OVERVIEW OF AUTOMATION IN BUILDING ENERGY MANAGEMENT

TỔNG QUAN VỀ TỰ ĐỘNG HÓA ĐỐI VỚI QUẢN LÝ NĂNG LƯỢNG TÒA NHÀ

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ABSTRACT

The increase population and the continued exploitation of fuel resources to meet the needs of development of economic and social over the past decades have led us to face with exhaustion of fossil fuel resources and many environment impacts. The building is a major consumer of energy, 40% proportion of global energy consumption. In the sustainable energy development, buildings are an essential objects to be researched. The revolution 4.0 brings us solutions to easily solve the energy problem in buildings. The aim of this report is about an overview about automation technologies in building energy management. The topics in this report included a summary of the energy context, the typical architecture of the energy management system, analysed some case studies, and discussed about the role of technology in improving performance and reducing energy consumption in buildings. Finally, we evaluated trends of this field in the future.

Keywords: *Automatic; building energy; smart building.*

TÓM TẮT

Sự gia tăng dân số thế giới và không ngừng khai thác các nguồn nhiên liệu để đáp ứng nhu cầu phát triển kinh tế và xã hội trong những thập kỷ qua đã khiến chúng ta phải đối mặt với nhiều vấn đề về cạn kiệt nguồn nhiên liệu hóa thạch và các tác động môi trường. Tòa nhà là đối tượng tiêu thụ năng lượng lớn, chiếm 40% tổng năng lượng tiêu thụ toàn cầu. Trong bài toán phát triển năng lượng bền vững, tòa nhà là đối tượng quan trọng cần được quan tâm nghiên cứu. Cuộc cách mạng công nghiệp 4.0, đã giúp chúng ta có công cụ giải quyết bài toán về năng lượng trong các tòa nhà. Mục đích của bài báo này là trình bày tổng quan về công nghệ tự động hóa trong quản lý năng lượng tòa nhà. Các nội dung bao gồm tóm tắt bối cảnh năng lượng, cấu trúc hệ thống quản lý năng lượng, phân tích một số nền tảng hệ thống điển hình và thảo luận về vai trò của công nghệ trong nâng cao hiệu suất và giảm tiêu thụ năng lượng trong các tòa nhà. Cuối cùng, chúng tôi đánh giá xu hướng nghiên cứu trong lĩnh vực này trong tương lai.

Từ khoá: *Tự động hóa; năng lượng tòa nhà; tòa nhà thông minh.*

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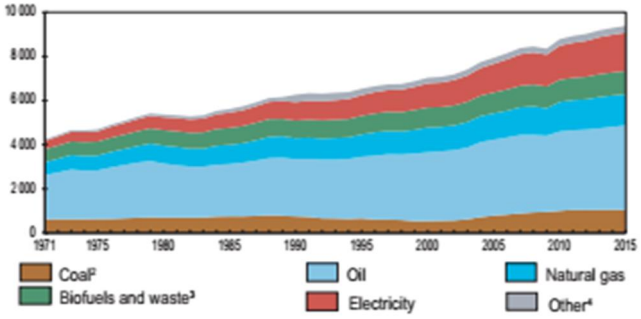
ABBREVIATIONS

BEMS	Building Energy Management System
BMS	Building management system
GHG	Greenhouse gas
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of things
IP	Internet protocol
EMS	Energy Management System
TFC	Total final consumption
NZEBs	Nearly zero energy buildings
ZEBs	Zero energy buildings

