



Residential electrical energy management: optimization of consumption through internet of things – IoT

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SUMMARY

This article presents a way to manage residential electrical energy through the Internet of Things – IoT, consequently optimizing energy consumption. It is a bibliographic article, which aims to help people who want to save their energy with easy-to-use technology. We use articles, coursework and websites for development. To better understand how this IoT device can be used to optimize energy consumption and management, an application created by Silva, Flauzino, Gomes and Silva was presented that demonstrates how this technology works for this purpose.

Key words:Internet of Things - IoT; electricity; management.

ABSTRACT

This article presents a way to manage residential electricity through the Internet of Things – IoT, consequently optimizing the consumption of energy spent. It is a bibliographic article, which aims to help people who want to save their energy with easy-to-use technology. We use articles, course completion papers and websites for development. To better understand how this IoT device can be used to optimize energy consumption and management, an application created by Silva, Flauzino, Gomes and Silva were presented that demonstrates how this technology works for this purpose.

Keywords:Internet of Things - IoT; electricity; management.

1. INTRODUCTION

In today's world, energy is a subject to be addressed in all spheres, due to the conditions we impose on the planet, given our current energy matrices. Energy crisis is a temporal moment of difficulty in energy supply and is caused by political, economic and environmental issues.

According to data from EPE (2020), the consequences of the current Brazilian energy crisis involve an increase in the cost of living for the population and the deterioration of the country's economy. Following the economic reason, in recent years the tariff flag has been changing its value, currently Water Scarcity is used, that is, R\$14.20 is charged for every 100 kW/h. According to EPE (2020), residential consumption grew by 3.1% in 2019. On average, consumption in Brazilian homes in 2019 was 162kW/h in the month, increasing consumption by another 1.7%.

Electrical energy is essential for everyone, especially in a world where the use of technology is increasingly used. According to Kim Dieter (2021), around 3 to 5 thousand watts are needed for the basic needs of families, which include: lighting, cooking, refrigerating food and pumping water in an artesian well, for example . Additional electrical devices for entertainment, heating, and other uses are also considered in this minimum requirement.

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Electrical energy management in a home is extremely important to identify the amount of energy consumed. *Internet of Things – IoT*, which in Portuguese means: Internet of Things, aims to connect and exchange data with other devices and systems over the internet, technology in a home can assist the user in whatever is established, in this case, managing energy consumption electrical.

Thinking about optimization and efficiency in the use of electrical energy, this article deals with the proposal of a means of generating reduce the energy consumption of a home. This way, people can save and avoid waste.

The study methodology used was bibliographic research, which, according to Gil (2008), the concept of bibliographic research is based on materials already covered, using mainly books and scientific articles. The bibliographic research used in the article was taken from websites, articles, TCC's and books, all of which are cited in the references. The research was carried out by each member of the group, each one researching something and bringing to the group what was interesting and true. Always researching, writing, creating the article and taking it for guidance to check. The research began in early April 2022 and was completed in mid-July 2022.

2. ENERGY CONSUMPTION AND MANAGEMENT

Electricity consumption in homes depends on which equipment is being used, as some consume more energy and others less. The main appliance that consumes the most energy and is present in most homes is the electric shower. The same, with a power of 5500W, and with an average use of 30 minutes, has a monthly consumption of 82.5 kWh, counting on a month of 30 days. For this calculation, the formula was used:

$$\text{Consumption (kWh)} = (\text{Power (W)} \times \text{Hour of use per day (h)} \times \text{Days of use per month}) / 1000$$

Anyone can access the consumption of each electrical device in their home, using calculations, such as the one mentioned above, and thus manual management can be carried out. But a more practical and comfortable way is to use IoT technology.

"In recent decades, billions of people have connected to the digital world" (MAGRANI, 2018, p.16). IoT is a communication network, capable of gathering and transmitting data, which aims to connect equipment and devices. In addition to being able to perform various functions without human interference and with excellence.

With the advancement of technology and people becoming more up to date, it is becoming more common to use a smart device, such as "Alexa", an IoT device that can be used to make your "smart home", a term used when The house has several technological equipment, such as voice control, locks and smart light bulbs, among others. According to the website www.cs.ind.br, "Setting up a smart home allows you to optimize energy consumption in your home. It is possible to turn off all lights, electrical devices and air conditioning when we are away from home, so that there is no waste of electricity." (CS COMUNICAÇÃO, 2020). This technological means has been aiming to make life easier for its users, not only helping to manage a home, but it can also be used to turn on the lights in any room, close the door, turn the air conditioning on or off, and many other things. features, in addition to increasing home security.

