Implementing BMS in household and commercial complexes using industrial PLCs as well as its impact on optimizing energy consumption

1. Mostafa Kermani, 2. Esmaeil Ghasemzadeh, 3. Taghi Vahidi, 4. Majid Reza Naseh

1. MSc Student,Electrical Engineering Department, Islamic Azad University, Birjand Branch, Iran

2. Southern Khorasan Electric Distribution Company (SKEDC)

3. Head of Research Group, Southern Khorasan Electric Distribution Company (SKEDC)

4. PhD in Electrical Engineering Department, Islamic Azad University, Birjand Branch, Iran

Corresponding Author E-mail:mkermani1388@yahoo.com

Abstract

Increase in global population on one hand and the restriction in energy resources on the other have persuaded mankind to focus on managing and optimizing energy consumption more than before. Since the housing complexes are the most energy consuming sectors in Iran, implementing BMS will be one of the efficient methods of optimizing energy consumption so that the desired execution of BMS in household and commercial divisions will lead to energy saving, increasing in building equipment productivity, and resident's welfare. At present, PLC is one of the popular methods for implementing BMS in household and commercial complexes in Iran. Therefore, we have focused on design and implementation of BMS in the aforesaid complexes using industrial PLCs meanwhile the required elements for controlling the existing systems at the buildings have been analyzed as well. Subsequently, the trend of implementing the project and describing its advantage and disadvantages have been discussed comparing other related methods.

Keywords*:* Optimizing Energy Consumption, Household & Commercial Complexes, BMS, PLC

1. Introduction

Energy supply in the 21st century may be considered as one the most important activities for mankind due to the vital role of energy saving in increasing the life quality. The trend of supplying required energy for mankind have been increased dramatically so that the policy makers of energy sector have focused not only on optimizing energy consumption, but also on using other alternatives like renewable energy sources together with the supplementary technologies for utilizing fossil fuels in order to manage the energy crisis. Also, each method of energy supply will have unique characteristics and its own advantages and disadvantages [1] & [2].

Optimizing the energy consumption is an invaluable factors in energy saving and this may be considered as one of the most important strategies for reducing energy consumption especially in the countries like Iran that their industry are threaten with old and high consumption technologies. Reducing the energy consumption can be carried out by taking measures such as insulating buildings, optimizing heaters, using energy saving bulbs, and so on. Moreover, although there are lots of energy sources in Iran, inefficient consumption of energy will lose the national budget and financial resources.

There are only two solutions for meeting the increasing trend in energy demands. The first solution is to increase the capacities to meet the requirements of energy consumption and the second and optimal solution is to utilize an appropriate pattern for energy saving by optimizing the energy consumption, selecting adequate time for consuming energy, and so on. Thus, the best alternative is the second solution, because it will both save energy and preserve the national capitals for meeting the community requirements in energy sector.

As the graphs of energy flow show, about 40 percent of energy consumption in Iran is related to building including household, commercial, and public customers. Hence, each kind of effective actions regarding the reduction in energy consumption in building sector will have a huge impact on energy saving [3].

This article aims to implement local automation in household and commercial complexes by BMS to optimize energy consumption together with an increase in customers' security level and their welfare.

2. BMS

BMS is an acronym for Building Management System and it utilizes the newest technologies in order to supervise the activities and affairs in residential buildings to apply the required changes automatically due to the environmental conditions. Depending on the usage of BMS in various building (residential, commercial, hospitals, etc.), the system not only controls the different parts of the buildings and creates an appropriate environmental conditions, but also optimizes the energy consumption and increases the productivity and efficiency level of the facilities via offering simultaneous services [4].

Attention must be paid that BEMS (Building Energy Management System) is similar to BMS meanwhile BEMS aims to manage energy at buildings and it's a subset of BMS. It also monitors the energy consumption of equipment and it may be connected to the metering apparatus for both logging and controlling the instruments in order to save energy using smart systems.

2.1 BMS tasks at the buildings

The tasks such as warning alarm at the buildings, opening the doors, disconnecting the main power of the buildings, closing the gas valves during firing, disconnecting the fan coils after opening the windows, setting up the indoor lighting based upon the sunlight, etc. are some merits of the application of BMS at the buildings. Generally, BMS may be an appropriate system for controlling the building components due to its capability in using standard protocols and also well-known

standard based architecture; meanwhile it has an ability to have communication with other systems.

