Energy Management in Building Objects Adapted for Users with Reduced Mobility

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Summary. Disability is one of essential problems of contemporary world. We can meet disabled people every day in the street in public transport or in shopping centers. However, we do not realize how difficult it is for such people to exist in the world today. The present article is devoted to the integration of electric systems in a modern building adapted for disabled users. In such type of objects it is particularly important to ensure the safety for occupants and property. Selected aspects of safe supply of electricity in hospitals have been discussed and electric devices functioning in course of fire have been described. Furthermore, the article contains the description of a laboratory stand for testing the energy efficient installations of KNX/EIB system to be used for devices management in nursing home rooms with hospital part.
Key words: intelligent building, installation, disability, integration, automatic control system.

INTRODUCTION

Through technological progress, important developments have also taken place in the scope of electrical installations. In recent years there has been more attention paid to rational use of energy. It is a sub-discipline of science constituting an element of essential importance for effective use of energy resources. Alongside with the improvement of building techniques and modern architecture solutions, the electrical installation is also mutating rapidly. Except of its principal purpose i.e. to provide power supply for households, an electrical installation performs the new roles: efforts to save energy, to increase the users' safety and their comfort and to improve its quality [8, 9, 10, 11, 12].

In order to cope with new requirements, there are new building management systems performing the tasks of a conventional installation and introducing many new functionalities making it possible to control individual systems in the building.

Currently, particular attention shall be paid to the optimization of energy consumption. Energy efficiency is a major challenge the contemporary building industry faces. Therefore, the requirements to be met by the building management systems are extremely high, because the awareness in the scope of energy consumption will require to make buildings more cost-efficient. The optimal energy consumption is possible in the building objects equipped with the systems supporting the energy efficiency approach.

DEFINITION OF A DISABLED PERSON

According to the definition established by the World Health Organization in the year 1980 "a disabled person is an individual with impaired functional ability or life activity that limits or prevents the fulfilment of social roles which are normal for that individual" [4]. This definition has been criticized due to insufficient description of interactions between the individual expectations and abilities as well as the conditions of the society in which he or she lives. Therefore, the aforesaid problem was discussed by European Disability Forum in European Parliament in the year 1994 and the following definition was established: "a disabled person is an individual fully enjoying his/her rights, but handicapped by environmental, economical and social barriers which he/she is unable to overcome like others. These barriers are too often increased by deprecating attitudes manifested by society".

It is impossible to create an universal electric installation suitable for everyone. There are solutions to be applied in case of a person using wheelchair and other solutions dedicated for an individual who is bed-ridden or blind. Therefore, an individual approach is required depending on specific case. The adaptation of public utility buildings is mandatory under applicable building act. Estimated number of disabled persons in Poland corresponds to about 14% of total population, including about 4% with high level of disability and about 100.000 persons using wheelchair.

There are many disability definitions, because it is rather difficult to define this term precisely. Initially, the disability was considered mainly in biological context and a disabled person was defined as an individual who "had the limitations, defects or deficiencies of physical (motor or sensory) or psychological nature" [1]. The following types of disability can be specified:

– moving with the aid of a wheelchair exclusively,
– moving with the aid of crutches, artificial limbs, walking sticks and walking frames,
– blind and visually handicapped,
– deaf and hearing-impaired,
– allergies, phobia and other.

According to the definition established by the World Health Organization "a disabled person is an individual with impaired functional ability or life activity that limits or prevents the fulfilment of social roles which are normal for that individual. Pursuant to the Act issued on 28.06.1997 three degrees of disability were introduced i.e.:

– strong – a person with impaired body ability requiring permanent or long term care and assistance from other persons due to significantly limited possibility of an independent existence,
– moderate – a person with impaired body ability, with ability to perform work on the work station properly adapted to the needs and possibilities resulting from his/her disability, requiring partial or periodical assistance from another person due to limited possibility of an independent existence,
– light – a person with impaired body ability, with ability to perform work, not requiring the assistance from another person,
– hotel guests are particularly the persons from the third and partially from the second disability group. They usually expect the hotel conditions sufficient for normal stay, frequently with family and without emphasized isolation.

