Intelligent building systems

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The paper characterizes some selected aspects of intelligent building technology. Various functions are described that enable optimal controlling of the devices operating in accordance with previously programmed instructions and with current information. Such control is aimed at ensuring economic functioning of the building by reasonable and sound management of its resources (chiefly the energy) and to guarantee safety and comfort of the inhabitants. Examples of realization of these functions are presented, together with the computation – visualization software. The DomoSim visualization – designing software is characterized, that is intended for control and automation purposes. Applications of the discussed systems in Energy-Saving Intelligent Houses (ESH) have been presented.

1. Introduction

An intelligent building is provided with an integrated and compact management system (*BMS – Building Management System*) and a set of fittings and devices, sensors and detectors ensuring the control process. Each of the elements is coupled with the others, and transmits the information of its current state or operation with the help of proper sensors and detectors. These elements reply to the obtained data in previously programmed manner [14].

Such solutions are known and implemented from 40 years, both in private and office objects, in new and adapted buildings [2, 7, 15].

Objectives of intelligent building management are:

- reduction of operational cost, with special attention paid to energy saving;
- ensuring safety of the inhabitants and the building;
- improvement of the comfort of building usage.

This goal is achieved with the help of several various functions. Management may be proper and effective thanks to the use of modern technologies and equipping the building with various sensors, detectors, control and automation elements [7, 14].

Management is accomplished by:

- the information collected by the system (the check, monitoring);
- appropriate analysis of the operation;
- proper decisions.

2. Realisation of basic functions of building management

Basic functions belonging to the building management system are shown in Figure 1 [1, 10, 14].

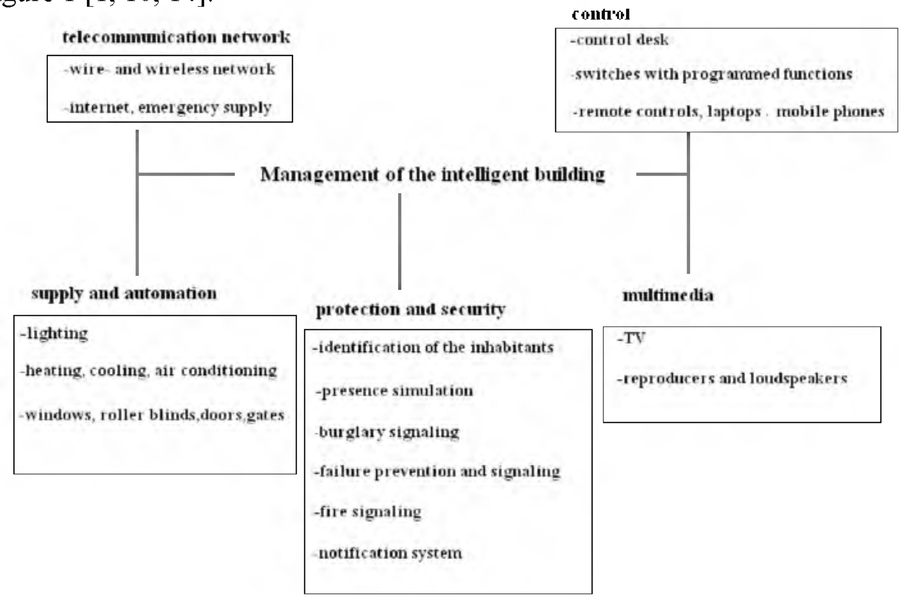

Fig. 1. Basic functions of intelligent building management

Equipment of the building in automation systems enables optimal controlling of operation of power receivers, according to previously programmed instructions and current information related to temperature, insolation, presence of inhabitants. Hence, the control enables reasonable and economical use of available power resources, and security [8].