The cell phone is also an IoT device, and energy management can be observed through an application. "In IoT applications, applications are mainly used to monitor and control implementations of systems" (JAVED, 2016, p.41 *apud* CUNHA, BATISTA, 2018, p. 45). These applications help you control and monitor the use of each device in your home. If the power and time of use of each device are included in this application, it will consequently help those who want to save their energy, as they have access to what consumes the most energy in their home.

Many companies are already using IoT to help reduce consumption. An example is the company Kellogg, which according to *itforum* magazine (2017), this company reduced energy consumption by US\$ 3.3 billion in the year with IoT. But not only companies can reduce energy consumption with this device (despite the amount saved

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be more significant in companies than in homes), homes can also take advantage of this technology and save money.

But IoT as a way of reducing energy expenses can also be used in homes, as home automation through technology offers the option of turning off, for example, household appliances – the largest consumers of electrical load in homes – over a long distance, at least cell phone, avoiding energy waste (ITFORUM, 2017).

3. ELECTRICAL POWER OPTIMIZATION

The purpose of optimizing electrical energy is to find ways to reduce energy costs, consequently making greater use of equipment and avoiding waste. In October 2020, MAG Seguros published an article with ways to save energy at home with some simple actions. Given the attitudes they mentioned, they are:

- Take advantage of natural lighting: Avoid turning on lights when not necessary; make use of skylights in ceiling, in places such as corridors and stairs, taking advantage of natural light; Furniture can also be repositioned to make the most of the light coming from the window.
- Adopt light colors in environments: "It may seem like an insignificant detail, but the choice of colors in the decoration also helps a lot when it comes to save energy at home. This is because an environment with dark tones will always give the feeling that it is necessary to turn on the light — even during the day."
- Use fluorescent or LED lamps: Both have the best cost-benefit, economy and durability. But difference is that the LED lasts three times longer than fluorescent.
- Find out how to save energy at home when taking a shower: The electric shower is one of the most energy-consuming energy in a residence. Keeping the shower in "summer" mode can generate savings of 30%, in addition, it is important to keep the shower wiring in good condition and regularly clean the holes where the water comes out. And the main thing, the duration of the bath, avoid wasting it when not necessary.
- Unplug electronics: "This apparently harmless practice can generate significant expense in end of the month, according to Proteste research. That simple little light on is a sign that your electricity bill could be higher." (MAG, 2020).

These were some of the attitudes they made available, which can be carried out by people who want to save their energy through individual means. But, as people don't always follow these tips, they don't have the time or they just don't want to, there is the most practical option, the option of an app. This application can help the user to optimize the electrical energy that is used in their home. Users of this app would receive an alert every time something electrical is being used.

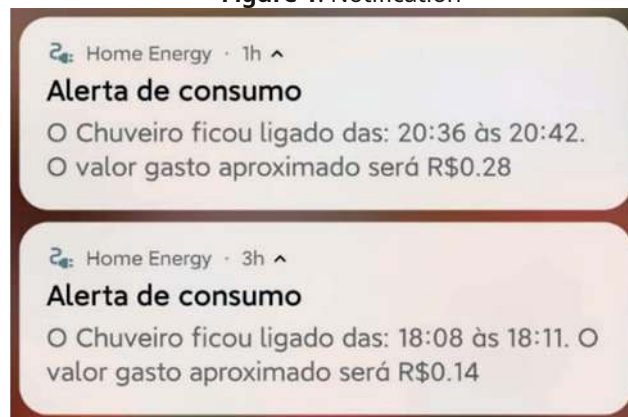
3.1 Application

An application for monitoring the consumption of a residence created by Silva, Flauzino, Gomes and Silva (2020), shows the expenditure in relation to the consumption of electrical appliances in a residence, in addition to the application providing a forecast of expenditure on the energy bill of the home. user. One of the group members said: "after logging in, the user views the information in real time, daily and monthly, simply by navigating between the tabs on the home screen."

Figures 1 and 2 were taken from the application. Figure 1 shows the notification received by one of the users, which alerts the time the electric shower was on and the amount spent obtained:

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Figure 1: Notification



Source: Silva, et. al, (2020).