In order to understand the required scope of adaptation, it is necessary to thoroughly analyze the anthropometric and ergonomic capabilities of a hotel guest moving with the aid of a wheelchair.

The consideration of visually handicapped persons should be an important element in designing phase in order to create proper floor and wall elements, passages, level differences for them and to intensify the illumination in some sectors. Due to their diseases, the disabled persons are often long term hospital patients. Therefore, energy security is an issue of vital importance to be considered.

ASPECTS OF ELECTRICITY SUPPLY SECURITY FOR HOSPITALS

The electricity is the most important medium for hospitals and other objects used by health service. Their functioning is influenced in an essential manner even in case of a short term power supply failure. Prolonged interruptions are impermissible. The electricity supply security for the hospital is increased in the form of two levels i.e. through increased reliability of power supply from electric grid and by means of emergency power supply sources. Local energy distribution company is responsible for the first level and the second task is assigned to the maintenance services in the hospital. It is unsafe to use only one transformer for hospital power supply. The technical condition of emergency power supply equipment: Diesel generator units and automatic control elements responsible for generators switching on in case of voltage decay in power supply grid is also an important element in energy security system of the hospital. The electricity demand in hospitals is increased due to the presence of large quantity of medical apparatuses and other technical devices. The emergency generator units are capable to meet only insignificant percentage of real needs in this scope. Therefore, potential overload of emergency generator unit should be taken into account. Frequent accidents are caused by poor knowledge of the users in the scope of safe operation of electric equipment and necessity to ensure uninterruptible operation of hospital facilities [4, 5, 6]. It is necessary to ensure continuous power supply as well as users and patients safety, because electric power supply is required for each electronic device.

It is impossible to ensure any absolute security but exclusively a lower or higher security level. There are the following three factors to be considered in case of analysis of electric security in health care objects:

– electric installation security level,
– security level of electric medical apparatuses,
– security level of use.

When increasing the security level, higher costs should be anticipated but not in a linear manner (Fig. 1) [12]. However, these costs are compensated for by reduced expenditures for elimination of effects of failure and effects of work interruption caused by failure.

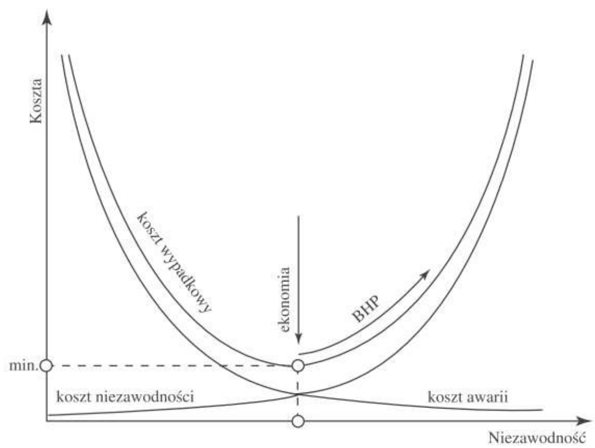

Fig. 1. Curve illustrating security costs [12]

For instance the maintenance of operating field lighting, even in case of complete electric power failure in the hospital, makes it possible to complete the operation and to ensure patient's security. The power supply from batteries is turned on automatically in case of voltage decay in power supply grid. The batteries supplying the operating light must not be used for other energy receivers.

The patients are particularly exposed to the risk of electric shock. It is often caused by their disease supporting the flow of electric current and the susceptibility to electric shock.

The following factors contribute to such condition:

– reduction of skin resistance as a result of increased body temperature and sweating,
– difficulties with perception of current flow by the patient, as a result of loss of consciousness, impact of pain killers or anaesthetics, immobilization or permanent connection with electro-medical apparatuses,
– disease load and fatigue.

The whole electric installation in health care objects should be made of copper wires in TN-S system. The steps shall be taken to ensure its compliance with applicable requirements included in the standard [13], as well as in regulation[14].

