DOI: 10.25100/iyc.v21i1.7653 ELECTRICAL AND ELECTRONIC ENGINEERING

Metodología de Diseño Conceptual de Sistemas Automatizados para Ambientes Educativos y de Servicios Tecnológicos

INGENIERIA ELECTRICA Y ELECTRONICA

Automation Systems' Conceptual Design Methodology for Educational and Technological Services Environments

Jorge E. Moreno-Serrano[1§], Jenniffer S. Guerrero-Prado[1,2§], Diego G. Galeano-Alegría[3]

[1]Servicio Nacional de Aprendizaje – Sena, Cali, Colombia
[2] Escuela de Ingeniería Eléctrica y Electrónica, Universidad del Valle/ Cali, Colombia
Servicio Nacional de Aprendizaje – Sena, Cali, Colombia
[3]Servicio Nacional de Aprendizaje – Sena, Chía, Cundinamarca, Colombia.
jemorenos@misena.edu.co § jenniffer.guerrero@correounivalle.edu.co dgaleanoa@misena.edu.co

Recibido: 03 de mayo 2018- Aceptado: 21 de diciembre 2018

Resumen
Este artículo es uno de los resultados de una investigación aplicada, realizada con el propósito de establecer una metodología general de diseño de sistemas automatizados orientados a la modernización de la infraestructura física y tecnológica del Servicio Nacional de Aprendizaje (SENA) en Colombia, con sistemas, equipos y aplicaciones encaminadas a la sostenibilidad, la eficiencia y el ahorro. El reporte tiene como objetivo "Proponer una metodología de diseño conceptual de sistemas automatizados de edificaciones". La metodología propuesta fue aplicada al diseño del sistema automatizado del Laboratorio de Servicios Tecnológicos (LST) del Centro de Electricidad y Automatización Industrial CEAI – SENA y su implementación constituye en un modelo de referencia para que los demás centros de formación del SENA la apliquen con el fin de mejorar las condiciones de seguridad, confort y gestión energética en sus instalaciones.

Palabras clave: *Confort; eficiencia energética; sistema de automatización de edificaciones; sistema de gestión de energía; seguridad.*

Abstract
This article shows the results of an applied investigation aimed to establish a general design methodology for the modernization of automated systems oriented to modernization of physical and technological infrastructure of the "Servicio Nacional de Aprendizaje" (SENA) in Colombia, with systems, equipment and applications oriented to sustainability, efficiency and energy savings. The objective of this work is to "Propose a methodology for the conceptual design of automated building systems". The methodology was applied to the design of the automated system of the Technological Services Laboratory (LST) of the Center for Electricity and Industrial Automation (CEAI)- SENA and its implementation constitutes a reference model for the other SENA training centers to apply in order to improve the conditions of safety, comfort and energy management in their facilities.

Keyword: *Building automation system; comfort; energy efficiency; energy management system; safety.*

1. Introduction

According to the institutional agreement between SENA, the Colombian Ministry of Mines and Energy (MME) and the Mining and Energy Planning Unit (UPME), the technological modernization of its environments oriented to provision services must be carried out through the design and implementation of Automation and Energy Management Systems, using natural resources if they are available, providing the best conditions for users and aimed to productivity, efficiency and savings, as promoted by ISO 50001 of 2011.

Currently in SENA, some of the training centers that provide educational and technological services in electricity have the capacity to transfer knowledge and technologies, as well as to carry out research and technological developments. Such skills are mostly related to the design, installation and use of electrical services and equipment used for distribution, transformation and final use of energy in SENA facilities. These capacities for development, innovation and implementation of renewable energy systems and automation of buildings are being improved at all national headquarters.

However, in the CEAI - SENA has been identified as a general institutional problem, the "insufficient methodological clarity to carry out the design of automation systems for buildings that can lead to energy saving, management, safety and comfort conditions for users that occupy their service environments". At this moment, there is a project to modernize the CEAI facilities arranged for the provision of educational and technological services to other companies. That is why it is necessary to have a methodological guideline of the conceptual design of automated systems for such environments.

This article is one of the results derived from the aforementioned applied research project, developed by the Technological Development and Innovation Applied Research Unit (UIADTI) at– CEAI. The work consists of the development of the automated system standard for SENA environments, and aims to "Propose a conceptual design methodology for automated systems for the SENA service environments". The methodology was applied to the design of the automation system of LST – CEAI as use case.

The current state of art of building automation recognizes that the development and integration of different disciplines and technologies such as architecture, electricity, electronics, telecommunications, computer science, etc., has led to the emergence of new concepts aimed to improve the conditions and give the greatest benefit or the people or users of such facilities.