1. INTRODUCTION

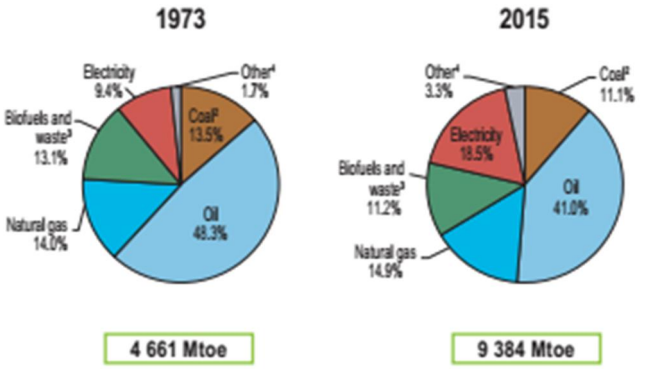
In the 21st century, the growing population, the development of the world economy, the demand for fossil fuel exploitation is dramatically increasing and causing bad effects on the environment. Fossil fuel combustion is a chemical reaction between carbon and hydrocarbon with oxygen and produces heat energy and carbon dioxide (CO_2) - a major contributor to the greenhouse effect. That causes global warming currently. According to the International Energy Agency [1], the world's total final energy consumption in 2015 is 9,384 Mtoe. The increase was nearly double that of 4661 Mtoe in 1973. Fossil energy accounts for 67% of total consumption. Oil accounted for the largest share (41%), followed by coal (11.1%) and natural gas (14.9%) (Figure 1).

Energy transition to sources such as hydro, nuclear, and recently, renewable energy sources are necessary. However, all energy has an environmental impact, even if their impact is limited. Sustainable energy involves solutions to adapt human energy needs, contemporaneous reducing environment impacts. This includes an increasing renewable energy production, a higher efficient energy and environmental improvement to reduce GHG emissions and sustainable urban areas [2].



(Source: IEA, Key world energy statistics, 2017)

Figure 1. World TFC from 1971 to 2015



(Source: IEA, Key world energy statistics, 2017)

Figure 2. 1973 and 2015 fuel shares of TFC

Building energy consumption represents the most important portion of global consumption (around 40%) [3]. In fact, the building sector is responsible for amounts of energy consumption and CO_2 emission. This has caused of an unprecedented increase in energy consumption, the supply-demand gap and the electricity bill have to be pay continue to go up every year. Solutions to manage energy flow in buildings not only create mechanisms to reduce energy consumption but also improve energy efficiency. A new paradigm recently is zero energy buildings (ZEBs) or nearly zero energy buildings (NZEBs). ZEBs use all cost-effective measures to reduce energy use through energy efficiency and balance energy use and energy being supplied in the building, even export energy to the grid or other network. There are long-term benefits in developing ZEBs, including lower environmental impacts, lower operating and maintenance costs, better resilience to power outages, natural disasters, and increased energy security [4]. Towards ZEBs is to ensure energy sustainability in cities and global. For this purpose, technologies plays an important role in building energy management.

Studies shown that adopting energy management systems helps assess the effectiveness of energy efficiency solutions in buildings. Even without energy-saving solutions, the installation of energy-saving technology also allows savings up to 2% of total energy consumption compared to unplanned through the positive actions on users' behavior [5].

The industrial revolution 4.0 with internet of things (IoT) technology, allows real data to be collected, and allows for extended interaction with the environment and changing the behavior of the users. According to Nils ARTIGES [6], the development of protocols and networks for building sensors and actuators could gather more data and control more diverse systems. Author commented that the wireless sensor network is promising to change the way we control the energy in the building. Obviously, automation technologies play an important role in energy management of building.

In Vietnam, the issue of energy management is one of the important item reflected in the green building assessment tools such as LEED, LOTUS and be considered in priority projects by Electricity of Vietnam Nation. Specifically, project development of intelligent electricity meters, toward smart buildings, smart grid, allows the construction of competitive electricity market.

This paper is an overview about automation technologies in building energy management. Section 2 identified the role of smart building technology in energy management issues. In section 3, the typical architecture of Building energy management system was shown. In section 4, case studies of Building energy management system were analysed. Finally, the conclusions were about the researches trend development of technologies in buildings energy management.