The function realizing the supply and automation (Figure 1) when properly programmed, ensures complex control of lighting of the whole building, based, for example, on measured light intensity [8]. The lighting may also operate in replay to motion sensors, e.g. from the MCR group. In this situation it is constrained to a given room. Such a solution may be used in staircases. Microwave motion sensor based on emission of high frequency and low power radio wave may operate through glass or wood. It is a safe, reliable, and power saving device. Once it is provided with a twilight sensor and potentiometer it allows for automatic switching the lighting on in programmed conditions. At the same time, it prevents switching the light on by daytime. The lighting may be controlled with the help of the Exta control system [18].

Proper management of natural daylight may be achieved by controlling of the shutters.

Figure 2 illustrates possible lighting control on the example of the DomoSim program (chapter 4). This goal may be attained with the help of dimmers that adjust the lighting intensity to the required level [18].

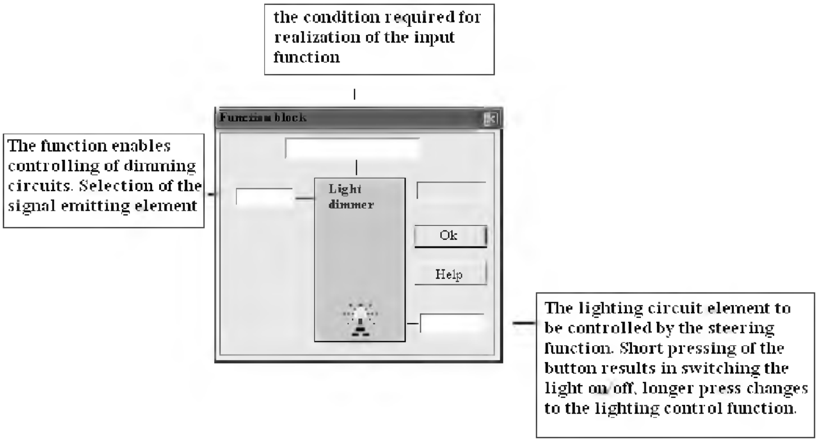

Fig. 2. The function changing the lighting intensity on the example of the DomoSim program

The information on current air condition (humidity, carbon dioxide) also allows to control the ventilation, air conditioning, and filtration.

The functions pertaining to the supply and automation also realize heat management. For most of the solutions full control of heating and cooling is possible. Operation of this function should be individually adjusted for each room. It may be performed based on the heating curve. The devices automatically switch on or off according to the signals related for example to temperature [15]. In winter ventilation may be considered as an additional heating system, since the heat exchanger it is provided with, recuperate the power used for heating the air flowing inside [17].

The shutter control system may operate both based on time signals or using the information coming, for example, from twilight or temperature sensors. The windows provided with controlled shutters prevent overheating of the room in summer.

In such condition the building interior is protected with outer shutters in the windows, on southern and western walls, that are automatically or manually controlled [23]. Appropriate shutters control also prevents cooling in nights.

Figure 3 shows the function of heating control [12, 22]. The planned ventilation is also provided thanks to central power management.

The system that is additionally provided with weather sensors/weather stations may decide of closing the windows.

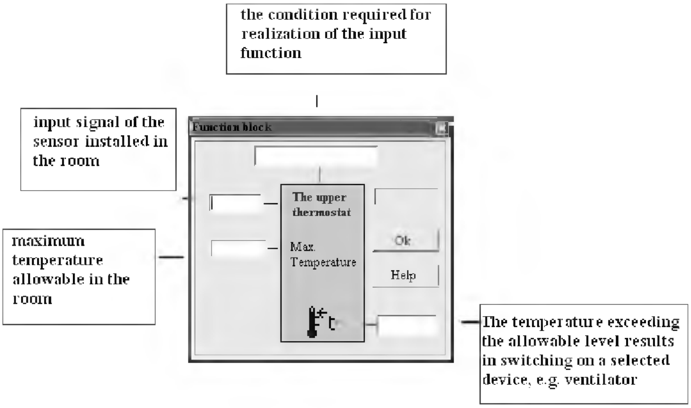

Fig. 3. The heating control function on the example of the DomoSim program

In this group of functions the switches controlling the doors and gates are programmed.

