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Home automation as a tool to Management household Electricity Consumption

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Abstract**—** *This article presents a feasibility study to use home automation as a tool to manage and reduce household electricity cost. It is a result obtained after checking different academic's research articles about domotics and the perception that there is a gap when it is related with home automation systems that perform the management of energy resources. To many academic's researches talk about the comfort provided by home automation, but a few about managing and optimizing the use of energy resources. At the end, some points and suggestions for future research are raised to complement this article.*

***Keywords* — Domotic, Home automation, Energetic efficiency, Temperature sensor, refrigerator.**

I. INTRODUCTION

Besides being associated with the productive potential and representing the society's hold, the electricity consumption is an important indicator of economic evolution. Therefore, in order to increase a nation's growth, well-being and wealth, it is essential a correct and appropriate consumption planning [1].

However, the constant electricity consumption increase has been indicated as one of the main responsible for environmental problems, such as greenhouse gas emissions and natural resources degradation [2].

According Brazilian Energy Research Company, Brazil's energy consumption increased by 1.2% in 2017, ranking among the 10 largest electricity consumers in the world, reaching 467 TWh. Consuming 29% of all electricity produced, the residential sector is the second largest consumer in Brazil, behind only the industrial sector. In a scenario where electricity production and consumption are environmentally impactful, current consumption patterns must be improved through more efficient and conscious use of this resource [3]

On the other hand, man always looking for ways to do his daily tasks quickly, efficiently and with minimal effort. Wheel's invention in the early days of our existence in order to reduce the effort to move things around and hydraulic mill for flour production in the tenth century are examples of our constant search to facilitate the day-by-day activities [4].

With technological advancement, repetitive and tiring tasks, which were executed by man on industries, stated to be performed by machines. In order to improve the quality of life and comfort, automation has also started to be introduced on people's daily tasks. In this scenario, home automation has become increasingly true in modern society. For the first time, it became possible to interact with automated environments even from a distance, due of internet and devices technologies progress [5].

However, most of the academic work focuses on the convenience, comfort, and safety afforded by home automation without indicate the energy consumption management that can be done through it. Cost saving and rational use of resources are the main reasons for home automation growth on Brazil during the last years. Based on it, makes sense invest in home automation not only for comfort, safety and convenience, but mainly to reduce electricity costs [6]

II. THEORICAL REFERENCE

Domotic term was coined to refer home automation, and originated from the word "domus", which in Latin means "home" with robotics. By definition, automation is a system or method whereby it is possible to realize and control housing resources, making use of the multidisciplinary combination of many specialties such as electricity, mechanics, psychology, telecommunications, computing and medicine which reflects on quality life of residents and users, generating comfort, safety, leisure, communication and energy saving, with sustainability and effective use of resources [7].

Although the earliest automation records have arisen in antiquity (such as the waterwheel, for example), it was during the industrial revolution and with the electricity trade that automation gained prominence and over the years began to employ home automation concepts. However, the automation used in industries is much more complex than that used in homes, being necessary develop

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specific and simpler technologies for residential environments [8].

The earliest home automation records date back to the late of 1970s in United States, where the first Power Line Carrier (PLC) modules came in and home's power line were used to send and received PLC. Although simple, these solutions were used to remotely turn on some equipment types or lights, but with no communication between them [9].

In 1975 a technology called the X-10 emerged on market. With this technology and from the first time, lighting devices and equipment could establish communication with each other. In the 1980s, PC automation software based on this technology was launched. Then in the 1990s the use of X-10 technology became quite popular because for the first-time people could have access to a technology previously used only by industries [8].

Today there are several home automation systems, but none of them have a communication standard defined. Only recently has the KONNEX protocol emerged in order to become the standard protocol adopted in home automation [10].

To have an adequate experience based on wishes, needs and conditions, there are several elements involved in home automation process, from simple sensors to complex automation centers. However, all projects must have some basic elements such as Sensors, Actuators, Bus Interfaces and controllers [11].

Besides converting physical quantities into electrical signals, sensors are devices that detect stimuli by measuring, monitoring, and converting these stimuli into a value that can be manipulated by computer systems. The sensors are responsible for collecting and forwarding information to controllers about event and subsequently send the appropriate commands to actuators [11].

Actuators are devices that receive commands from the controllers to activate equipment, converting electrical, hydraulic or pneumatic energy into mechanical energy. They are drive modules, connected between electrical network and equipment [12].

The physical environment responsible for data transfer is called Bus. Basically, there are 03 ways to transport information [13].

Powerline – The use of this technology to data transfer has minimal impact regard to physical changes since the housing power grid is reused by home automation system;

Cable – May be more wasteful and require a greater investment especially in existing housing. However, the use of cable ensures greater stability and immunity to external interference, as well as providing high data transfer speeds; Wireless – Similar to powerline, has minimal impact with physical changes on housing to be installed, but it is subject to external interference and variation in data transfer speed.

Interfaces are devices or mechanisms that allow user to view information and interact with system. Interface examples are internet browsers, remote controls, panels, switches, etc.