2. SMART BUILDINGS AND ENERGY MANAGEMENT ISSUES

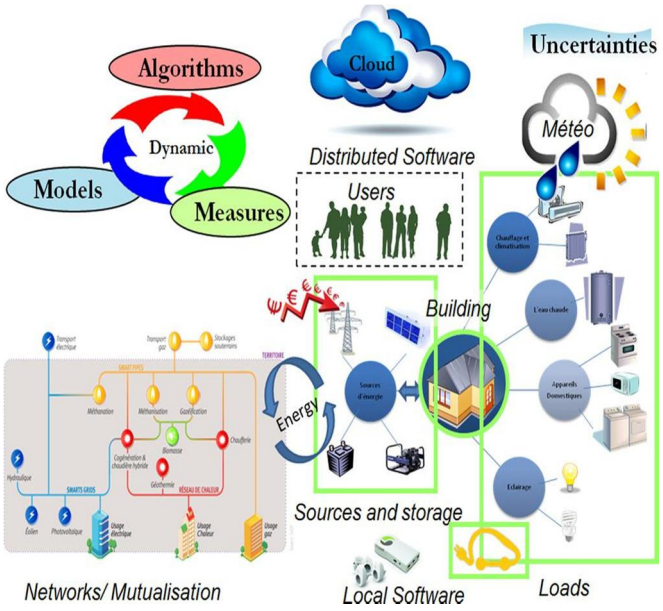
With the use of advanced technologies in smart building, the user or the system itself is capable of lowering the energy consumption or postponing the energy demanding operations concerning the present electricity price by managing the electrical features and under the condition of ensuring a positive comfort level. For instance: room heating can be adjusted according to user preferences and weather; lighting in the room can be changed in daylight; Energy saving by automatically turning off electrical equipment when it is not needed or adjusting the operating power according to the needs of the user, thus avoiding excessive use of energy. Smart building has been researched and developed for last decades.

L.C.D. Silva et al. [7] describes a smart home as an intelligent environment and automatic control, capable of responding to resident behavior.

According to Wang et al. [8] Smart Buildings is part of the next generation building sector. In their studies, the authors tackled sustainability energy issues using smart technologies to achieve the optimal human comfort and energy consumption.

Frédéric Wurtz and Benoît Delinchant [9] suggested that "Smart building" can be first seen as the adaptation of the smart grid concept at the level of the building micro-grid.

The idea is to propose a multi-source, multi-load, and multi-storage system, all of it massively orchestrated by information and communication technologies.

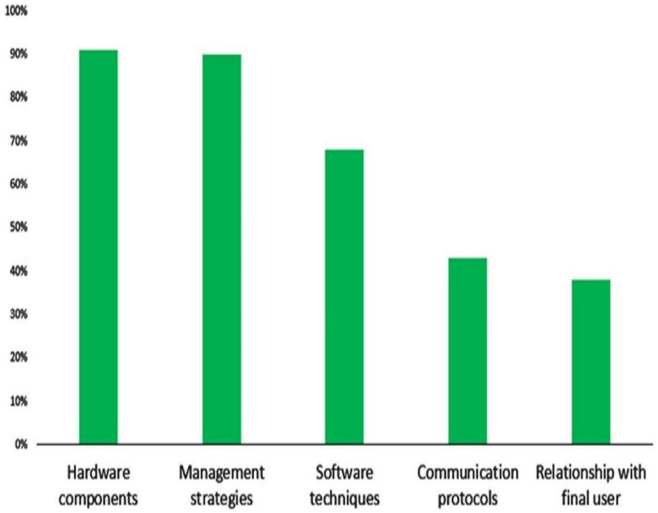


(Source: http://predis.grenoble-inp.fr/smartbuilding/doku.php)

Figure 3. "Smart building" at the interfaces of energy networks and external environment

Figure 4 shows that the building is a complex object and closed involvement of factors: the hardware deployed at the residential level and the distribution network; Communication protocols allow interaction between all components in the process, including end users; and the software allows control of various variables, which affects the system, and also the implementation of management strategies. Energy management in smart buildings include renewable energy sources with an intelligent power consumption mechanism and a collaborative smart grid to ensure the interconnections between them. J.A. Nazabal et al. [10] proposed an Energy Management System (EMS) that includes renewable energy sources for the efficient use of energy created by a Smart Home and the energy consumed by the electric appliances with approaching an overall system, from software protocol to employed hardware is presented.