2.2 Advantages of using BMS at the buildings

The main advantages of using BMS at the buildings can be listed as energy saving, economical benefits, reducing maintenance costs, increasing the welfare level, optimal usage of equipment that extends their life cycles, controlling and monitoring all the controllable points by various methods, acquiring statistical reports of whole equipment and their applications that help optimize energy consumption, increase in building safety, and so on.

As addressed above, the buildings are the most energy consumers in Iran (about 40 percent) and BMS will reduce the energy consumption up to 30 percent at the best cases. Therefore, utilizing standard BMS will save energy considerably all over the country. In addition, by integrating both the installation management and various systems at the buildings, all the equipment will operate accordingly and no interference and problems will threaten the equipment and facilities.

3. BMS in Iran

Although BMS technology has been entered Iran about two decades ago, it has not still been popular. The reason for unpopularity of BMS in Iran may be discussed considering four aspects of geographical, technical, economical, and cultural prospectives.

Based on an appropriate geographical conditions in Iran on one hand and the huge potential of energy on the other, the topics of energy optimization, enerrgy management, and using renewable energy sources have not seriously pursued in the past decades. Relying on oil and gas as the major sources of energy in Iran is a main reason for consuming energy among the people. Furthermore, the Iranian position in the first ranking of using non-renewable energy sources is another reason that shows the lower value of energy in the country.

From the technical aspect, we can address to problems such as lack of observing civil standards at the buildings in the past decades, lack of implementing BMS in the major projects of the country, and so on. Fortunately, observing the national rules and regulations as well as supervising the projects by "the Organization for Engineering Order of Building" in recent years have been a commencement for executing BMS in the country.

From the economical view, the execution of BMS in the buildings will have a high primitive cost, but these kind of costs will be compensated in the early years after impelementing the system and therefore, BMS will have an economical justification in the near future only after implementation.

Analyzing the statistics relating to the cultural prospective reveals that the energy consumption in recent years specifically after the execution of Targetted Subsidy Plan has been declined considerably and undoubtedly, all the power customers are trying to save energy as much as possible. Figure 1 shows the energy consumption

by the customers during the period of 1385-1389 (Iranian calendar) that is an equivalent for the interval of 2006-2010 [3].

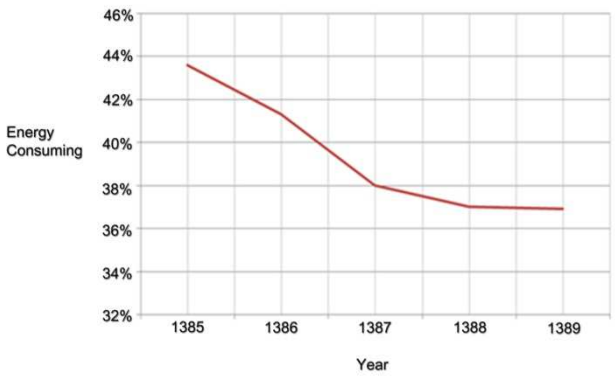

Figure 1: Energy consumption by the household, commercial, and public customers (as a percent of total energy consumption)

Analyzing the energy annual report especially the consumption in building sector including household, commercial, and public customers reveal that the high share of energy consumption relates to the building and therefore, cultural activities will have a key role in optimizing energy consumption.

4. Research Problem

As stated at the beginning of the article, the essence of human community to energy on one hand and the shortage of non-renewable energy sources on the other have highlighted the importance of utilizing Building Management System (BMS) Therefore, the big residential complexes will require the BMS due to their high share of energy consumption.

Although BMS covers various aspects in the buildings, there's no need to implement all its features and only the specification relating to energy saving has been discussed by the authors in this paper. As an example, managing subsystems like lighting in a building, may lead to both safety level and welfare as well as the continuation of an energy saving trend.

Statistical data reveal that lighting, heating, air conditioning, and cooling/chilling systems have the most energy consumption rate at the buildings. Henece, a huge part of the energy consumption at the buildings can be managed by automating the important divisions of a building [5].

5. Automating the household and commercial complexes by industrial PLCs

Executing the Targetted Subsidy Plan in recent years have persuaded the majority of employers of the residential and commercial complexes to implement the automation system partly or completely. In small buildings, it's possible to use small controllers like ARM, AVR, etc.; but in the complexes, only strong controllers such as

PLCs must be utilized due to the essence of observing some factors like using various sensors, the distsnce between sensors and the controller, and also the necessity of having an efficient processor.

