A SURVEY ON SMART METERING SYSTEMS USING HUMAN-COMPUTER INTERACTION

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RESUMEN.
Las nuevas tecnologías asociadas con la cuarta revolución industrial están transformando el mundo en el que vivimos y la red eléctrica no es la excepción ya que ha sido provista con inteligencia. Una de las aplicaciones mejor conocida son los sistemas de medición inteligente, los cuales permiten medir en tiempo real el consumo/producción de energía, así como otros beneficios tales como cortes y reconexiones de forma automática. Las nuevas generaciones de medidores inteligentes tienen mayores capacidades de cómputo permitiendo nuevas aplicaciones. Este trabajo muestra el diseño tanto de hardware como de software para medidores inteligentes usando técnicas de interacción humano-computadora. Los resultados muestran que son alentadores para los usuarios finales que suelen retraerse de utilizarlos.
Palabras Clave: AMI, HCI, Smart Meters.

ABSTRACT.
The new technologies associated with the fourth industrial revolution are transforming the world in which we live and the power grid is no exception since it has been provided with intelligence. One of its best-known applications is smart metering systems that allow real-time energy consumption/production to be known, as well as other benefits such as outages and reconnections automatically. The new generations of smart meters have more computing capacity allowing new applications. This work shows the design of both hardware and software for smart meters using human-computer interaction techniques. The results show to be encouraging for the end-user who is reluctant to use them.
Keywords: AMI, HCI, Smart Meters.

1. INTRODUCCTION

With the arrival of the new technologies of the fourth industrial revolution, many human processes have been benefited in the way of improving the quality of life. One of the most benefited processes is the electricity sector, allowing a reliable, quality, environmentally friendly, and cost-effective supply of electrical energy [1]. One of the most visible parts of the Smart Grid (SG) is the Smart Metering Systems (SMS) that allow the monitoring of the consumption and production of electrical energy by prosumers at all times and automatically, reducing costs in the medium and long term. One of the essential SMS architectures is the Advanced Measurement Infrastructure (AMI) [2], which is based on the use of smart meters and other components that allow two-way communication and data processing [3].

Currently, all systems must be understood as cyber-physical systems since they are a combination of objects, people, processes, and data. So SMS is no exception. These systems are described below as cyber-physical systems [4].

The most relevant part of any system is people. The human factor is essential in the proper functioning of any order. The Human-Computer Interaction (HCI) aims to improve how people relate to the hardware and software elements of cyber-physical objects in our environment through data and processes [5].

The SMS are made up of:

1. Objects: smart meter, data concentrators, measurement database servers, wireless links, wired, telecommunications equipment, among others.

2. People: consumers, small producers, prosumers, lecturers, technical operators of distribution and transmission lines, managers of telecommunications networks, operators of computer systems and databases, among others

3. Processes: Measurement of consumption readings and production of electrical energy, data communication, data storage, consumption patterns, billing, statistical reports, among others.

4. Data: consumption, production, variables of the electrical signal, energy prices, dates, state of the electrical and telecommunications network, customer data, among others.

In recent years, various studies related to HCI have been carried out in multiple areas of SG [6], but few in SMS [7], being a relevant factor in the lack of confidence of end-users in many countries [8]. This work shows a comparative study of various related researches in the field of HCI for SMS, showing its main characteristics. Later, the results found are discussed, proposing improvement.

2. STATE OF THE ART

Below are the central works related to the HCI area in SMS, describing them briefly.

One of the most relevant aspects for end-users is knowing their consumption of electrical energy that allows them to save money by making better use of their electrical appliances. In general, SMS has a web or mobile application to show the information to customers; even in some countries, specialized devices have been installed to display the info called home-displays. However, such interaction is more informative, with little or no user interaction. In [9], work is shown where the interaction between users and the public service company is achieved through mobile devices, giving feedback to both the users and the electricity company that translate into cost savings and service improvements. Besides, [10] shows the design of an SMS application focused on mobile apps.

Social interaction is highly relevant in practically any cyber-physical system; for this reason, some research has focused on managing social media to achieve greater interaction by users. For example, [11] shows the combination of social networks with SMS to improve the display and persuasion of user.

One of the most relevant concerns of SMS clients is the cybersecurity and privacy of their information [12] and [13]. Therefore, today, any SMS system must consider it as a fundamental part of its interaction with users.

Not all innovation can be considered successful when end users interact with it. In [14], a study is shown of how the non-use of the services that provide SMS can be successful in countries like Finland. In [15], a study is shown with the main concerns of users who use SMS. In turn, [16] shows a study on visions on the energy issue for smart homes that share the same concept with SMS.

In general, there are various studies of HCI that can be taken up to be applied in the context of SMS. For example, in [17], general guidelines for creating smart environments are shown, which can be easily adapted to SMS environments.

On the other hand, some works have focused on the analysis of data patterns through various statistical and machine learning techniques to show the consumption behavior of users. For example, in [18], work is shown to extract, visualize, and interpret the consumption data of residential customers; however, the HCI is little considered. In [19], a study of information services based on energy consumption for inhabitants of a smart home is shown.