The technological evolution of different disciplines such as electronics, telecommunications, computing, architecture, etc., have enabled a dynamic interaction leading to the concepts of *home and building automation*. These concepts involve the development of equipment and systems capable of being integrated into a single entity, whose purpose is to meet the needs and interests of people living in both homes and buildings.

Home Automation refers to the set of techniques used for the control and automation of single-family houses [(1)]. That is to say, the objective of the home automation is to assure to the user of the dwelling an increase of the comfort, the security, the energy saving and the communication facilities. On the other hand, Building Automation refers to the technical management of buildings, and therefore is oriented to hotels, town halls, blocks of flats, museums, offices, banks, etc. The same techniques of home automation will be used, but particularized to the automation systems to be incorporated. In real-state installations, building safety and efficient energy management are often given more importance than other services such as comfort and communications [(1)]. *Asociación Española de Domótica e Inmótica* (CEDOM) defines building automation as "the incorporation to the equipment of singular or privileged buildings, included in the tertiary and industrial market (not intended for housing), automated the installations" [2].

In a house or building there are a lot of systems to manage. These systems are also often called services or applications and different classification criteria can be used when grouping them. The most common classification of systems to be managed is that which groups them depending on the type of service, forming the following systems: energy management, safety management, comfort management and management of communications [1–3].

Energy management is responsible for optimizing energy consumption according to the measurement of outdoor and indoor temperature sensors, activation of appliances in reduced tariff hours (assuming a differential rate scenario), disconnection of non-priority lines before reaching a preset value of power, etc. Safety is one of the most important areas to consider, since physical integrity of people and the property depends on it. Safety integrates three security fields that are normally controlled by different systems, such as prevention, reconnaissance and the reaction to alarms. The comfort management is responsible for facilitating the user to obtain a greater level of wellbeing in the activities that develop within the dwelling or building. The management of communications, or technical management of information, is responsible for capturing, transporting, storing, processing, and disseminating data or information generated by these elements.

It is recognized then, that the evolution of automated building systems is a differential fact at present, not only because of the integration of electricity, electronics and telecommunications technologies with architecture, but also because said systems are being implemented to provide users and buildings with greater comfort, safety, efficiency and sustainability.

The previously introduced systems involve reference concepts for the study of the design methodologies of automated systems in buildings as was presented before. Despite this, in the literature review, it is recognized that there are insufficient conceptual design methodologies of automated building systems, which is the objective of this report. With this purpose, the following section is a general review of the state of the art of this type of systems and applications, as well as some projects and companies focused on these technologies, and different application cases. Next, the methodological reference framework of this work is shown and then, the main result of the article is presented as a conceptual design methodology proposed by the authors for projects oriented to Building Automation Systems (BAS). Finally, some conclusions are presented to consider for future developments.

2. State of Art

In the study of the state of the art, two fundamental concepts related to automation have been identified: Building Automation Systems (BAS) and Energy Management Systems (EMS); however, the focus of this paper is the first one. Below is a brief reference to these terms, as well as some cases of related studies around the world.

2.1 Building Automation Systems

For a building to be considered intelligent, it must be able to automate the operation of its subsystems with the less human interference possible, responding to dynamic characteristics and creating a productive environment for its occupants and operationally efficient for its owners[4].

In this sense, the concepts of BAS and EMS become relevant although they lack clear industry definitions, leading to some level of confusion among industry and academy participants. BAS refers to a network system integrated by computer elements that automatically control different operations of a building, such as lighting, security, access control, thermal conditions and management system (BMS). On the other hand, EMS are vital in a home and especially building automation systems since they are designed to minimize the costs of public services, integrate different energy sources to the energy chain supply and support strategic business decisions around energy consumption [5].

Regarding to projects developed in this area, there are several of them dealing with subjects of building or home automation; some of them are leaded by companies around the world which are nowadays aware of the need to meet the evolving building automation market needs. The Open Interconnect Consortium [6] is working to define a common communication framework for wireless data transmission and information management. Meanwhile, [7] aims to use network technologies to connect and control products in the home. The work from [8] develops internationally unified communication standards to network domestic equipment and energy efficiency applications; it is the leading European initiative in the domain of "Internet of things" and brings together manufacturers in the energy, telecommunications, electronics and automotive industries.

Although there are many companies with projects focused on the automation of buildings, this issue has reached greater boundaries and sometimes its scope has reached the implementation of case studies for some cities. Some projects worthy of mention are the Commerzbank headquarters – Germany [9], the Building as a Service (BaaS) in Germany, Greece and Spain [10,11] and the VRISSA project, developed by SENA in Colombia [12].