The duty of securing safety and protection (Fig. 1) seems particularly important. It includes the fire protection system that, in reply to the signals obtained (smoke, dangerous temperature growth), undertakes the action even when inhabitants are absent. It notifies proper service and inhabitants, switches off power supply, starts the air extractors, closes the fire walls and seals.

Figure 4 shows examples of the functions carrying the fire protection into effect.

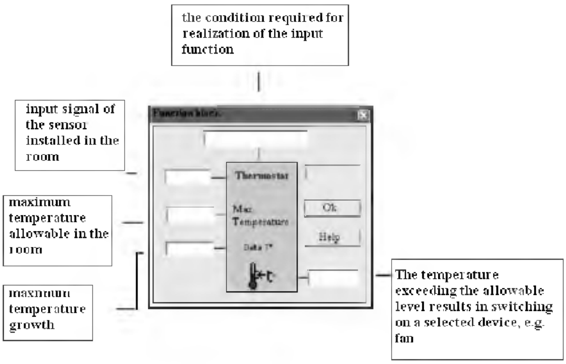

Fig. 4. The fire protection function in DomoSim software.

The BMS System is also provided with burglary protection. Thanks to monitoring and infrared protection barriers it signalizes any untypical events and sends appropriate information. A specific burglary protection is provided by simulation of building inhabitants presence. The duties belonging to this group include also identification of the persons and vehicles [5, 14].

Another type of preventive mean includes breakdown protection, among others by automatic switching off the devices that are unnecessary when inhabitants are absent.

Further group of the functions (Fig. 1) consists in multimedia and loudspeakers control. It plays lower role and allows using the TV signal in any room. Sounding control with the use of remote controls or laptops enables receiving music programs in a selected room, provided that a CD reproducer with disk changer is available and loudspeakers are assembled in the walls. This function belongs to the group that gives comfort to the inhabitants.

Universal wiring or wireless communication allows using a computer, stationary phone, and internet in any room.

An intelligent building should be provided with emergency supply. It is of particular importance considering the need of supplying the alert system.

The control function, Fig. 1, includes the control desk that is the system centre. It allows to observe operation of integrated equipment and current changes. This is also facilitated by specifically programmed switches and remote controls. The bistable switches [18] may be of remarkable importance in this case. They enable independent controlling of any device from many locations. The control may be performed by means of a laptop or mobile phone.

3. Review of common programs serving the building management

The computer market includes many computation – visualization programs that may be used for analysis of power flow in the building. They enable determining the power demand and its possible generation [8, 19].

The software that allows to determine the power demand, the rate of air flow or the temperature distribution is called DesignBuilder [11]. It is characterized by easy modeling of a real building and possible dynamical analysis of the power flow in it [4]. In order to compute the power characteristics of a building the DesignBuilder software uses the EnergyPlus (a modern simulation tool). It may provide, for example, visualization of temperature distribution. Such a visualization analysis may, for example, suggest extraction of the warm air from the upper storey down [using proper fans] in order to stratify temperature in the building [11].

The program Audytor OZC 3D assists the design computation of thermal load of the rooms. It is helpful in determining the heat demand and drawing up the Energetic Certificates [11]. The building model data required for these purposes may be imported from the Autodesk Revit Architecture 2012 software.

The TRNSYS program is used for dynamical simulation of the building, mostly what concerns heating, air conditioning, and ventilation [11].

In the domain of energetic simulation the idea of BIM becomes more important, together with the applications ArchiCAD, Bentley Systems, RevitAutodesk [22]. The most important quality of BIM consists in possible definition of a virtual model that includes full information on the building in an integrated form, that may be updated according to current needs. The program performs 3D modeling and enables automatic evaluation of the costs of particular solutions.