Microcontrollers have a processor, memory, input and output peripherals, timers, serial communication devices and other devices, all within a single chip. They are the natural result of technological advancement and complexity digital circuits increased, on the other hand they are simple, inexpensive and compact, used and widespread in worldwide [14].

Home automation systems can be divided into centralized and distributed. On centralized system it is used a single central unit that controls the entire system, from information gathering to system supervision. In the distributed system, there are several devices with information processing capabilities that talk to each other [15].

Between 1995 and 2011, household energy consumption increased 77% from 63,000 GWh to 112,000 GWh, an average rate of 4.2% per year. This growth is directly related with income Brazilian improvement and consequent household electronics growth, has well as increased access to the electricity grid in rural areas [15].

Energy planning in Brazil has always sought to expand supply looking at consumption growth. However, the power generation expansion capacity has shown signs of decline in recently years, as new generation plants require high investments in addition to generating social and environmental impacts, either in the flooding of large areas or in the displacement of local communities [16].

According statistical yearbook of electricity [3] households' electrical consumption is almost 29% of all energy generated in the country. In addition, consumption has been growing year after year driven by the improved purchasing power of the Brazilian population, which reinforces the need to adopt means that can help manage and optimize the way of electricity is used.

	2013	2014	2015	2016	2017	Δ% (2017/2016)	Part. % (2017)*	
Brasil	**463.142**	**474.823**	**465.708**	**461.780**	**467.161**	**1,2**	**100**	**Brazil**
Residencial	124.908	132.302	131.190	132.872	134.368	1,1	28,8	Residential
Industrial	184.685	179.106	169.289	165.314	167.398	1,3	35,8	Industrial
Comercial	83.704	89.840	90.768	87.873	88.292	0,5	18,9	Commercial
Rural	23.455	25.671	25.899	27.266	28.136	3,2	6,0	Rural
Poder público	14.653	15.355	15.196	15.096	15.052	-0,3	3,2	Public Sector
Iluminação pública	13.512	14.043	15.333	15.035	15.443	2,7	3,3	Public lighting
Serviço público	14.847	15.242	14.730	14.969	15.196	1,5	3,3	Public service
Próprio	3.379	3.265	3.304	3.355	3.277	-2,3	0,7	Own use

Fig. 1: Electrical energy consumption by sector in Brazil

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As Fig2, most of the electricity consumption is concentrated in air conditioning, refrigerator, lamps and TV, where the four groups account for 88% of all consumption in a residence in the northern region.

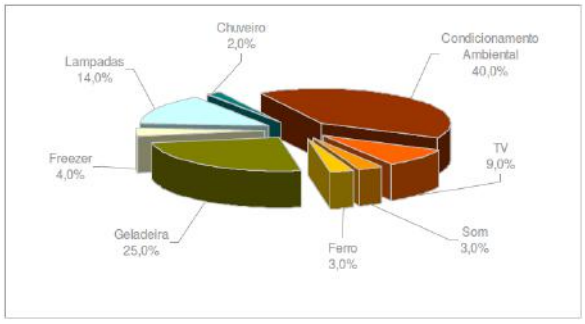

Fig. 2: Residence electricity consumption, north region.

Appliances are responsible for most of the monthly electricity consumption in a home. Making equipment energy efficient will lead to a decrease in electricity consumption in the residential sector.

Currently there are two strategies for achieving energy efficiency: The first one through changing consumer habits by programs and policies that encourage rational energy use and the second through new technologies [17].

Air conditioning is responsible for the most share of energy consumed. Therefore, it is essential that temperature control is effectively performed, since a one-degree increase in temperature provides savings of around 7% in electric power [18].

The refrigerator is the second largest responsible for household consumption, and just as the air conditioner must have an effective temperature control, ensuring that not freeze food outside the designated compartment for this activity, which characterizes waste of energy.

By to the popularization of LED's lamp, values have been dropping which makes the use of this technology increasingly accessible to the entire population. For this reason, we will not address the use of lighting technique in this article.

The objective of this article is to analyze the process of home automation as a tool to manage the power consumption in electronics with greater impact on the bill such as refrigerator and air conditioning.

III. MATERIALS AND METHODS

To do this article was used in the research the quali-quantitative method. This type of research involves qualitative and quantitative methods, in order to obtain an understanding and broader subject studied explanation. According to [19] the qualitative method aims to interpretatively analyze the data and information obtained in natural setting and in a non-quantifiable manner in order to understand the attitudes, motivations and group's behaviors. As [20], this method deals with the phenomena's explanation and allows to analyze the concrete data, deducing the constant, abstract and general elements.

According to [21] the quantitative method uses different statistical techniques to quantify opinions and information for a specific study and comes to understand and emphasize logical reasoning and information that can be measured about human experiences.

This study deals with a literature review, focusing on research about what has already been published in home automation area and energy saving in refrigerators.

Electricity consumption in households has been rising over the years, doing constant electricity bills increases. However, the solution to consumption growth lies not only in generation growth, even though necessary and strategic.

According Brazilian Association of Energy Conservation and Services Companies, about R$ 12.6 billion is the negative balance of electricity waste in Brazil. Almost of this total, around R$ 5.51 billion, is residential consumer type [22].