Figure 2 shows the record of consumption per use of the shower. One of the group members said: “if the user wishes to consult the amounts spent on consumption received in notifications, records from the last 48 hours will continue to be available on the application interface.”

Figure 2: “Consumption record for shower use”

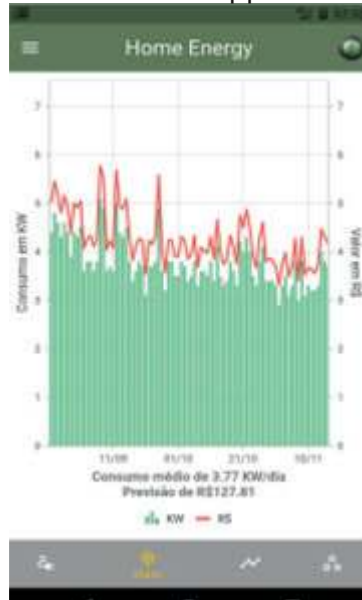


Source: Silva, et. al, (2020).

This system allows users to be aware of all movement occurring in their home. Being able to check in real time the consumption and amounts spent at the moment, thus understanding which devices are consuming more than expected.

The creators of this application carried out tests using the application to find out if it was really viable. The tests were to find out if the application would match what was shown on the energy bill. The application showed that the energy bill would be R\$127.81, but the amount billed for the month of November/2021 was R\$126.60. The value of daily consumption for that same month, according to the energy bill, was 3.73 kW per day, and what was reported in the application was 3.77 kW per day. The possible values of the energy bill and daily consumption shown by the application are present in image 3 and the actual values shown by the energy bill are present in images 4 and 5.

Figure 3: Volunteer application data.



Source: Silva, et. al, (2020).

Figure 4: Volunteer's energy bill

Mês/ano	Consumo em kWh	Valor em R\$	Dias
NOV21	112	3,73	30
OUT21	120	3,87	31
SET21	111	3,58	31
AUG21	120	3,63	31
JUL21	93	3,20	29
JUN21	105	3,50	30
MAY21	108	3,85	28
ABR21	118	3,57	30
MAR21	95	3,16	30
FEB21	97	3,46	28
JAN21	114	3,45	31
DEZ20	122	4,20	29
NOV20	132	4,00	30

Source: Silva, et. al, (2020).

Figure 5: Volunteer's energy bill

Valores Faturados			
Descrição	Quantidade	Tarifa/Preço (R\$)	Valor (R\$)
Energia Elétrica kWh	112	1,13043802	126,60

Source: Silva, et. al, (2020).

To find out the accuracy between the energy bill and the data shown in the application, the team members made a comparison:

$$(3.73 \text{ kW}) / (3.77 \text{ kW}) \times 100 = 98.93\%$$

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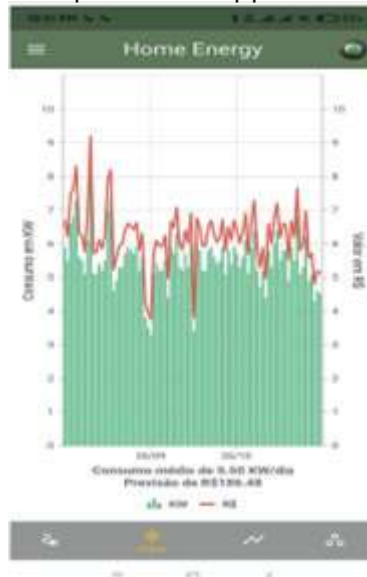
Thus showing that the application had 98.93% accuracy in relation to the volunteer's residence. In relation to the member of the group who also tested the application, with a higher consumption, it showed an average consumption of 5.23 kW per day in the last 90 days. In the application, it showed that the daily consumption obtained was 5.50 kW per day. In image 6, it shows the consumption statement for the 3 months of this member and in image 7, it shows what the application predicted for this consumption and for the value of the invoice.

Figure 6: Extract of group member's consumption

Mês/Ano	Consumo kWh	Média kWh/Dia	Dias
NOV/21	181	5,36	30
OUT/21	148	4,93	30
SET/21	173	5,40	32
AGO/21	176	5,67	31
JUL/21	192	6,19	31
JUN/21	174	5,80	30
MAI/21	158	5,64	28
ABR/21	184	5,57	33
MAR/21	161	5,36	30
FEV/21	154	5,50	28
JAN/21	164	4,96	33
DEZ/20	145	5,00	29
NOV/20	143	4,61	31

Source: SILVA, et al, 2020.