The advance technology solutions, including IoT, is a new opportunity for the development of sensor and actuator networks covering in large area to address the energy efficiency building, contributing to sustainable urban development. Innovative technologies allow handling the complex objects and multi interactions in building systems to achieve high energy efficiency while take into account user comfort conditions. In recent decades, researchers have concentrated on proposing solutions related to building energy management. According to A.M. Vega et al [11], in figure 4, most authors (91%) have studied about energy management systems relating to hardware or technology platform.



(Source: Vega, F. Santamaria, E. Rivas, 2015, modeling for home electric energy management: A review, Renewable and Sustainable Energy Reviews 52 948–959)

Figure 4. Percentage of models involving the analysed characteristics

3. FOUNDATION OF BUILDINGS ENERGY MANAGEMENT

- **Buildings energy management system (BEMS)**: based on smart building technology including digital controllers, building automation devices, communication standards to exchange information processing in the system. BEMS is usually considered as a part of buildings automation system with energy management functions; be considered as a monitoring and control system for services that contribute significantly to the energy consumption in buildings [12].

- **Communication protocols:** allow all the devices being integrated in a buildings management system. Protocols may be open standards (free for all use), according to the type of license standard (open to all licenses) or type of owner (only for manufacturers or manufacturers). On the market, there are many standards for communications used in buildings. Some of them are:

ZigBee: technology to facilitate communication in the source domain and optimal traffic [13, 14];

X-10: Home control via home wiring [15];

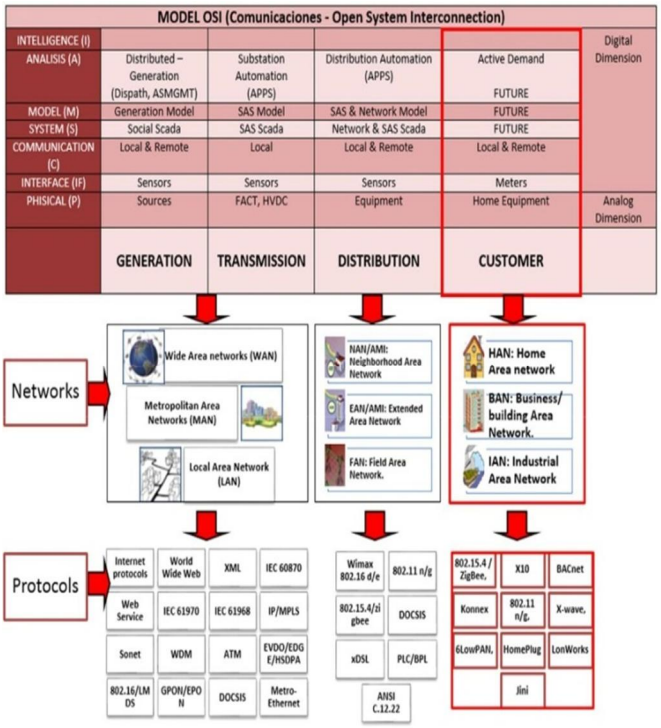
BACnet: Protocol building network automation and control [16];

Konnex: House and Building Control Standards [17];

LonWorks: Communication and Deployment in Microprocessors [18];

Jini: Adaptable, expandable and flexible networks [19]

Figure 6 shows the main protocols used such as generation, transmission, distribution, and end-users. Similarly, the relationship between these protocols and the communication network and their interaction in the OSI7 communication model is observed [20].