The system BAS of building automation allows to integrate the technical fittings with a view to optimize the power expense [19] with the use of the IT technology. Integration of intelligent systems of the buildings is conducive to reasonable and economic use of the energy [22]. As an example of such an approach the additional daylight lighting of the rooms or the lighting systems operating in the follow-up mode (following the motion of persons) [19].

The DomoSim visualization-designing software is usually used for intelligent systems in which the meaning of control and automation is of particular importance.

Among popular solutions of Home Building Electronic a system of building automation KONNEX/KNX is reckoned (formerly EIB European Installation Bus, developed in 1990). It joins all the building management functions and, first of all, its lighting, heating, ventilation and air conditioning, operation of awnings and shutters, signalization, regulation and supervision of electric equipment and audio devices of the building. Its important feature consists in possible communication with other systems by means of existing electric network, radio waves, Ethernet and its own bus – Instabus. This includes such external systems as Honeywell, SAUTER, Johnson Controls, Bechhoff, WAGO.

Particular realization of the EIB system may be based on the LonWorks bus (T.A.C., ERCO) [26].

KNX is a decentralized solution – its every element is provided with own intelligent control, nevertheless not precluding a complex control [6]. The KNX/EIB system may be used in individual houses, office buildings, or even for external lighting control. The last option is used in Salzburg, where, based on the information transmitted from proper sensor, it controls 19 thousand street lamps and 200 reflectors. The installation itself is relatively inexpensive, simple, and reliable, ensuring reduction of the lighting cost by 2.5 percent.

Programming may be effected on two ways. The Easy mode is used in more simple installations, where particular modules are configured with the use of proper buttons and knobs. More advanced System mode must be complemented by a computer with appropriate software.

In the paper [13] the examples of technologies of intelligent measurements within a building automation system KNX are presented, with a view to reduction of the building maintenance cost.

On the other hand, the LCN system (Local Control Network) is based on standard electric wiring. In this case the system may be also directly controlled, that enables reduction of energy consumption and, in consequence, reduction of the cost.

The system is distinguished by the lack of additional bus cable and by modular structure, that allows for relatively easy development of the system and low assembling cost. The system may connect up to maximum 30 thousand modules. The modules are elements of the LCN bus. Each of them is provided with a microprocessor that guarantees its independent communication, operation and response. They are provided with separate feeders which ensure autonomous operation, not precluding, at the same time, their cooperation with the bus. The system is widely used in intelligent building industry, in smaller dwelling houses, commercial, sports, and office buildings.

Among the example realizations of the above mentioned system the following should be noticed: Main Tower in Frankfurt (the control of 2550 roller blinds and 5000 lamps, heating, ventilation, air conditioning, and fire protection). The system is popular in Poland too. It is used in a hospital in Częstochowa and in a hotel in Karpacz.

Xcomfort is a wireless system for controlling the heating, lighting, roller blinds, and the devices connected to electric sockets. It is used mainly in housing industry (for example in Tricity, Poland). It may be controlled by means of a pilot, console or switch [9].

Lutram is a system designed in principle to lighting control. It may cooperate with an alarm system, audio system, or air conditioning control. It is simple and reliable.

Teletask controls power management of a building, including its lighting, operation of shutters and roller blinds, heating and air conditioning. Additionally, a multimedia systems or touchscreens may be used with it. Particular elements of the system cooperate by means of fast cable bus –Autobus. The system is based on the Prosoft software package.

Fibaro is a wireless system designed for lighting, shutters, and heating control, i.e. for energetic management of a building. Estimated electric energy saving amounts up to 30 percent, in case of thermal energy the gained saving may reach up to 23 percent.

Luxor from Theben Company is a system of simple configuration, easy for installation, requiring no computer programming. It is designed for lighting control, including lighting dimming and time-scheduled switching on and off. It is provided with clock module, weather station, and illumination sensor, thus facilitating control of the shutters or external lighting.

The wireless Hometronic system from Honeywell is composed of a central unit, sensors, and actuators. The central unit allows for creating time-scheduled programs, simulation of presence, and control of up to 32 receivers.