Figure 7: Group member application data



Source: Silva, et. al, (2020).

They once again compared the energy bill and the data provided by the application:

$$5.23\text{kWh}/(5.50 \text{ kWh}) \times 100=95.09\%$$

Showing an accuracy of 95.09%.

In relation to the value shown on the application, estimating the value of the invoice, it showed R\$186.48. And the value of this group member's energy bill in November/2021 was R\$181.98. Image 8 shows the real value of the group member's energy bill.

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Valores Faturados			
Descrição	Quantidade	Preço	Valor (R\$)
Energia Elétrica kWh	181	1,13043802	181,98

Source: Silva, et. al, (2020).

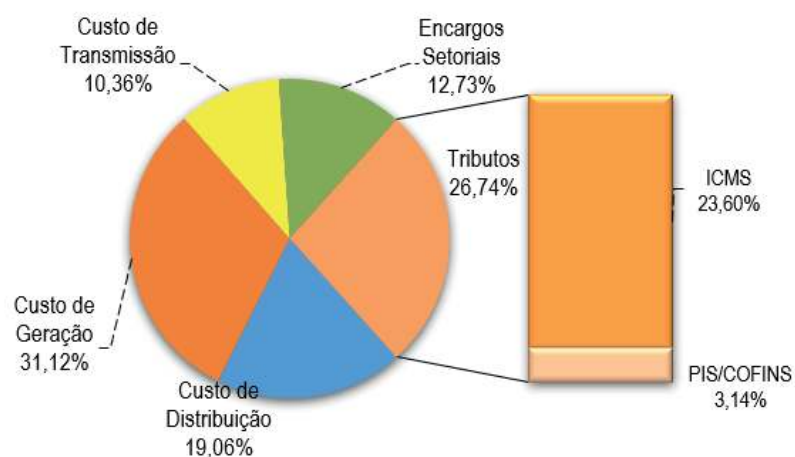
The same rate per kW/hour as the energy bill was used in the application. It can also be changed by the application itself, if necessary.

4. COST AND FEASIBILITY

Many people who think about using an IoT device think about the cost it has, however, they don't think about how having this technology can influence energy bills. It is an investment made once and lasts a lifetime. For each home, the value of this technology is relative; in the research carried out, no values were found, only the cost-benefit that this device can have.

In August 2020, the website brasil.edp.com made percentages and a graph available, referring to the amounts paid by the consumer in the monthly energy bill: “41.5% refer to costs in the energy generation and transmission segments; 39.5% refer to sectoral taxes and charges; 19.0% are the costs of energy distribution, that is, those necessary to take the electricity to your consumer unit (part allocated to EDP).” (EDP News, 2020).

Figure 9: Energy tariff



Source: EDP News (2020).

On the energy bill:

“With the adjustment, a residential consumer who used to pay a bill of R\$100.00 will now pay around R\$106.00. For every R\$100.00 of a monthly invoice presented to the customer, R\$19.06 will be allocated to EDP ES, to cover the costs of operation, maintenance and investments in the electricity distribution network. Another R\$41.50 will be allocated to the payment of expenses with Energy Generation and Transmission, while the remaining R\$39.40 will be allocated to sectoral charges, taxes and duties” (EDP News, 2020, online).

According to the data shown, the distribution of what is paid on the energy bill is noticeable, excluding the equipment that is used and that consumes a lot and that can change in this value, in addition to the waste that ends up going unnoticed and that also adds to the value of the invoice. This is why the IoT device is viable, so that problems such as waste and high-consumption equipment do not go unnoticed, so that each person who has this device can actually know what else is being consumed in their home and consequently avoid waste, and thus, the energy bill has a good saving.

7 CONCLUSION

Due to the facts mentioned, it can be seen that the IoT device is a great way to optimize electrical energy consumption, using applications, such as the application mentioned in the article. Some ways of optimizing this consumption individually were presented, it is the basics that can help to save energy, but with an IoT device, this means of saving becomes easier. The user can know the electrical device that

consumed more energy in your home, in addition to having the possibility of checking the time in which that device was used.

Therefore, the article showed that the use of an IoT device is viable, due to it being a reality of everyone, and a practical way to save. The application's accuracy, which was above 95%, in relation to the consumption spent and the amount that could reach the monthly energy bill, proved that this technology can indeed help its users to manage the consumption of their homes. Ultimately, saving money and avoiding any significant waste.

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