Currently, with the integration and lowering of energy generation systems by renewable sources such as photovoltaic panels and wind turbines, it has become possible for end-users to produce their energy and sell the surplus to the electricity company and even to other users. This type of new electrical energy commercialization system has been called transactive systems, which is why some works, such as in [20], have focused on the interaction of various prosumers to exchange their own energy. One of the technologies that have enabled this class of transactional systems is Distributed Ledger Technologies like blockchains.

A novel application of SMS is its integration with electric and autonomous vehicles (EV). Some works such as [21] have focused on how these vehicles can be integrated into the smart grid through SMS. However, little work has been done in the HCI field in this regard. In [22], schematics of Human-Machine Interfaces (HMI) for EV and its evolution towards Human-Robot Interfaces (HRI) are shown, which may also apply to SMS.

An essential part of innovation within the HCI area is the use of new user interfaces, both hardware and software. For example, [23] shows an ultrasonic touchscreen 3D interface with gesture recognition for use on smart devices. This type of interface could be installed in next-generation SMS. In [24], a review of the various electronic instrumentation components of SG systems, including SMS, is shown. In [25], a study of quality in HMI for embedded systems is shown, which may be applicable in the context of SMS.

Developing software on any cyber-physical system is challenging and SMS is no exception. Various works have focused on this aspect. For example, [26], [27] shows various software models focused on SG and within its domains on SMS.

Finally, one of the most important aspects of all HCI is the design of hardware interfaces. For this reason, various works such as [28], [29] and [30] show the development of smart meters with the design of relevant electrical-electronic components and extremely useful for improving the user experience (UX) in SMS.

3. RESULTS AND DISCUSSION

From the literature review, the following highly relevant elements were found in the design, development, and implementation of HCI in SMS.

First, access to the SMS application must be accessible through various devices and adapted to the different display and processing capabilities.

Second, electricity consumption and production information should be displayed simply. Data analysis should be performed and displayed graphically. It is imperative that the user can interact with their different high-consumption appliances such as refrigerators, air conditioners, heaters, irons, washing machines, lighting systems, among others. This interaction must show very clearly how much energy (and especially money) when one or other devices are turned on.

Third, aspects of social interaction should be considered, such as showing customers on social networks that billing from one period to another, seeing how that consumption improved as well as the socialization of various aspects of electricity service.

Fourth, cybersecurity and data privacy should be essential, especially if social interaction between different clients is expected. It is important that the readings of both the

consumption and production of electrical energy are safeguarded. In turn, it is necessary that said information, if it is shared, have the informed consent of the client, since this information is classified as personal data.

Fifth, for Mexican residential customers, it is essential that SMS interfaces make it possible to know the costs of electricity at all times. In Mexico, although there are already some places that have SMS, their use in the country is not widespread, so it will be necessary to have an introduction campaign that shows all the possible advantages of these systems since the Mexican user is generally extremely reluctant to install new smart meters.

Sixth, SMS must be easily integrated with various smart home technologies to be able to interact with these devices and, above all, to know their electricity consumption and the costs involved in said consumption.

Seventh, SMS development should include disruptive technologies that, in recent years, have revolutionized our daily lives. Among these technologies are blockchains that allow information to be stored safely. Derived from blockchains, the concept of transactional energy systems emerges, allowing prosumers to market to each other the energy produced from renewable sources using cryptocurrency schemes. For this reason, it is necessary that SMS have a wide variety of payment methods and that they are updated frequently.

Eighth, the SMS must be integrated with the EVs to measure their high consumption of electrical energy and, above all, allow the e-mobility of any electrical charge, particularly those with high consumption and which are easy to move. For example, tomorrow, if a friend wants to connect his EV in our house, this high consumption of electrical energy and, therefore high cost, may be billed and charged to his account of his utility.

Ninth, smart meter hardware development should consider that unlike traditional meters that could last a lifetime, smart meters have a 10-year life span due to rapid hardware obsolescence. For this reason, the meters must continuously update their software. On the other hand, for smart meters to have greater market penetration, they need to have greater functionality. For this, sensors such as temperature, humidity, movement, or even a video camera can be integrated to help new applications such as climate control and video surveillance.

Finally, SMS must be smart enough so that it can be adapted to different types of clients with varying types of roles and characteristics. For this reason, they must have sufficient computing capacity to carry out artificial intelligence processes and the deployment of friendly user interfaces that improve the experience of users in the use of electrical energy in homes, offices, and industry.

4. CONCLUSIONS

It is imperative to know the characteristics of the users and especially the environment in which they are developed. The fact that SMS is used successfully in other countries does not guarantee that it will be used in the right way in another country or region. For this reason, this work shows a comprehensive study of various investigations in the field of HCI for SMS. It summarizes the main characteristics that must be taken into account in the development of next-generation SMS so that users can best use these systems, and there is little chance of rejection.

5. ACKNOWLEDGEMENTS

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