4. Control system characterisctics on the example characteristics of DomoSim software

The program is provided with graphical functions that enable preparing the building plan [5]. Simulation of its operation becomes possible already at the designing stage. The functions of the DomoSim program includes the control of:

- the lighting (light dimming, creation of advanced light scenes);
- garage and entry gates;
- heating, individually for each of the rooms and their users, according to time schedules;
- watering of lawns and gardens;
- pumps, electric catches e.g. of the doors, electrovalves (water, gas).

The program includes 512 combinations (24 of them of priority meaning [22]).

Figure 5 presents a plan of fittings of an intelligent individual house, inclusive of locations of the PIR-type sensors, control box, manipulator, and signaling device. For purposes of lighting control 7 motion sensors of PIR type and a twilight sensor are used. Alternatively, the lighting may be controlled with the use of a time schedule switch.

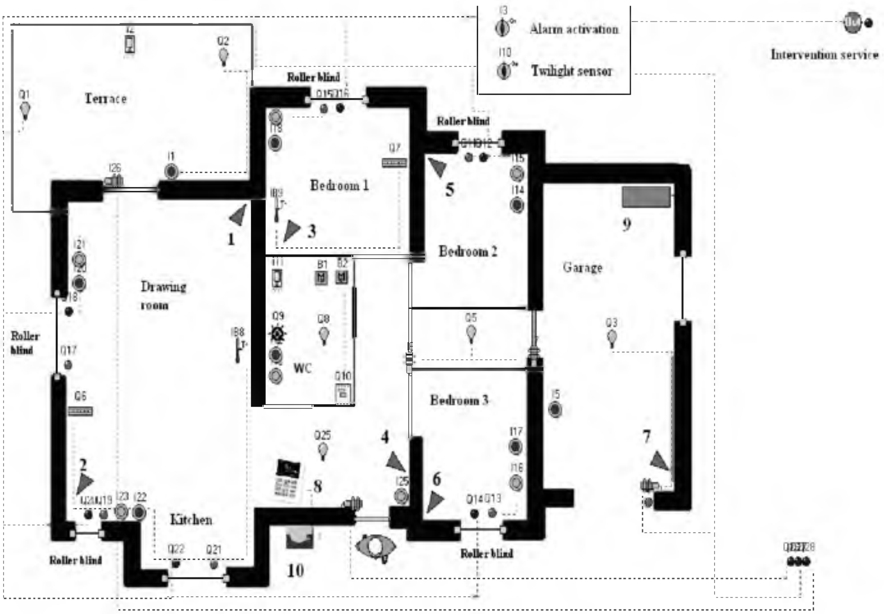

Fig. 5. Plan of arrangement of intelligent fittings of an individual house. Denotations: PIR sensors (1)-(7),manipulator (8),control box (9), signaling device (10)

In the bathroom a motion sensor switches the lighting on or off, according to presence signaling. It controls ventilation with the use of virtual elements and memory bits. For purposes of controlling the lighting of windowless rooms the reed relays of cross connection are used. Thermal management of the building is controlled similarly. Temperature is adjusted by means of sensors (with module output to electrovalves of the heaters) or according to time-schedule (Fig. 6), taking into account such factors as the outer temperature, presence of the inhabitants, night- or day-time.