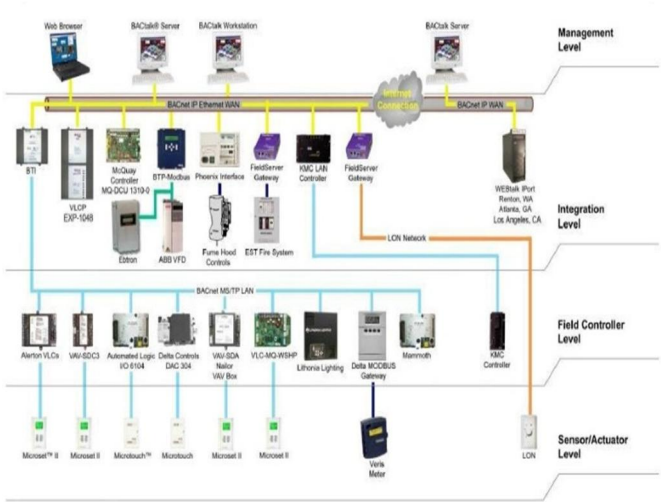
(Source: Vega, F. Santamaria, E. Rivas, 2015, modelling for home electric energy management: A review, Renewable and Sustainable Energy Reviews 52 948–959)

Figure 5. Protocols used in the electric system attached to the OSI Model

4. CASE STUDIES

4.1. Platforms in GreEn-ER [21]

- Schneider's BMS system: This platform is part of the PREDIS science / technology project in the G2Elab lab, which provides a training and research tool in the field of energy and networking, enhancing the efficiency and safety of Power distribution networks take into account the diversity of the source and capabilities of users engaged in the production, storage or consumption of electricity. The GreEn-ER building's BMS system is owned by Schneider.

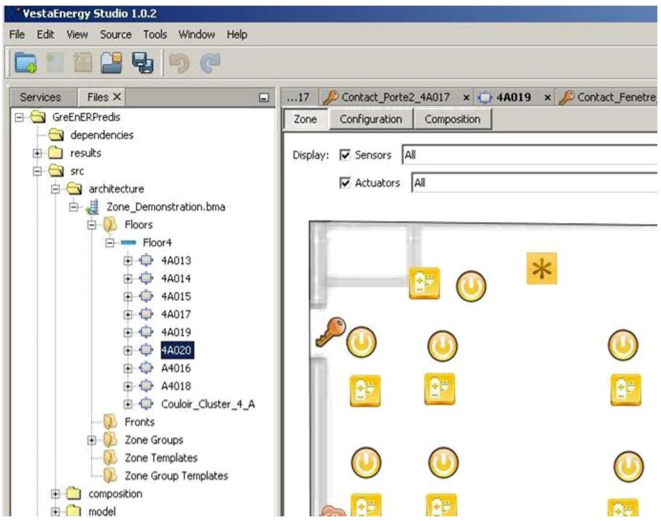


(Source: PRASAANT BALASUNDARAM, 2017, Implementation of Supervisory control for heterogeneous PLC, thesis master 1, University Gnenoble, Génie Électrique)

Figure 6. BMS Layout from Schneider Electric

In figure 6, the BMS has a four-level architecture because there is a field level that the sensors retrieve data and feed the controllers. This is a networked control system that can transfer data by network or group share network (not only for data transfer but also for control action). The BMS system in the GreEn-ER is comprised of many hardware points and a numerous amount of soft points which contribute to the IO summary of the whole building. It might be seen that some systems don't have a field level protocol rather than a direct communication with the automation server. The lighting system has a field level protocol as well as a management level protocol. In practically, Schneider Electric has its own proprietary control system and also a functional block programming associated with the BMS (for performing the control actions). Any engineer may not be able to interpret it easily. They have developed other BMS platforms inside building like VESTA, JEEDOM, to easy changing parameters without need depth knowledge in a complicated proprietary software of own proprietary control system. Using Wireless sensor network and open source help promoting work of their students, researchers.