The implementation of the BAS and its components must consider multiple characteristics and requirements that depend both on the needs of its occupants, and on the availability of economic, technological and environmental resources. Considering this, some authors have proposed strategy methodologies focused on facilitating the design and implementation of this type of systems [13–15]. Some of them have focused on methodologies for specific components of a BAS: [16], proposes a design method for the control system; [17] focus on the study of control techniques to achieve energy efficiency. Even authors like [18] present methodologies that go beyond design and seek to evaluate the performance of such systems. However, the approach presented by [19] shows a general methodology to design a BAS and its respective components, framing in a general way the conceptual steps for its development. The work from [19] turns to be mostly of interest for authors of this paper, since it presents an approach in line with our research group's lines of work involving different aspects like automation of buildings, systems cooperation, and strategic design. The methodology is presented briefly below.

2.2 Design Methodology Framework [19]

The reference model of Open Distributed Processing (ODP) offers a general framework upon which open distributed systems can be developed. In this context, the work from [19] proposes an approach for building automation design based on ODP and the utilization of object-oriented concepts through Unified Modelling Language (UML) and formal models such as Petri Nets (PN). The proposed approach encourages iterative development, by allowing the various activities to provide input to each other, considering two viewpoints: enterprise and information/computational. The enterprise viewpoint proposes a business-level design, which facilitates decision making in a general way and is aimed to management change. For its part, the information and computational viewpoint, facilitates the technical design of specific components at the technological level of components of the system under development. These viewpoints cover the main activities:

• Domain Modelling: seeks to identify business process, goals and requirements. The results of this activity are related to “enterprise viewpoint” and defines an overview of the system.

• Modelling of Relationships and Service of the System: two aspects of the system are modeled: objects and information flow. This activity concerns to information and computational viewpoints.

• Dynamic Modelling and Formal Analysis: It is the final and more detailed stage of the methodology. It is divided in two sub activities: System Modelling through Petri nets and Formal analysis. More details of each stage of this methodology can be found in [(19)].

Considering that the work from [(19)] has some characteristics of interest for the project presented in this article, some modifications have been proposed as required for this case study. The general methodological stages proposed by the author have been taken from the **Institution (SENA) viewpoint** and the t**echnological viewpoint**, but the representation of each stage has been simplified as shown next in Figure 1, since no Petri net or UML diagrams are used.

3. Results: Conceptual Design Methodology for Electrical Management Systems and Building Automation Systems. Use case for LST

The general model is represented by a diagram composed of blocks and flow lines indicating relationships between the stages. Each stage has a causal relationship that ranges from the strategic (institutional) to the systemic (environment).

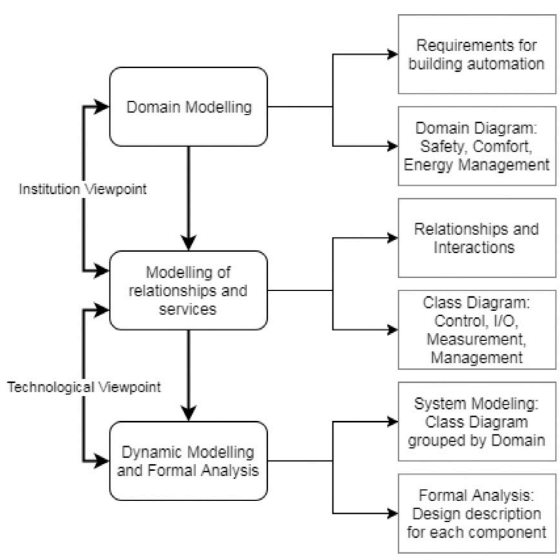

Figure 1. Proposed Design Methodology.
Source: The authors

Figure 1 shows the structure of the proposed methodology, which is made up of domains, relationships and their respective analysis. The proposed approach, has been applied to the conceptual design of the automated system of LST, one of the most demanding environments for the provision of services in SENA. Both, the proposed methodology and the use case for LST are simultaneously described next.

3.1 Domain Modelling

It is framed into a project oriented to modernization of the physical and technological infrastructure of an environment arranged for provision of technological services in SENA. The project is developed according to the concepts of sustainability, efficiency and energy saving, aiming to improve conditions of safety, comfort and energy management of those who work or are served in said environment. In accordance with the policy, regulations and programs developed in SENA, the project and the proposed methodology will be scaled to 117 training centers the institution has in the country, of which, starting with CEAI - SENA; its application will be carried out in a built area of about 20,000 m^2.