The range of products proposed by the manufacturers of building management systems encompasses the solutions which are compatible with conventional electric installations and with intelligent systems, which can be dedicated for the use in health service objects [10]. The activities are promoted which lead to the achievement of objectives in the scope of sustainable development. Their scope encompasses energy efficient management in hospitals, care homes and outpatient clinics.

The energy saving in the buildings dedicated for health service uses depends on the awareness of their users who recognize the need to use energy efficient solutions and whose activity contributes to the achievement of energy efficiency. The following actions are also important:

– application of efficient motors and drives, which are often manufactured with economic mode,
– factory assembling of electronic systems enabling more efficient motor control, particularly in case of incomplete loading,
– use of energy efficient agricultural processing equipment in the farms,
– installation of alternative sources of electric energy e.g. wind turbines, photovoltaic panels or heat pumps.

The integration of individual installations is an essential element in the designing of an energy efficient object. Designed station makes it possible to examine interactions between devices installed in a room occupied by a disabled person.

As a result of integration of all the systems existing in the building: heating, air conditioning, ventilation, recuperation, lighting, shutters, it is possible to use energy in an optimal manner and to eliminate mutually excluding functions of the systems e.g. heating and cooling.

In case of system integration in the building it is possible to achieve the real savings in the amount of up to 45% of general costs of the buildings. The devices in the station being the subject matter of the present article are integrated by means of EIB/KNX system.

ELECRICAL FIRE PROTECTION SYSTEMS

Except of electrical installations providing power supply for energy receivers, the buildings are often provided with the systems responsible for fire safety. The fire protection installation is defined as the system consisting of compatible elements jointly forming a system with determined configuration. In general, they are responsible for the detection of fire hazards as soon as possible, alerts as well as for broadcasting of evacuation signals and messages, for power supply and control of fire protection equipment [11]. Quick detection of fire source gives more time for the completion of building evacuation and for efficient protection of its occupants as well as property accumulated therein. Fire resistant conductors ensuring the functioning of detection and control installations are also used for power supply of electric equipment. In case of electric equipment it became necessary to ensure proper safety level thereof through the use of conductors non – producing any harmful and toxic compounds in course of combustion and through the assurance of functioning of some installations in course of fire [5]. The supply in case of power supply equipment and the use of electric energy receivers is often associated with the release of significant energy losses in that area; most often this energy is converted into thermal energy. In normal operation conditions the thermal energy is transferred to ambient area without causing undesirable significant temperature increase on installations and equipment. The situation is different unless the basic principles are maintained in the scope of correct design, completion and use of installations and equipment. Such installations should be also provided with proper power supply, cables and conductors with proper fastening system. The fire protection master switch is also required in some buildings in order to turn off the power supply for all the receivers excluding the circuits providing power supply for installations and equipment the functioning of which is necessary in case of fire.

POWER SUPPLY FOR ELECTRIC EQUIPMENT FUNCTIONING IN CASE OF FIRE

The special group of electric energy receivers encompasses the electric devices the functioning of which in case of fire directly contributes to occupants safety in the object; said devices are responsible for early detection and limitation of fire, its propagation as well as hazard data transmission and correct evacuation of occupants from the building under fire [15]. The installations encompassing such devices should be provided with conductors and cables dedicated for functioning in fire conditions and with proper fastening systems. This scope mainly encompasses the following installations [5]:

– fire alarm installation (systems of control, hazard signalling systems),
– back-up and evacuation emergency lighting (solution with central battery),
– sound warning systems (loudspeaker lines, connections between CSP and CDSO when located in different rooms),
– fire fighting equipment (control lines),
– fire fighting ventilation (control functions),
– power supply and control of fire fighting lifts,

- smoke and heat extract equipment (power supply for actuators and control buttons),
- power supply for water pumps for firefighting; chemicals pumps,
- safe shutdown of equipment,
- power supply and control for fire doors and gates.