Nowadays, the PLC manufacturers have designed and manufactured special controllers for building automation, but it's possible to implement the automation of complexes by use of industrial PLCs. Therefore, Iranian experts have established automation for residential building due to their experience on industrail PLCs and communicative protocols without utilizing household networks and special controllers for household automation.

The stages for executing the project and also its advantages and disadvantages have been discussed and analyzed in the following sections.

6. History of industrial PLCs

PLC is short for Programmable Logic Controller and its history is related to the late 1960s that PLC was used in automation for the first time. From 1960 up to now, PLC has experienced many changes and modifications. It should be noted that PLC for the experts of automation accompanies the name of companies like Siemense, Allen Bradley, AEG, Modicon, etc.

The control systems which have been used before PLCs were the hardware systems and each alteration in the process control was done by change in wiring and relay circuits [6]. After recognizing the PLC capabilities and removing the relay circuits, PLCs evoluted increasingly and the stndardization of both communicative protocols in 1980s and programming language in 1990s by IEEE or other PLC manufacturers were presented. In addition, the Standard IEC 1131 was also presented after about 12 years following various discussions and analysis so that it covered different aspects of industrial PLC including design, hardware, installaton, test, and communication [7]. In general, industrial PLC have been composed of three parts named CPU, input modules, and output modules. The input modules receive signals' data from Field Level and send it to CPU after converting it to the digital signal. CPU applies the required signals to the system for process control based upon the defined instructions and mainly via the output modules. A sample of industrial PLC has been shown in Figure 2.

Figure 2: A sample of an industrial PLC

Attention must be paid that PLCs have not been designed only for utilizing by factories and complicated processes but it may be used in special cases like automation of building systems, transportation, and so on. Industrial PLCs are one of the important components of automation systems that play an inevitable role in automation of various industrial equipment and facilities.

In projects like automation of giant complexes, the network can be configured as DCS, i.e, Distributed Control System. In other words, some PLCs will be required for high capacity of data and/or ET (Electronic Terminal) must be used because of preventing both high volume of wiring and appropriate sending of signals. Sensors' data are sent to ET and then ET sends all the data to PLC via the network. Thus, using industrial PLC does not suffice in these projects and all automation equipment such as ET, Transceiver, Repeater, Special Modules, Drivers, Various Types of Grid Cards, etc. are being used as well.

7. Determining the automation Level

Defining BMS by building employers and/or consultants have been presented differently. In fact, the different aspects of BMS is a main reason for different viewpoints relating to BMS. Figure 3 shows the various systems of BMS [8].

System	Usually integrated into building automation	Increasingly integrated into building automation	Systems that are controlled by DDCs or other building automation components
Heating	×		×
Cooling	×		×
Ventilation	×		×
Power supply	×		
Lighting control	×		×
Blinds	×		×
Sanitation	×		
Central fire alarm	×		
Burglar alarm		×	
Access control		×	
Video surveillance (CCTV)		×	
Network engineering		×	
Multimedia		×	
Elevators		×	
Telephones		×	
Maintenance management		×	
Payroll/accounting		×	
Facility management		×	

Figure 3: Various systems of BMS

The importance of execution of household automation system does not merely depend on application level of BMS, because it's possible to implement various levels of BMS based on the expectaions and costs offered by the employers. However, implementation level of various Building Management Systems will cause energy saving and attain security and welfare for the residents. The consultats and contractors who are involved in installing BMS must notice the future expansions in time of designinig and they also have to consider all the aspects of project for implementing and operating standard BMS.

7.1 Integrating systems

Nowadays the small controllers are used for optimizing energy consumption in many buildings which are equipped with central heating system. These controllers are effective, but we suggest installing automation system in old residential complexes in order to integrate the automation system considering the characteristics of managerial structure in control systems. It will enable us to both control and monitor the whole set of system and execute control orders in managerial level.

Local systems of lighting used in complexes is an example of integration system. Integration aims to supervise the local sensors and controllers via managerial level of BMS so that each sensor/controller has an individual address in PLC. As an example, for calculating the rate of energy in lighting system, precise control on each part of lighting system using the sensors that provide security are of benefits of system integration.

8. Stages of executing project

Like automation of industrial processes, the execution of household automation has three fundamental stages addressed in the following parts.

8.1 Determining automation level and data gathering

The first and the most important step in each industrial process is data gathering because it facilitates the execution of automation. Determining the automation area that is carried out by the complex employer indicates many frameworks and information, because the automation area specifies the number and type of sensors, distance of sensors from each other and from PLC, distance of PLCs from each other, communicative networks, etc. As a matter of fact, the project configuration is commenced in this stage and all the precasts and cost estimations will be performed in this stage as well.