3.1.1 Requirements

Apprentices, instructors, professionals and researchers who work and people who attend the service environments in the CEAI need better comfort conditions, safety and energy management. One of the environments in which there the conceptual design methodology can be applied is LST - CEAI, formed by the areas of Electronic Technological Development (DTE) and Technological Development in Electricity, Instrumentation and Automation (DTEIA). The objective and scope of the technological modernization of LST is the implementation of an automated environment focused on the three beforementioned concepts, through the implementation of sub-systems based on the use of materials, devices and equipment with technologies, brands and technical certifications accepted in the national industry.

Through the design methodology of the LST automated system, it is expected to obtain a conceptual model to implement not only a service environment with the conditions of safety, comfort and energy management that benefits users, but also a show room that can be taken as a reference by people from communities, institutions and companies in their building automation projects.

3.1.2 System domains and use case modelling

Considering the above requirements, in this case three main domains have been defined, grouping other subdomains on which the updating and technological modernization activities in the LST will focus. In this case, UML has not been used, but simple diagrams for its representation, as shown below in Figure 2.

• Safety: Referring all elements related to entrance security, such as door access and safety inside LST such as floods, fires and closed circuit television (CCTV).

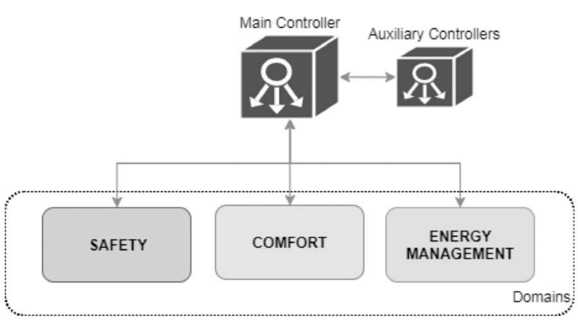

Figure 2. System Domains. Source: The authors

• Comfort: Referring all elements related to the welfare and comfort of the members of the LST, such as environmental variables (temperature and humidity) and lighting.

• Energy Management: Referring elements in charge of an efficient energy management. In this case, an alternative power source of and energy meters are included to obtain a balance of the electricity consumption/generation of the laboratory.

3.2. Modelling of Relationships and services of the system

In this stage, the sub-systems forming each domain and their respective interactions have been identified.

3.2.1 Conceiving relationships and interactions

Each domain of the system refers to general conditions to be maintained in the LST, which includes some subdomains or system variables to be automated. In the case of the proposed methodology, it is applied as follows:

• In the case of the security domain, sub-domains are managed where people access and presence inside and outside the LST is monitored, as well as its flooding status. The video is made through the closed circuit television (CCTV) and the flood and presence sensors.

• In the comfort domain, lighting and temperature subdomains are included. Light control is carried out through sensors, devices and on/off and adjustable luminaires, and the temperature is controlled with sensors and air conditioning units.

• In the domain of energy management, there are the energy and power quality subdomains. The measurement and analysis of data is done by primary and auxiliary energy meters installed in each air conditioning unit and in the inverter of a photovoltaic system installed in the laboratory as a renewable energy source.

In this domain, data and information delivered by a power quality analyzer are also analyzed. In general, the "information" from all domains in the system flows through the sensors, detectors, meters and analyzers that are in contact with the physical and electrical variables in form of digital signals, to the components in charge of data acquisition. The integration of domains and subdomains is presented in Figure 3.

