that applies to the user's consumption reality.

Initially, the design and prototyping of the functionalities of the web and mobile platforms were built in a visually pleasing way and with intuitive operations for the user. The construction of a logo highlights the project's identity in the context of the electricity consumer in Brazil. Next, the software system consists of the development of the web and mobile platforms, an API (Application Programming Interface), and a relational database. Figure 3 shows the main dashboard of the web platform [1] and Figure 4 illustrates the visualization of the same dashboard in the application for mobile devices, allowing the user to consult his consumption history and understand his energy profile.

[1]The Web Platform can be accessed at this link https://www.uainergy.com.br/ (only in Portuguese)

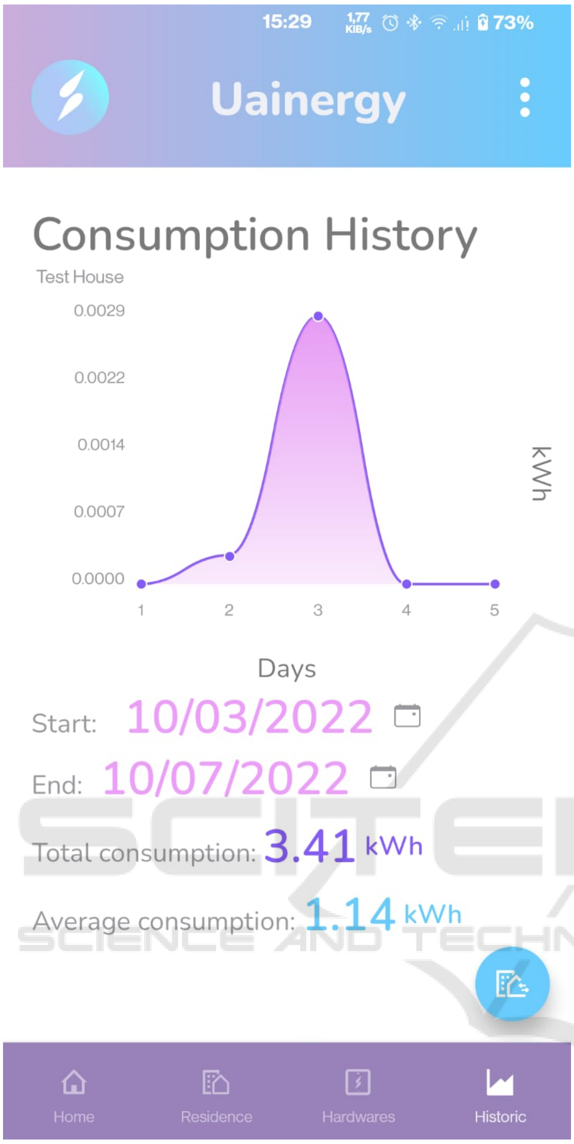

Figure 4: Mobile Platform Dashboard.

The integration with the hardware is done, initially, by Bluetooth connection. From there, the consumer provides the Wi-Fi user information and password. The hardware can then send the read data to a server. With the data available in the cloud, the user will have access to it in real-time and to the tariffs best applied to his consumption pattern, through his application.

5 PRELIMINARY RESULTS

The modeling of the system evolved during the smart meter's development, since the prototype's behavior when faced with certain problems that needed to be refined to ensure its efficiency.

Regarding the performance of the project's hardware, it is highlighted that it met the expected goal, considering that it successfully measured energy consumption in tests performed with the prototype. These tests were performed with certain loads and the energy consumption was represented graphically. Furthermore, it carried out experiments to analyze the behavior of the system in the face of certain disturbances such as the lack of internet and problems with the Wi-Fi connection.

To exemplify, Fig. 5 presents a test measurement and data submission with the smart meter prototype graphically.

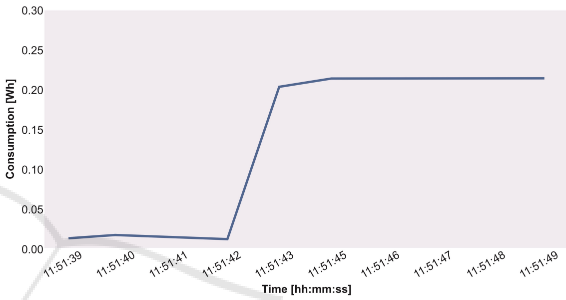

Figure 5: Prototype testing using a load.

It is possible to observe that the time and consumption (in kWh) are displayed. At the exact moment when a load is connected to the meter, consumption has shown a significant increase.

As concerns the system software, both the prototyping and the construction of the web and mobile platforms for Android, with the name and visual identity of the product, were executed and fit satisfactorily with the desired goal of the project development.

The integration between hardware and software was also tested and achieved significant results in terms of application effectiveness and measurement accuracy.

6 FINAL REMARKS

If we consider that the smart meter uses wi-fi signals and this is a common signal in the residences, there is no new signal inserted in the houses. So, there is no new inconvenient side effect. In addition, considering the preliminary results presented, the proposal presented in this work proves to be viable and useful for its respective target audience. Finally, it is important to emphasize that the solution proposed aims to give confidential information to the households. It means that it will help them to check the electricity bill.

In terms of future work, the objective is to finish the construction of the final product, which includes the completion of the hardware printed circuit board and the production of the meter case with the design already created. In the context of software, the intention is to expand the use of the mobile platform to iOS users. It is worth noting that the search for partnerships for the possible implementation of the product in people's daily lives is of vital importance in ensuring the application of its benefits, as well as the availability of the proposed product for testing by the end user.

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