8.2 Selecting hardware

In this stage, the processing abilities of each PLC, sensors, and commmunicative networks may be determined due to work experiences and technical calculations. In fact, the work experience and full cognition of devices used for automation is the necessity of selecting an adequate hardware. One of the important issues in this stage, is future expansion of the project.

8.3 Programming

After data gathering and selecting the suitable hardware, programming for PLC software is the third stage of the project. Actually, programming of automation system is the instructions related to controlling process parameters. Being familiar with processes under control, software of PLC programming, communicatve networks, and recognizing different sensors are of important cases in the above mentioned prohect [9]. In addition, programming of a project can be carried out during its implementation and also the installation of automation devices. After implementing the automation system, the program will be tested to be found any probable defects and all aspects of the project must be controlled as well.

9. Protocols of industrial networks

One of the topics in automation process is the relation between the components of automation system. Communication and data exchanging among the sensors and PLC, and also the relation between the different levels of the system are of the cases that can be established efficiently and throughly. Furthermore, before selecting the communicative protocols, one must be familiar with the pyramid of industrial automation systems as shown in Figure 4 [10].

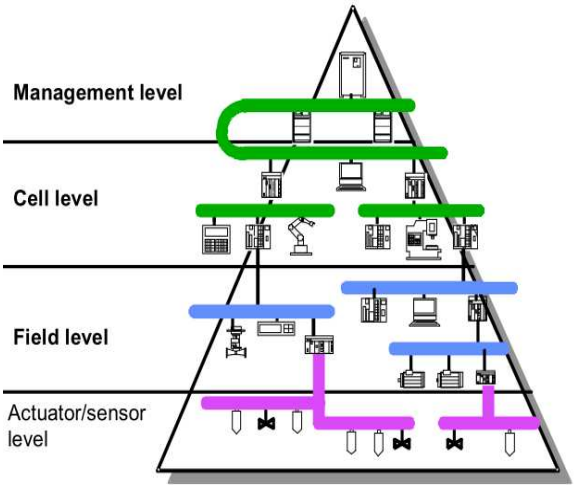

Figure 4: A pyramid of industrial automation systems

Various definitions have been presented for pyramid of automation, but the overall cases can be categorized in four levels. The lowest level is called Actuator/Sensor Level and it's an area for sensors and actuators. The second level is Field Level that is only for records, remote I/O equipment, and so on (It should be noted that in some definitions, the Actuator/Sensor Level and Field Level are merged as one level). Another level is Cell/Control Level that PLC controllers or DCS and monitoring systems are positioned in it. The upper level is Managerial Level that contains a huge capacity of information and in this level, the transmission speed of information is less important than other levels, meanwhile all system information is controlled by manager (s).

By analyzing the above mentioned pyramid, one can conclude that the information capacity and the required speed for data displacement in each level of the pyramid is different from each other and it has been caused to have communicative networks with unique characteristics.

9.1 Selecting an optimal communicative network

There are some factors that are effective in selecting network protocol. These factor are as follows:

- operational and adequate ability of the network,
- considering the delay average of data transmission,
- network efficiency in special environments,
- future expansion, and
- the networks which will be added to the system.

The networks such as Profibus, Modbus, CAN, Interbus, and Industrial Ethernet are the most important and applicable protocols of industry. Each of these protocols are used in special range of automation pyramid, but we do not intend to describe them in this article. In general, selecting protocols is depending on various factors and for this selection, we need to have experience and future vision as well as carrying out some technical calculations [11]. A comparison of current networks in industry has been depicted in Figure 5.

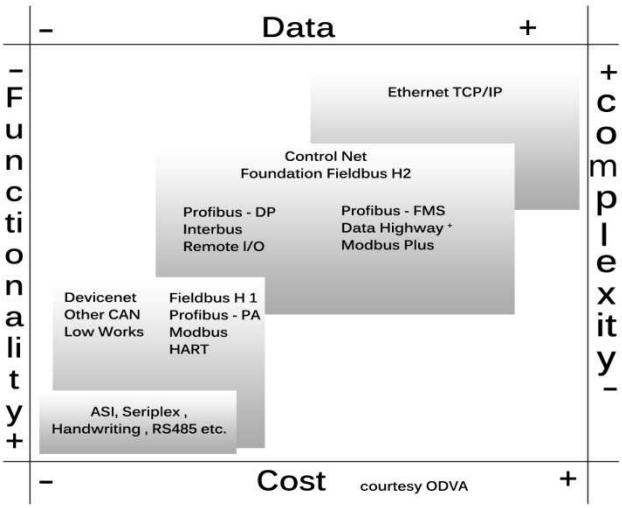

Figure 5: A comparison of current networks in industry

Protocols named Lon Works, KNX, and BAC net are examples of current protocols in household networks. Protocols of Profibus and Modbus have been designed by PLCs for automation, but nowadays they are used in BMS and are considered as household automation protocols. Figure 6 is a sample of standard network in building automation [8].