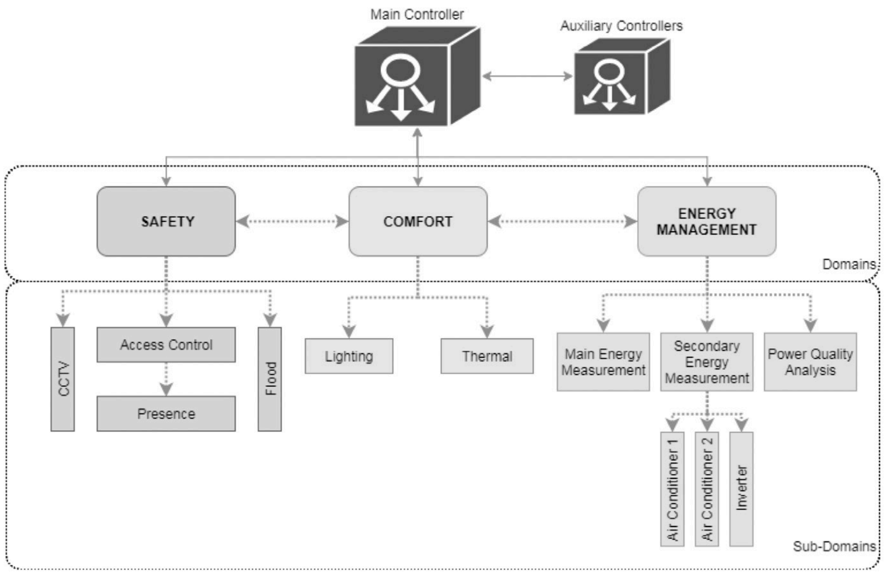

Figure 3. Domains and sub-domains of the system. Source: The authors

3.2.2 Definition and construction of class diagram

All components are integrated to each of the subdomains defined to achieve the structure and functionality of the automated system and the improvement of laboratory conditions. The components included in the system are of the type: i). Control, ii). Measurement, iii). Input and output of data (I/O) and iv). Data management. The relationships between components flows from measurement elements and entry data to control elements, and then from the latter to data output elements. The integration of the subdomains, together with the four classes of components or categories mentioned before is presented next in Figure 4 and later described in detail.

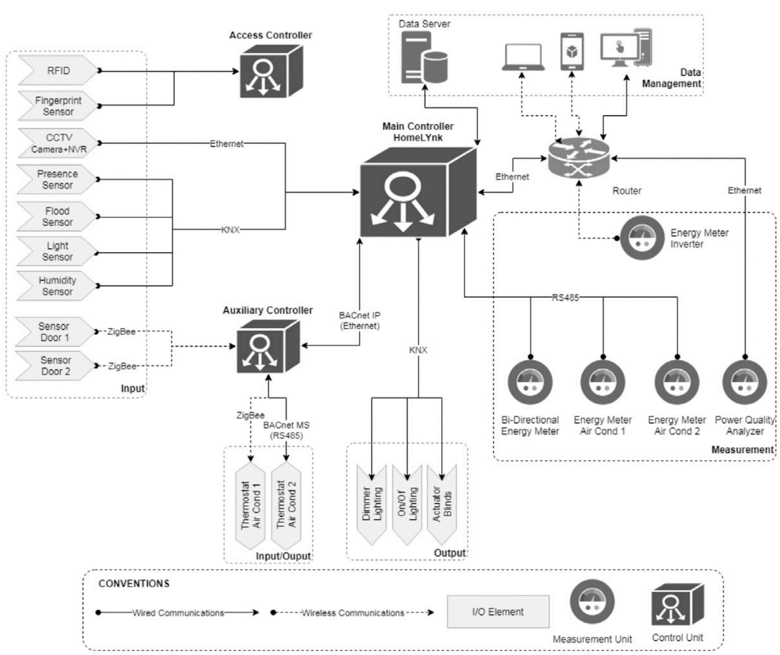

Figure 4. System Class Diagram. Source: The authors

In the case of the proposed methodology for the automated LST system, most of data, measures and control logic are centralized using a control/ management platform: Schneider ® HomeLYnk main controller [20]. The platform was chosen for its ability to dynamically connect measurement components of different physical and electrical variables, and integrate multiple communication protocols, considering communication standards to establish relationships between the components of the system, described below.

3.2.2.1 Control Units

This category contains three elements:

• Main Control Unit (HomeLYnk): it is the central control of the system. In this module all the control logic is programmed for each input (sensors and meters) and output (actuators) element. This platform is a programmable device, which acts as an integration gateway for the MODBUS, RTU, KNX and RS485 protocols; it also has an Ethernet port in which it supports multiple protocols, including TCP / IP and BACnet IP.

• Auxiliary Controller: It receives signals from sensors located at the doors of each laboratory areas and also interacts with the air conditioning units. It is used to include elements with ZigBee and BACnet IP communication that cannot be directly connected to HomeLYnk platform.

• Access Controller: Currently this control module is not interconnected to other components of the system. It is responsible for access control of users to LST areas by RFID card or fingerprint.

3.2.2.2 Measurement Elements

These elements are responsible for measure/ analyze energy flow at different points in the electric system of LST. In this category the elements deliver data to HomeLYnk using two protocols:

• Ethernet: Provides data coming from a router, which collects data from a power quality analyzer and also via Wi-Fi from the internal meter located in the inverter of the photovoltaic system.

• RS485: This protocol connects a bidirectional meter that measures energy consumed and generated by the entire system, two unidirectional meters that are connected to each air conditioning unit.