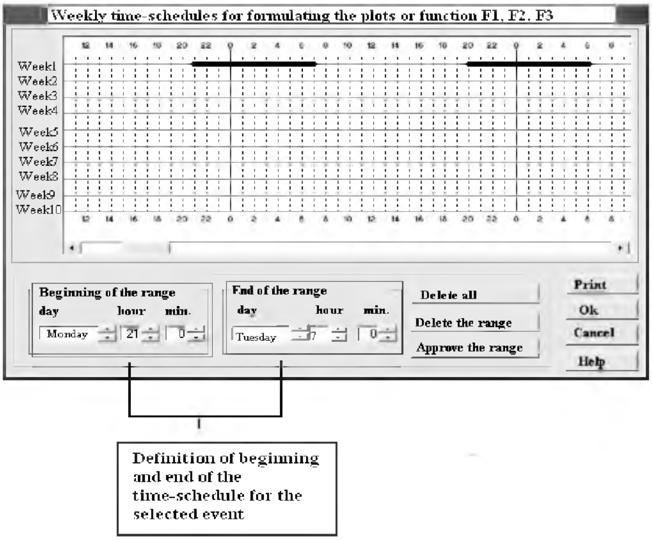

Fig. 6. Example of a time-schedule

5. Energy saving aspect of an intelligent building

The share of building industry in total energy consumption in the European countries amounts at present to 40-50. It results not only from heat loss but, first of all, from the power consumed for purposes of ventilation, cooling, and lighting of usable premises. The requirements imposed by European Union aim at reducing the energy loss. This is a goal of the EPBD Directive (Energy Performance of Buildings Directive) of 2002, with its novelization – so-called RECAST, adopted by the European Parliament on May 18, 2010. It determines energetic standards for building structures [4]. The objective consists in developing conception of a building of zero energetic balance. On one hand, the building should be distinguished by extremely low energy demand and, on the other, it should gain significant part of the required energy from renewable sources or in the recuperation processes [4].

It is estimated that an energy-saving active building provided with optimal control of its receivers (i.e. intelligent building) uses by 40 percent less energy than a standard building [4]. Such a solution requires consideration of various aspects of the matter, application of various technologies, and the use of simulation programs and the software of complex control of the building energetic management for energetic assessment of the buildings. This concerns both the newly designed buildings and the modernized ones [4,28].

Figure 7 specifies energy production and consumption in standard and intelligent building.

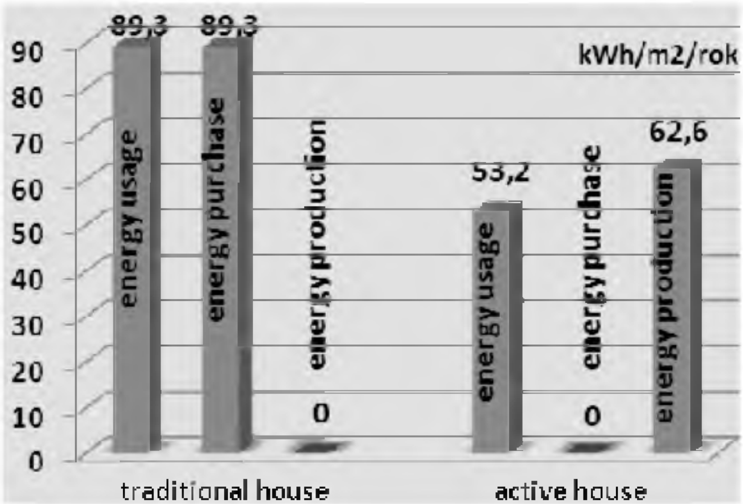

Fig. 7. Comparison of energy production and consumption in standard and energy-saving house, own elaboration based on [28]

Some interesting solutions of energy-saving intelligent buildings are presented [4].

Research Centre of the Polish Academy of Sciences in Jabłonna

Construction of the Research Centre of the Polish Academy of Sciences in Jabłonna is planned to be initiated in 2013. It will include a model Energy-Saving Intelligent House (ESH) designed as a hotel with seminary rooms. It will be distinguished by high standard and will be provided with a set of interconnected devices with intelligent control, that should ensure its energetic self-sufficiency from renewable energy sources. It will be a unique construction in the whole country.

The intelligent building in Jabłonna will be provided with such elements of energy-saving system as: steam electric power microstation supplied by a boiler fueled with bio-mass and waste material, photovoltaic cells with a collector, wind power plant, energy storage with a basin, and an intelligent module for controlling the electric energy and heat. In order to obtain possibly the best use of solar energy the hotel will be properly situated. The roof photovoltaic system is aimed to south (γ = +25,57° to -41,93°, β = 30°). A facade installation will be assembled too. A sketch of the energy-saving intelligent house is shown in Figure 8.