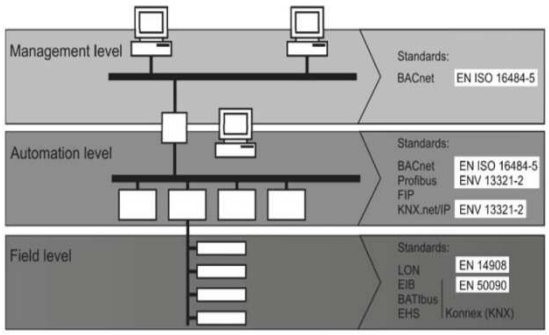

Figure 6: A sample of standard network in building automation

In selecting the network protocol, the hardware (communicative module of network for PLC) must be provided and transmission lines for data (physical layer) have to be chosen as well. As an example, based on protocols of each pyramid level, we can select physical layers of data transmission such as parallel multi-strand cable or fiber optics or even communicative standard of RS 485, HART, etc.

Among the above mentioned protocols, standards of BAC Net and KNX have high capabilities, various characteristics, and integration ability among the different manufacturers and can be categorized in a high position of usage.

It should be mentioned that we can add interface modules in PLCs to have communications with other protocols [12]. Figure 7 shows a combination of KNX network and the equipment for industrial automation.

Other than the above protocols, it's possible to use wireless technologies such as Z-Wave, Zigbee, and Bluetooth for automation of small buildings. Wireless technologies in small buildings have higher efficiency, but in this project, we don't recommend it due to the space width and security reasons.

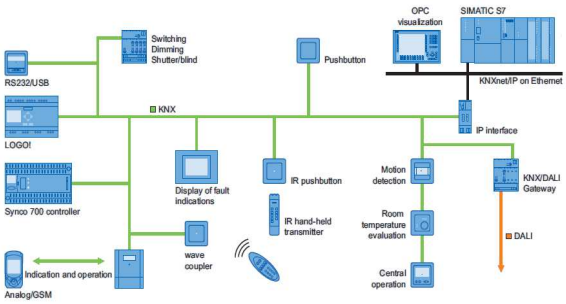

Figure 7: A combination of KNX network and the equipment for industrial automation

10. Monitoring

In this project, monitoring of under-control systems (lighting, heating, security, etc.) are located at the upper level of automation pyramid and can be considered as one of the most important stages of the project. Monitoring systems or HMI (Human Machine Interface) that are interfaces between human and machines are able to present the under-control process as graphic characteristic together with various facilities.

Monitoring of cases such as instantaneous position and stability of system parameters, location of defects, processes as graphical characteristics, and the possibility of changing in system set points can be attained by monitoring the automation system in complexes [13]. In this project, it's possible to use big touch panels in one or more points of the commercial complexs. Also, there's a possibility of using small touch panels at the desired points for local control of different points of the complex. Therefore, each residential unit can be controlled via both the touch panel installed in the unit and the central touch panel installed in control room.

An important point in applying touch panels is that the usage of monitoring screens is dependant on CPU power and type of communicative network protocol in different levels of the pyramid and it's difernt for each system [14].

Nowadsy, due to the increase in prices of energy transitions and also public awareness in the field of energy saving as well as the execution of Targetted Subsidy Plan; most of building which use central heating system, utilize small controllers (as DDC) for controlling optimal consumption of energy. Therefore, it's recommended to use an integrated automation system in old residential complexes to both control the monitoring of total system and control the system in managerial level.

11. Analyzing a sample project

In this section, BMS project for the Export Terminal of Plant and Flower in Mazandaran has been analyzed. This terminal has been erected in a four-floor complex located in an area of 120,000 m^2 in Mazandaran Province.

In the BMS project of the aforesaid terminal, central heating and cooling system, air conditioning, lighting, panel boards, elevators, emergency generators, four central engine rooms, and totally 1200 fan coils are being controlled by industrial PLCs.