3.2.2.3 Data Input / Output Elements

This category contains elements that receive data from sensors and or deliver data to any actuator element in the system. All these elements are connected through different protocols to the Main Control Unit:

• Ethernet: With this protocol the Closed TV Circuit is connected, which also has an NVR (Network Video Recorder).

• ZigBee: With this protocol, the two sensors of the DTE and DTEAI doors are connected to an auxiliary controller, as well as the rheostat for the control of the air conditioning unit which is located at DTE.

• BACnet MS: With this protocol running over RS485, the rheostat controlling the air conditioning unit of DTEAI is connected to the auxiliary controller.

• BACnet IP: With this protocol running over Ethernet, the auxiliary controller is connected to the Main Control Unit (HomeLYnk).

• KNX: connects lighting, humidity, flood and presence sensors to the main control unit. It is also used to activate the light actuators (ON/OFF and dimmable) and the blinds.

3.2.2.4 Data Management Units

In this category two type of components are grouped:

• Data server: designed to store historical and general system operation data. This server allows the system the ability to integrate big data tools.

• Management devices: These elements, such as cell phones, laptops and pc play a role comparable to the front-end branch of a SCADA (Supervisory Control And Data Acquisition) system, so users can perform data visualization and some control actions on the platform.

3.3 Dynamic Modelling and Formal Analysis

In this section, the conceptual design methodology of the automated system is consolidated. Dynamic modeling and formal analysis are done to integrate all elements that make up the design methodology, considering it was applied in order to provide better conditions for LST users in aspects of safety, comfort and energy management.

3.3.1 System Modelling

Modeling is based on the use of objects and is done integrating all domains and classes, interfaces and communication protocols of the system, which configure the methodology in the conceptual design. The modeling of the system is shown in Figure 5 and is described later.

3.3.2 Formal Analysis

This section details each component or domain and its function within the system, according to the class to which it belongs.

3.3.2.1 Security

Its main goal to preserve integrity of users and the good condition of the equipment. It has a CCTV system with Wi-Fi cameras and IP communication. As the HomeLYnk system only has transmission capacity (retransmission), the use of NVR has been incorporated for video recording. To grant access control, there is an identification system that uses RFID and fingerprint cards, as well as presence detectors within the laboratory. In addition, there is a flood alarm system.

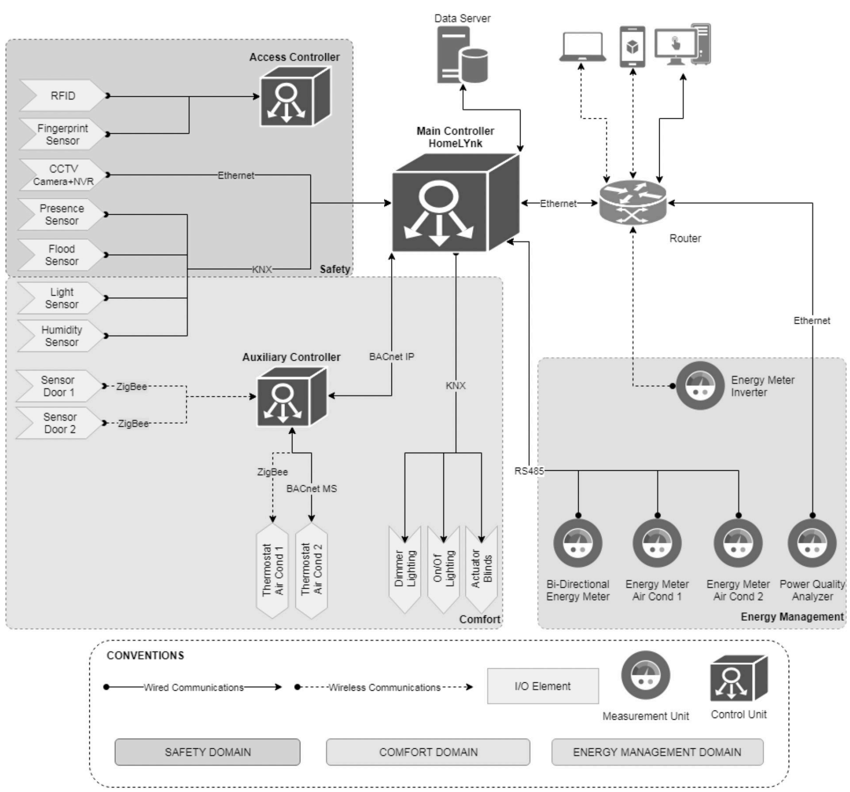

Figure 5. System Model: Class diagram grouped by domain. Source: The authors

3.3.2.2 Comfort

It is aimed to offer comfort conditions for LST users. It is associated with lighting and thermal comfort. It is implemented through a KNX main network that works through HomeLYnk, as the main platform for system integration and is responsible for all measurements.