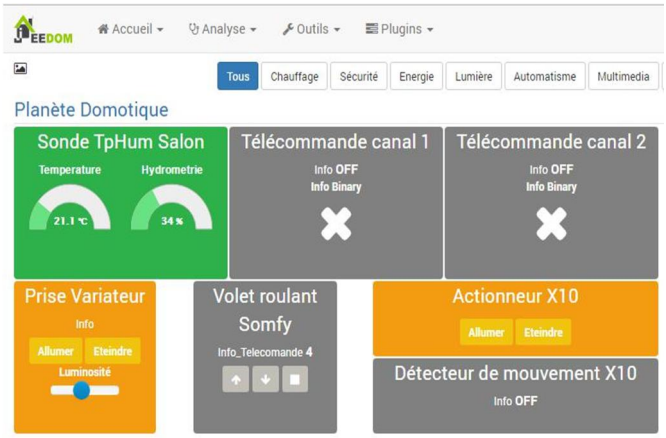
- **The VESTA energy management system:** has a micro box which houses an EnOcean communication dongle for the collecting data, the sensor included here are the wireless sensors for temperature, CO2, luminance, presence detection and for the detection of opening and the closing for the doors. Figure 7 shows the sensor that work under the VESTA energy management system for a room.



(Source: PRASAANT BALASUNDARAM, 2017, Implementation of Supervisory control for heterogeneous PLC, thesis master 1, University Gnenoble, Génie Électrique)

Figure 7. VESTA Energy management system

- **The JEEDOM energy monitoring systems**: is responsible for monitoring the power available and the energy utilized by the PC's located at the PREDIS hall. The communication between the devices is due to the Z-Wave protocol. Figure 6 shows a sample JEEDOM monitoring system.



(Source: PRASAANT BALASUNDARAM, 2017, Implementation of Supervisory control for heterogeneous PLC, thesis master 1, University Gnenoble, Génie Électrique)

Figure 8. JEEDOM platform display

4.2. Others

- Smarthome market in Vietnam: BKAV, Lumi are the most famous Vietnamese's company in smart building sector. However, all their solutions for smart building only focus on automation: Their smart home is a home in which all equipment such as lights, curtains, air conditioners, water heaters, sound, security cameras or garden watering systems are communicated with humans using the Internet, allowing users control electrical appliances in the home remotely by their smartphone or "voice" [22, 23]. Energy management functions only are available by ordering or project requirements.

- USTH platform: Over the last few years, research in the Department of Energy has focused on smart grids and smart houses to reduce energy consumption in buildings, towards NZEBs [24]. In the studies of Hoang [25], he set up a platform (see Fig.9) for measuring internal environmental parameters, measuring power consumption based on Z-Wave devices and JEEDOM energy monitoring systems. The author simulated the thermal model of the platform based on the analysis of the collected data.

(Source: Bui Tien Hoang, 2016, Building Energy Management: Thermal modelling for calculation of thermal comfort and thermal energy consumption, thesis master 2, Hanoi University of science and technology)

Figure 9. Temperature sensors of corridor and Cleaned Lab

Researches on smart building with energy efficiency in Vietnam have been developed more than 10 years, but the results still were limited. In fact, not many buildings are installed energy management systems that use renewable energy because the cost of such buildings are relatively high. The lack of this important platform has limited the research findings on building energy and smart homes in our country. Recently, the issues of building energy management are interested in many projects of the Ministry of Construction of Vietnam. In EP-01, QCVN 09:2013/BXD [26] stipulates additional meters for loads to monitor the level of energy consumption in building. Green Building Rating Tools such as LEED, LOTUS, consider energy management an important item. However, the value of investment is not much. Specifically, in the projects on energy efficiency, funded by DANIDA, USAID, and UNDP are carry out energy audits and collected energy consumption data. However, this can only be done for a short period time without reflecting the actual energy consumption.

5. CONCLUSIONS

Existing energy management systems, and energy-consuming devices in building are provided by different manufacturer, which results in difficulties in operating and optimizing the entire energy system. The current research trend is to design the system with open communication interface towards stable connection, not limited devices that use energy. The high-performance buildings, toward ZEBs is a modern trend and high potential in the market. IOT technology make us easier to extend an automated energy building management system to achieve the goal. This also creates opportunities for students and researchers in Vietnam in their research activities in the field of building energy. The platforms like Photovoltaic system in HoaLac Hi - tech Park is significance for development studies about ZEBs in Vietnam.

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