The devices functioning in aforesaid installation must operate in course of fire; some of them for a shorter period of time, e.g. in case of smoke or heat detector and other for a longer period e.g. in case of smoke extract systems or pumping stations. Part of them does not need any power supply from the grid, because it has been provided with its own emergency power system, e.g. fire alarm system, smoke dampers system or some evacuation lighting systems [10].

Unfortunately the electricity demand is high in case of some devices e.g. mechanical smoke extract systems, fire fighting water pumping stations or lifting devices for rescue teams. The fire protection master switch is also recommended in order to turn off the power supply for all the receivers excluding the circuits providing power supply for installations and equipment the functioning of which is necessary in course of fire.

The building where the voltage decay in power supply grid may create the danger for human life or health, serious hazard for environment as well as significant property losses, should be provided with at least two independent automatically turning on electric energy sources and equipped with automatically turning on emergency (buckup or evacuation) lighting. A high rise building should be provided with emergency Diesel unit as one of power supply sources [12].

The equipment provided with power supply in course of fire should ensure reliable operation e.g. for 60 minutes the outbreak of the fire in the building. It is directly associated with an alternative power supply system: An alternative power supply system consists of:
- alternative source of electricity,
- alternative cable route i.e. other than the basic route, different cable ducts and shafts, other cable racks and routes in general spaces of the buildings,
- in order to ensure the correct flow of current in fire conditions, the materials and cabling insulation structure of the fastening or racks must be certified for required fire resistance,
- proper cabling cross – sections must selected due to increasing resistance in case of ambient temperature increase.

A frequent error is the transmission of the current from an alternative source of electricity e.g. emergency Diesel unit and from the basic source using the same cabling. This case can be accepted from the power supply failure e.g. substation or power unit but it is unacceptable in case of correct operation of fire-fighting equipment. Therefore the analysis is important for each building [10].

The laboratory stand has been built for testing of intelligent electric installations installed in health service objects and in nursing homes for disabled persons in the Energy Efficient Building Systems Laboratory.

LABORATORY STAND

The stand can be arranged as a model of hospital room or a room occupied by a disabled person. The stand has been made of acrylic glass (so called plexi) in the form of rectangular prism. The electric installation management is possible thanks to the installation of an intelligent KNX/EIB bus system.

The functioning of KNX/EIB bus system as well as of other intelligent system is based on three types of devices:
1. Sensors – responsible for data acquisition from ambient area; this scope encompasses various sensors i.e. temperature, humidity, smoke sensors etc. but also switches.
2. Actuators – output devices performing determined commands. Their name originates from the fact that their task is to update the statuses of outputs being controlled.
3. Processing devices – the principal system element encompassing the devices processing the information collected by the sensors and controlling the actuators by means of aforesaid information.

The plan of building with actuators arranged thereon (buttons, bulbs, LED controls) is the principal element of the stand. System modules and buttons used for actuators operation are located beneath the plan.

The stand has been completed on the basis of Master Room RM/S 1.1 device. The device has been installed on a mock-up representing the room (Fig. 2). The graphical representation of the room has been provided with diodes as elements signalling the switchover of controller outputs.