• Lighting: It is implemented by pushbuttons and binary actuators that, in addition to controlling the light of each luminaire, allow to measure the current flowing through each one of them. DTE area also has two adjustable lighting circuits that integrate light quantity sensors, to minimize the use of artificial light and, in accordance with the concept of sustainability, efficiency and energy saving, use natural light. The lighting of the first circuit, in the main corridor of LST is managed by a single-channel controller; the second circuit, in DTE area, is commanded by one actuator with multiple analog and digital inputs and outputs. Another component of the lighting system are actuators associated to the blinds that are located in the exterior windows of the DTEIA area, through which the entrance of natural lighting is regulated, in case of wanting greater use of the renewable resource or projections with video equipment.

• Temperature: The system has high efficiency air conditioning units that due to their thermal capacity, have high energy consumption and require measurement and analysis for their integration into the management platform. The measurement of energy consumption of the units is done using two unidirectional energy meters directly connected to their circuits, through MODBus registers that are part of the energy management system. The control of these air units is done by thermostats whose function is to switch on / off to maintain a comfort temperature and are integrated into the management platform, through an auxiliary controller that manages signals coming from each air conditioning unit through the BACnet protocol. MS / TP, in the case of the unit located in DTEAI area and ZigBee, in the case of DTE.

In addition to energy management, by measuring the temperature, there are two conditions in the control logic that have been programmed and restrict its operation and contribute to the energy efficiency of the system: i). If the laboratory door is open, it is not possible to turn on the air conditioner and ii). If the air is working and the laboratory door is open, the air is turned off after a certain time. These two conditions are met using the ZigBee sensors located on the doors that indicate their status (open or closed) and whose information is also collected by the auxiliary control unit.

3.3.2.3 Energy Management

The power supply system of the LST is hybrid (composed of a conventional electrical public network and a photovoltaic plant of 4 kWp). The loads are represented by elements arranged for the services (lighting, air conditioners and access and security system) and the equipment used for the provision of technological services in the LST.

• Energy Measurement: are made from information provided by meters and the power analyzer. With these elements, energy delivered by the power two sources and energy consumed by the services and equipment in the LST is quantified (balanced). For this purpose, a bidirectional energy meter has been installed using current transformers. Data from these measurements are collected using MODBus protocol. The inverter of the photovoltaic plant has a Wi-Fi card that delivers the data through MODBus TC / IP protocol.

• Power Quality: Considering that the photovoltaic generation system implemented in the LST can influence the quality of the energy in the laboratory and in the public network, the automated system analyzes the power generation behavior when it is working at maximum power and there are environmental conditions (clouds, rain) that modify its behavior, which allows to know and control the quality of the power (harmonics, power factor, etc.) to make decisions on the impact of the use of the photovoltaic system. For this reason, a Schneider ION7650 ® power analyzer has been installed, which is located at the energy exchange frontier, that is, where the conventional electrical network and the photovoltaic system are integrated.

4. Conclusions and Upcoming Developments

This article presents a conceptual design methodology of a Building Automation System for facilities intended for the provision of educational and technological services at SENA, which can be adapted for the design of BAS in other institutions or companies.

The review of the state of the art shows how BAS have become a research focus, due to the increase in the development of technology and applications oriented to security, comfort and energy management in buildings.

The proposed design methodology, focused on three of the domains that represent the most common conditions in buildings such as: safety, comfort and energy management; this was applied to the design of the automation system of the Technological Services Laboratory LST of CEAI – SENA, Thanks to this implementation, prominent results were obtained such as: better conditions for users, consolidation of a reference automated environment for institutions and companies, energy balance benefiting natural energy sources and an increase in the culture of rational and efficient use of energy.

Considering that the application of the methodology to the design of the automated system improved the feasibility of its implementation, from s cost/benefit point of view, since it had an average cost of USD 400/m^2 to improve conditions of security, comfort and energy management; it will be applied to the development of projects aimed to modernize the physical infrastructure in the institution buildings. It is important to note that this system not only has the ability to integrate different technologies and communication protocols, but also to integrate additional elements and applications dedicated to data management with more complex processing, involving booming concepts like Big Data and Knowledge Discovery in Databases (KDD). This ability of further integration will allow punctual analysis of the performance data in the system and the possibility of supporting decision making at the management/institutional level.