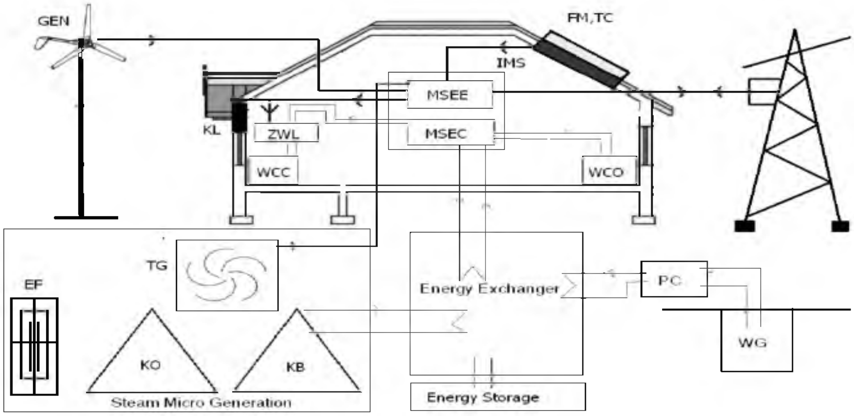

Fig. 8. A sketch of the Energy-Saving Intelligent House with the equipment ensuring its energetic self-sufficiency. The hotel – seminar building and, at the same time, the largest building in the Laboratory Complex of the Centre, own elaboration based on [9].
Notation: EF – electrofilters; TG – turbogenerator; KB – bio-mass boiler; KO – waste material boiler; PC – heat pump; WG – ground-coupled heat exchanger cooperating with the heat pump; FM+TC – photovoltaic cell cooperating with a thermal collector; GEN – wind power plant; ZWL – chiller (chilled water); KL – air conditioner; WCO, WCC – heat exchangers for heating/cooling the rooms; IMS – intelligent energy control module; MSEE– electric energy control sub-module; MSEC – thermal energy control sub-module

Ark Hotel

Conception of the Ark Hotel is a project originated from the International Union of Architects, within the framework of the program Architecture for Disaster Relief [21,26]. Besides characteristic construction of the hotel that ensures its security even in case of natural calamity, it is designed in accordance with bio-climatic requirements and with the use of renewable energy sources, taking into account its energy-saving features. The light may penetrate through the walls and transparent roof. The hotel is provided with an integrated energetic system. Its dome is conducive to generating an air vortex that may drive a tornado-type wind turbine. The roof surface is optimally inclined towards Sun and provided with photovoltaic panels. In the upper part of the dome the warm air is collected that may be later used. The energy is stored in electric batteries and hydrogen cells. The building makes use of the external heat (air, water, geothermal heat). Thermal collectors of special structure are used for water heating [20,25].

An office–warehouse building complex of Schüco Company, in Siestrzeń near Warsaw

The building has been designed in accordance with the Energy Program, with the use of energy-saving and energy generating building surfaces [28]. First of all, optimal location of the building has been defined already at the designing stage. At the south-west side, distinguished by higher insolation, a special Schüco FW50+façade has been used, including Schüco ProSol photovoltaic modules. They are designed, among others, to generating the electric energy supplying the mechanical ventilation and cooling system. In order to protect the rooms located at this side of the building from overheating the external shutters are placed there. Water is heated by Schüco Premium collectors located at the roof of the warehouse bay. The facade of north-west part of the building is covered with two-layers coating of better thermal parameters. Central energy management includes proper control of the windows (ventilation) [27].