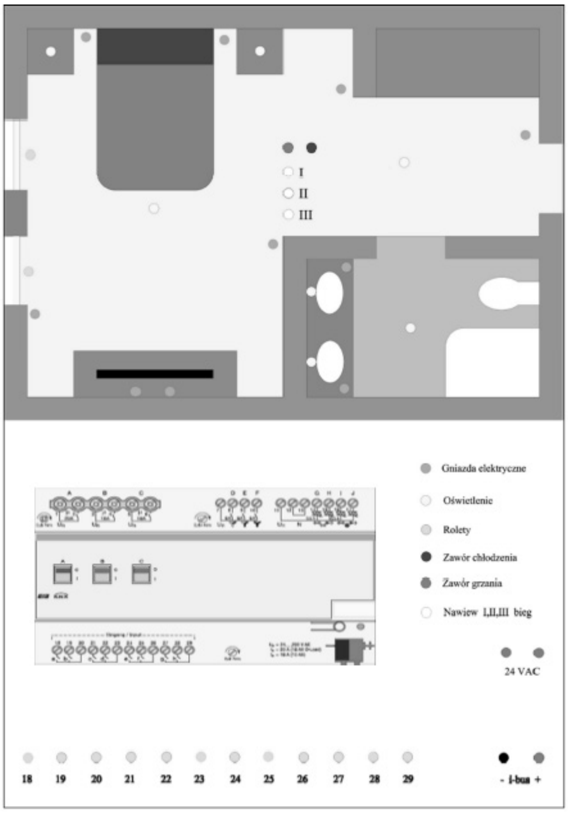

Fig. 2. Laboratory stand

The correct operation of the stand is possible when the following conditions are met:

– connection of KNX i-bus (terminals i-bus, +, –),
– connection of power supply 24VAC actuators end (terminals24VAC),
– connection of sensors (functional buttons etc.) to binary inputs (18-29),
– connection of thermostat RDF/A (element is equipped with temperature sensor and makes possible to control heating, cooling and ventilation functions in local mode),
– correct configuration of Master Room in ETS4 program.

The schematic diagram of controller use on the stand is illustrated in Figure 3. The diodes inform about the active status of lighting elements, heating and cooling valves, shutters opening/closing, electric sockets switching on.

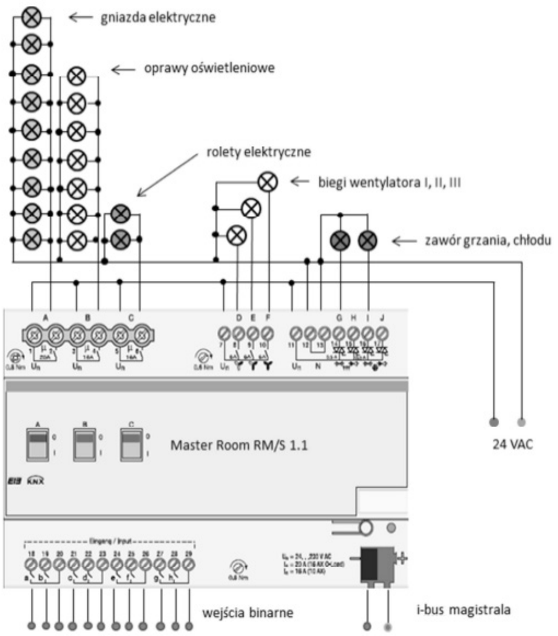

Fig. 3. Schematic diagram of energy efficient installation model in a nursing home

Application available in Tebis Visualization utility program is used for intelligent installation operation.

The program is characterized by a simple and user friendly interface and intuitive operation. Therefore its operation is easy even for the user running the program for the first time. Such solutions were applied before in public utility buildings in residential buildings [2, 3].

The scope of program, except its basic function i.e. system elements configuration, encompasses also reports systems for installed elements. The monitoring of current status of devices (device enabled/disabled, button high/low state, number of starts) is possible from the program level.

The elements of KNX/EIB system used in the course of the stand construction represent a complex solution which can be used as the basis for the creation of fully functional intelligent installation. The schematic diagram of the testing stand is illustrated in the figure below.

The stand has been designed in a manner enabling the execution of the basic device functions used in typical room.

The described system makes it possible to control the following elements of the object:

– lighting,
– HVAC installation (Heat, Ventilation, Air Conditioning),
– household appliances & audio/video devices,
– shutters,
– collaboration with alarm/fire protection/access control systems.

Application available in Tebis Visualization utility program is used for intelligent installation operation.

The program is characterized by a simple and user friendly interface and intuitive operation. This feature is particularly important in case of older persons or users with reduced mobility. Such solutions have been applied before in public utility buildings in residential buildings [2, 3].

The scope of program, except of its basic function i.e. system elements configuration, encompasses also reports systems for installed elements. The monitoring of current status of devices (device enabled/disabled, button high/ low state, number of starts, etc.) is possible from the program level.