5. Acknowledgments

To SENA, for its policies and regulations aimed at favoring sustainability and efficiency in the use of resources within the institution. To SENNOVA - SENA for the guidelines, programs and resources assigned to applied research projects, technological development and innovation at training centers. To the instructors and professionals linked to the UIADTI - CEAI who participated in the development of this BAS for LST and, in particular, to the apprentices at the center's research who also carried out the implementation of the automated system.

6. References

1.Romero MC, Vázquez SF, De Castro LC. Domótica e Inmótica: Viviendas y Edificios Inteligentes. Madrid: RA-MA; 2007.
2.Asociación Española de Domótica e Inmótica - CEDOM. Qué es Inmótica. Asociación Española de Domótica e Inmótica; 2016. Available from: http://www.cedom.es/sobre-domotica/que-es-inmotica
3.García SCM; Moreno MFA. Perspective from Artificial Intelligence applied to Home Automation. Una Panorámica de la Inteligencia Artificial aplicada a la Dómotica. Madrid; 2014. Available from: https://docplayer.es/11633519-Una-panoramica-de-la-inteligencia-artificial-aplicada-a-la-domotica.html
4.Batov EI. The distinctive features of smart buildings. Procedia Engineering.2015; 111: 103 - 107.

5. Wambui KB. Concepts of Building Automa¬tion Systems and Its Effect. Thesis. Department of real estate and construction management, school of the built environment. University of Nairobi; 2014. Available in: http://realestates.uonbi.ac.ke/sites/default/files/cae/artsdesign/realestates/B04%2035938%202010%20-%20 RESEARCH%20PROJECT%20ON%20 'CONCEPTS%20OF%20BUILDING%20AU-TOMATION%20SYSTEMS%20AND%20 ITS%20EFFECT%20ON%20REAL%20PRO-PERTY%20VALUES'_0.pdf

6. Open Connectivity Foundation. Open Con¬nectivity Foundation (OCF) 2017. Available from: https:// openconnectivity.org

7. Thread Group. Thread Group - Home 2017. Available in: http://www.threadgroup.org

8. EEBus Initiative e.V. EEBUS 2017. Available in: http://www. eebus.org/eebus-initiative-ev

9. Noble C. Commerzbank?: A Sustainable Skyscraper; 2002: 68-78. Available in: http://www.civil.ist.utl.pt/~cristina/EBAP/FolhasE¬difAltos/commerzbank/commerzbank.pdf

10. BaaS Consortium Partners. BaaS Project. Internet 2017. Available from: https://www.baas-project.eu

11. Butzin B, Golatowski F, Niedermeier C, Vica¬ri N, Wuchner E. A model based development approach for building automation systems. Emerging Technology and Factory Automa¬tion. 2014; 1-6.

12. Noticias Servicio Nacional de Aprendizaje SENA. Future House designed by SENA ta¬lents, source of income Casa del futu¬ro diseñada por talentos SENA, fuente de in¬gresos 2015 Internet. Available in: http://www.sena.edu.co/es-co/ Noticias/Paginas/noticia.aspx?IdNoticia=182

13.Heidemann A. Conceptual Development of Low Energy Buildings. Regenerative Ener¬gien in der Gebaudetechnik (in German) VDI; 2002. p. 1-38. Available from: https://www.tib.eu/en/search/ id/BLCP:CN045558393/Conceptual-Develo¬pment-of-Low-Energy-Buildings/

14. Dibowski H, Ploennigs J, Kabitzsch K. Auto¬mated design of building automation systems. IEEE Trans Ind Electron. 2010;57(11):3606-13.

15. Abdulrahman TA, Isiwekpeni OH, Suraju¬deen-bakinde NT, Otuoze AO. Design, Speci¬fication and Implementation of a Distributed Home Automation System. Procedia Compu¬ter Science. 2016; 94:473-8

16. Schild T, Futterer J, Muller D. A mode-based implementation framework for advanced con¬trol methods in building automation systems with Petri-Nets. IEEE Int Conf Adv Intell Mechatronics. 2017;213-8

17. Behrooz F, Rahman RA, Samsudin K. A survey on applying different control methods approach in building automation systems to obtain more energy efficiency. International Journal of the Physical Sciences. 2011;6(9):2308-14.

18. Makarechi S, Kangari R. Research Methodo¬logy for Building Automation Performance Index. International Journal of facility Mana¬gement.2011;2(1):1-14.

19. Bastidas G, Miyagi PE, Pina IB. Development of an Open Distributed Approach for Building Automation. 2006 ;2:150-7

20. Schneider Electric. HomeLYnk. Scheni¬der Electric. 2017. Available from: https://www.schneider-electric.es/es/product-range/62143-homelynk/827516485-productos