PKO BP Building

Floor area of the building equal to 9000m^2. The building is provided with the most complex EIB system in Poland. It includes the control of lighting, heating, air conditioning, ventilation flaps, lifts as well as monitoring of fire protection, building supply, UPS feeders, and ventilation control stands. The system is integrated with a visualization system and cooperates with the fire protection system. The whole equipment includes 1590 bus devices [26].

The Poznan Financial Centre

The EIB system of this building includes 1500 bus devices. Among its the most important functions the following ones should be mentioned: the control of lighting and various equipment items, central control by means of buttons and LCD panels, PC-added supply visualization [26].

Poznan Financial Center is shown in Figure 9.

Fig. 9. Financial Center as an example of intelligent building [phot. Artur Bugała]

SFS Polska

Conference rooms of SFS Polska in Poznań are provided with EIB control system, allowing for energy-saving management of the building functions: the control of lighting and screens, automation of central and individual control in every room [26].

Delta Office in Poznań

Delta conference office located on Towarowa 35 street has been equipped with a fully air-conditioned, thermally isolated room providing a panel discussion for 150 people. In each room there is a possibility of separately controlling the lighting system and the visualization. With one control panel sound system work is adjustable. [24].

Fig. 10. Delta conference office in Poznan as an example of intelligent building [phot. Artur Bugała]

Individual house in Aarhus

The energy-saving technology is more and more popular in individual houses too. The first model houses of such a type have been designed in Denmark (6 experimental active houses). They are provided with an intelligent system of inside climate control. The active house in Aarhus in Jutland Peninsula is intended to generate more energy from solar radiation than is needed for its purposes [28], according to Figure 7.

Danish architects elongated the south part of the roof provided with a set of photovoltaic panels (the surface of 50 m^2 of the roof is covered with 100 cells) and heat collectors, of total surface of 6,7 m^2. It is expected that the roof PV system should cover the whole electric energy demand of the house and a part of its heat demand. What concerns the natural light management the windows of 75m^2 surface area allow the solar light to reach in winter from the southern to northern side of the building. In summer solar radiation does not penetrate the house interior due to the elongated roof that prevents overheating. Proper insulation is ensured by three-panel windows. The window to floor area ratio equal to 40 percent in this house is the parameter which differs as compared to conventional houses, where it amounts to 20-25 percent. The windows serve for lighting, ventilation, and heating the rooms. Additional ventilation is ensured by opening casements, while the system controlling them is supplied by small PV modules [28]. Outdoor and indoor shutters stop 90 percent radiation.

6. Summary

Designing an intelligent building not necessarily leads to large expense. Nevertheless, the cost will be repaid within several or even more than ten years.

Moreover, the intelligent house ensures security and comfort of the user. The main constraint in designing modern fittings lies in imagination of the end user. Therefore, the use of the software that enables visualization of the building provided with the home automation elements becomes important.

Implementation of BIM ideas enables:

- Ensuring energy-saving features of the building (according to the 2010/31/UE Directive. One of the design criteria consists in saving the electric and thermal energy. Reasonable management of the power resources gives a definite advantage. The operational cost of an intelligent building may be reduced even by 50 percent as compared to conventional solution.

This is attained by observing economic operation leading to minimum cost, in result of permanent monitoring of energy consumption and lighting. It should be noticed that modern intelligent building industry should be distinguished not only by energetic but also ecological aspects of economy.

- ensuring optimal conditions for people by direct control of the ventilation, heating, and air conditioning systems;
- supervision of operation of the assemblies and devices in the building, with immediate response in case of damage;
- ensuring safety of the building, its inhabitants and their property;
- reduction of employment and safety cost of the operating personnel.

These requirements are met by the intelligent control systems presented in Chapter 3.

Relatively few investors remark in Poland the need of BIM idea implementation. This is in so far important as the efforts aimed at this goal should be made already at the stage of building design. Later modernization is difficult and gives no satisfactory results. Taking into account growing energy and fuel prices the investment in this range should very soon give also financial saving. The so-called outside cost born by the environment in case of conventional energetic solutions should not be ignored.

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