ETS4 program window with logical structure of the project is illustrated in the drawing presented below.

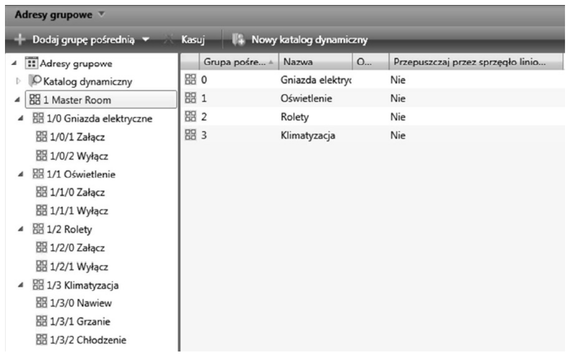

Fig. 4. Logical structure of devices management design in nursing home apartment [10]

Figure No 5 illustrates the operation principle in master mode with the devices management aided from dispatching point, e.g. from medical personnel room.

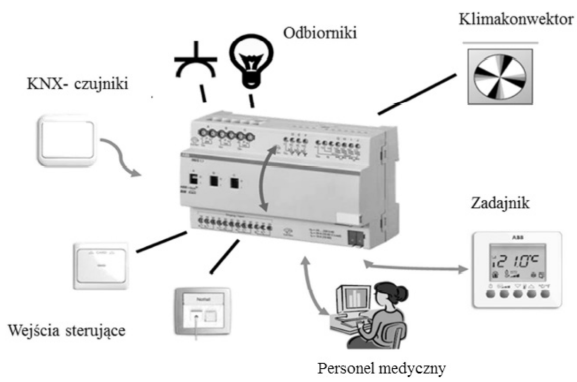

Fig. 5. Devices management design in a nursing home apartment

CONCLUSIONS

In the modern electric installations age with wide spectrum of solutions available on the market, it should be reflected whether to implement such solutions in the buildings dedicated for nursing homes for sick and disabled persons.

The solution presented herein for energy management systems integration in the rooms in a nursing home for disabled persons or in the hospital room is an attempt to implement an energy efficient solution in hospital conditions. This solution can be customized i.e. developed together with increasing needs of its users. The selected KNX/EIB system is the best available building system at the moment. Thanks to its easy installation, components of the system and low power supply voltage of the bus, the patients

staying in hospital or disabled persons living in a nursing home have the possibility to operate the devices in a safe manner. Further extension of installation may consist in the connection of the next actuating modules to existing bus.

The reaction to commands may change depending on the number of modules.

The cost of cabling for EIB/KNX system is about 20 – 30 % higher than in the case of conventional systems and the total cost depends on the building size and the scope of its use. Its undisputable advantage is openness i.e. the possibility to use equipment from different manufacturers and the fact that the system can be extended gradually. In the framework of further works it is possible to extend the stand by next modules and elements in order to increase it functionality. It is possible to add the pushbuttons for the enabling of scheduled actions, sensors detecting lighting intensity or weather making it possible to close or open the shutters automatically.

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ZARZĄDZANIE ENERGIĄ W OBIEKTACH BUDOWLANYCH PRZEZNACZONYCH DLA OSÓB NIEPEŁNOSPRAWNYCH RUCHOWO

Streszczenie. W publikacji poruszono ważną problematykę integracje ze społeczeństwem osób niepełnosprawnych. Zdefiniowano pojęcie osoby niepełnosprawnej. Opisano zastosowanie instalacji inteligentnych w nowoczesnych budynkach przystosowanym dla osób niepełnosprawnych. Omówiono również wybrane aspekty bezpiecznego zasilania szpitali w energię elektryczną oraz urządzenia elektryczne funkcjonujące w czasie pożaru. Ponadto opisano stanowisko laboratoryjne do badania energooszczędnych instalacji systemu KNX/EIB, zarządzających urządzeniami w pomieszczeniach domu opieki z częścią szpitalną.

Słowa kluczowe: budynek inteligentny, instalacja, niepełnosprawność, integracja, system automatyki.