According to the existing climate condition of the region, three factors of humidity, temperature, and CO2 are measured in all parts of the terminal. In addition, water pumping motors are controlled via special drivers and also power of motors can be regulated based upon the information of pressure sensor located on water pipes, meanwhile the starting current is reduced as well.

In this project, three PLCs of series S7 by Siemense company have been utilized and all the PLCs have been selected from type of S7-300 (315-2DP). Also protocols of Profibus, Modbus, and MPI have been used in Field Level and Control Level and Industrial Ethernet Network have been utilized in Management Level.

Based on the big area of terminal and the distance among the sensors and PLCs, some Rack Rooms have been installed in each floor and ET (Electronic Terminal) has been positioned in them. Using a Siemense made module of ET/200M, firstly all I/O in each floor are connected to ET. Then ET sends the sensor data via the network to PLCs. Due to the distance in Field and Control Level, Repeater has been used for Profibus network and part of the network has been executed using fiber optics. In fact, DCS has been implemented in this project. On the other hand, administrative systems including bank, exchange, university, and restaurant have been controlled by a PLC, and other sections including north and south departments have been controlled via two PLCs. In addition, some sensors for measuring pressure, gas, temperature, humidity, CO2, and lighting have been utilized and totally 2500 digital signals and 900 analogue signals can be found in the project.

Ethernet network has been connected to the World Wide Web via CP (Communication Processor) and it's possible to control all parameters of BMS in the terminal from each point of the world using Simatic Manager Software by having program source and its password [15].

12. Analyzing the advantages and disadvantages of the project

In this section, the advantages and disadvantages of using PLCs for implementing BMS as well as the total application of these systems have been stated.

12.1 Advantages

The most important advantages of the project are as follows:

- High safety coefficient of the system and high resistance of PLC in encountering noises and environment disturbances due to the special and modern design of PLCs,
- High security of information for under-control processes,
- Finding system defects in the least time via PLC software,
- Using the various facilities of PLC internal processor such as timers, counters, mathematical blocks, etc.,
- Increasing the input and output signals using developed modules and other ancillary devices,

- Capability of communication with different household and commercial networks in some PLCs using interface modules,
- Using PID controllers and also having the ability of controlling the special processes of some parts of the complex using fuzzy logic and neural networks [16],
- Using powerful PLCs and implementing Redundant systems for high safety of the system and execution of automation in sensitive complexes, and
- Connecting system to Internet via industrial networks and controlling system from each point of the world.

12.2 Disadvantages

Although the disadvantages of the project comparing its advantages are negligible, following disadvantages can be listed for the project:

- High costs of industrial PLCs and implementing industrial networks,
- Supplying some devices of the project is complicated due to using modern and industrial automation devices,
- In case of lack of changing form automatic state to manual state, any defects in automatic state will lead to losses for the system, and
- The essence of skilled manpower for hardware and software support.

Discussion and conclusion

The energy consumption rate in residential complexes with a big area of land is depended to various factors, but it's possible to obtain an estimation of energy consumption of each division. For instance, Figure 8 shows an estimation of energy consumption costs in a commercial building [17].

Statistics have revealed that there's no any need to execute BMS in all levels. In other words, we do not require a BMS to cover all the systems ideally. Power curtains, multi-media control systems, modern visible controls, telephone communication control, etc. are the important parameters of BMS, but high costs and inappropriate image of employers in execution of BMS is an obstacle in implementing such projects. Figure 8 shows that lighting, air conditioning, colling and heating systems in the complexes have been considered a great deal of energy costs (about 80 percent) and it's possible to reduce the energy consumption by using standard systems and managing these systems by BMS. In addition, it may be possible to have a complete managerial system in the future by installing further BMS phases due to the ability of being modular and flexibility of industrial PLCs.

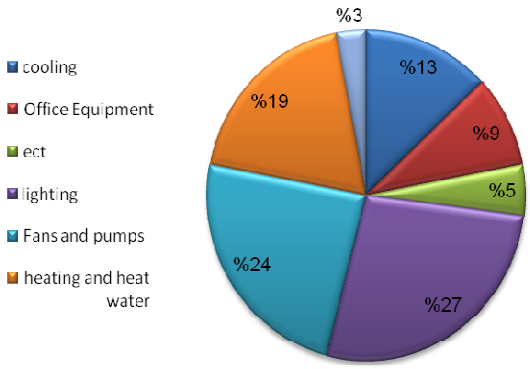

Figure 8: Estimation of energy costs in a commercial building

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