Waste losses of "460,000 GWh are estimated in four years (sufficient to meet the country's demand in one year) [23]. In this scenario, home appliances are the largest consumers of energy and are responsible for the increase in the electricity bill. Even though it is impossible to stop using them, it is important to act strongly in reducing their consumption.

According to [24] energy efficiency is the act of rationally and efficiently using energy to achieve a result and is the relationship between the amount of energy employed in this activity and that available for this performance.

It is observed that the consumption of electricity in the homes is more accentuated in appliances for refrigeration, indispensable in the daily's life population. It is true that over the years and with technological advancement, these objects have become more efficient, consuming less electricity, but still they have a great economic impact on household income and home automation can help to manage, control and reduce consumption.

The refrigerators are turned on 24 hours a day, often freezing products more than necessary and wasting electricity. This is directly related with the mechanical control made by a factory preset thermostat and allows only the measurement and thermal control functions, being inaccurate and having a high response time.

According to [25], temperature sensors are commonly used by computers and other electronic devices to prevent overheating. Furthermore, electronic thermometers are

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thermostats that keep the temperature constant through voltage control, turning device on or off whenever necessary.

Whether to ensure food quality stored in a refrigerator or the temperature of a boiler in a chemical process, temperature control is related with lots of measure in our daily lives. [26]

One way to improve the energy efficiency of refrigerators is using an electronic thermostat. In addition to accurately measuring and controlling the temperature, the electronic thermostat allows to program and time actions such as minimum, maximum temperature and compressor trigger intervals.

Using a refrigerator with the following manufacturer information (consumption 36.6kWh; compressor EMU40CLP 1/8 hp). (1) summarizes that:

$$1CV = 735{,}5W \rightarrow \frac{1CV}{8} = x$$
$$x = \frac{735{,}5W}{8} \rightarrow x = 91{,}93W$$

Based on calculation, the compressor uses approximately 100W of power. Also, according refrigerator and compressor consumption information, it is possible to calculate the compressor cycle time in 10 minutes. In other words, compressor runs for 5 minutes and shuts off for another 5 minutes.

Table 1 – Compressor cycle time use

Compressor cycle time calculation			
Variable	Compressor cycle time ON	Compressor cycle time OFF	Total
Minutes	5	5	10
Hours	12	12	24
Month/ Hours	360	360	720
Month consumption (Wh)	3600	0	3600

Analyzing above information, the power electricity is consumed only when the compressor is on, during 50% of the time. The rest of the time the compressor is off and therefore without consuming electricity. In one month, the compressor runs for 360 hours. By applying (2):

$$\text{Consumption} = \text{time(h)} \times \text{power (W)}$$
$$\text{Consumption} = 360\text{h} \times 100\text{W}$$
$$\text{Consumption} = 36{,}6\text{KWh}$$

The monthly consumption is the same as reported by the refrigerator manufacturer on label.

Using the national average household electricity consumption in 2017, which was 134.368Wh (Figure 1), the consumption of 36.6kWh is equivalent to almost 27% of the monthly consumption in a household, which confirms the data collected on Figure 2.

According to [24] Using an electronic thermostat can improve the operating cycle time of the compressor, reducing the compressor cycle time on interval and increasing the compressor cycle time off, impacting the electricity cost because the actuation and reaction time on electronic thermostat is much smaller as well as more accurate and efficient.

Also, an electronic thermostat can last longer than the refrigerator's life, which, according to the BBC, ranges from 10 to 16 years. A mechanical thermostat has an estimated service life of between 3 and 5 years.

In addition to energy savings, the use of an electronic thermostat can extend the life of the refrigerator since reducing the compressor's cycle time on, working less and therefore last longer. Therefore, the cost of the electronic thermostat can be deducted from maintenance that will not be performed in the refrigerator during its useful life.

For this study we used a small refrigerator used in a low-energy home. In larger homes or commercial establishments with various equipment such as freezers and refrigerators, the savings can be quite significant. In addition, AI (artificial intelligence) can be used to monitor refrigerator operation, indicating non-standard spikes and warning the user when something is wrong (such as a forgotten open door or insulation problems) because during this kind of occurrence, a drive peak out of the normally will happen. When the compressor is started out of normal use, the system warns the user by message, alarm or any other chosen way. Also, using AI can even make decisions such as turning off the refrigerator to avoid unnecessary expenses.

IV. CONCLUSION

This study made possible to better analyze the use of home automation as a tool to manage and reduce the electric energy expenses in the refrigerators. As any technology, there are advantages and disadvantages but has proven effective and the results are very encouraging, although implementation costs are still high.

Despite the clear advantages and benefits of the electronic thermostat, industries are unlikely to adopt it in their products due to the cost being slightly higher comparing with mechanical thermostats. In addition, the use of the electronic thermostat would extend the life of the compressor and other components, which would result

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in fewer new equipment being sold, thereby reducing the profits of large companies through planned obsolescence.

Analyzing the management of electricity consumption in homes was important because makes room for further studies to be done in other electronics such as air conditioners and lamps, being a suggestion for future articles and research.

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