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COMPUTER – AIDED DESIGN OF VIRTUAL SUPERVISION SYSTEMS FOR THE ELECTRIC SYSTEM IN CONTEMPORARY BUILDINGS

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Summary. The purpose of the present article is to discuss the role of the information system in the building management systems as well as the use of computers for computer – aided design and operation of intelligent electric systems in contemporary buildings. Special attention is devoted to KNX system as one of the most popular systems applied in the buildings management solutions. The article presents the basic principles of the creation of KNX system design in TP (Twisted Pair) version in ETS4 tool and the procedure of its startup.

Key words: intelligent electric systems, designing, integration, virtual supervision.

INTRODUCTION

The idea of intelligent building engineering and so called intelligent systems became popular and more present in our everyday life in recent years. Nowadays "an intelligent" house is not a luxury any more but becomes a more and more commonly applied solution. The first electric systems in the buildings were equipped with conventional accessories i.e. fuses, sockets, circuit – breakers, cam switches, light fittings. Owing to continuous trends towards the improvement of the standard of contemporary buildings, further development in the scope of the conventional electrical systems is practically impossible. The development of electronic engineering and computerization in many fields of life is also reflected in the electric systems sector. New control and regulation systems are created by the manufacturers of the systems equipment introducing control engineering solutions into building management systems. Owing to their advanced development and complexity, it is necessary to find a new approach to the designing of these systems, power supply methods, as well as to the localization and elimination rate of potential disturbances [7, 8].

The intelligent electric systems have been created simultaneously with the general access to personal computers. The field of the computers applications has also been extended to the private companies and industrial centres. The reason of these changes was obvious – using the computer with proper software the companies were able to meet the investor's need in a faster and more effective manner and consequently to survive in the market. However, the role of the computer was not essential in the work of designers, because appropriate tools to be installed in the computer i.e. dedicated software are more important.

At that time it was a group of specialized computer programs enabling the creation of the diagrams of conventional electric systems e.g. CAD programs. Furthermore, the designers could perform the computations and to prepare the design documentation by means of computation support software and text editors, for example by means of MathCad and Word.

Another new application of computers in the intelligent systems consists in their use for the startup (activation) of the components of the intelligent systems as well as for the supervision over and control of the building systems [1, 5, 9, 10].

INFORMATION SYSTEM.

The information system performs an essential role in the contemporary modern buildings as an important element of automated systems. Such solution makes it possible to ensure the communication between the elements being the components of the building management systems. The adherence to relevant principles as early as in the course of its construction is important for the correct functioning of an information system.

Most often there are four levels (stages) in the structure of this system (Fig. 1):

- The system encompasses several subsystems (at least two) and constitutes an assembly of interconnected parts creating the whole. Each system performs the role of a subsystem in a higher order system (or: a higher order system performs the role of a superior system over the lower order system) e.g. heating control system in the building can perform the role of the subsystem in BMS (Building Management System). The purpose of the information system is to enable the acquisition and processing of information necessary for correct management.
- The subsystem is an element included in the higher order system. It is isolated in the system through the establishing of principles which correspond to relevant objectives in the systems and to management tasks. Another criterion used for the subsystem definition is its function performed in the system e.g. planning, records, inspection etc. or in accordance with other established principles. The subsystem is provided with a decision making member responsible for the decision making process in the determined decision area.
- The functional unit constituting a part of the subsystem is the smallest element of the whole structure of the system, which can be operated independently. The task of the functional unit consists in the processing of a separate task. The functional units are separated in a manner enabling the operation of every unit in one processing sequence.
- The module constituting a component of the functional unit encompasses a separate fragment of an issue e.g. temperature measurements in individual rooms and heating medium control in accordance with pre-programmed temperatures. The module is situated on the lowest level in the system's hierarchy structure. Its implementation is the easiest but independent operation is impossible.

The system, subsystem, functional unit and module constitute the levels (stages) in the system's structure. The structure of an information system is presented below as the model of modular structure. Such structure makes it possible to combine the simplest elements (modules) in an easy manner and to create various forms of higher order structures. Such systems are easy to design and implement and can be easily modified in accordance with varying requirements of the user.

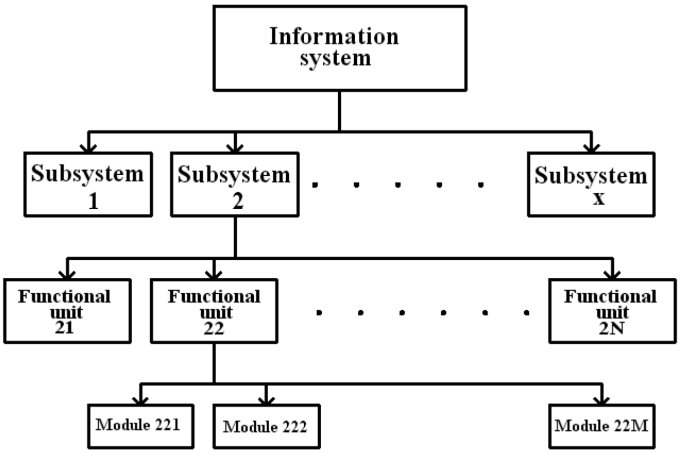

Fig. 1. Diagram of the information system structure [3]

KNX BUS SYSTEM; TP TYPE

The control structure applied in the building management systems is frequently called the complex processes control structure in the literature. The systems contain several controlled inputs with $u_1, \ldots u_j, \ldots, u_m$ signals and with the following operators A_i:

$$y_i = Ai(u_1, \ldots u_j, .., u_m), \text{ where } i=1, 2, \ldots j, \ldots, n \tag{1}$$

In particular case of a multidimensional linear system the form of the equation (1) is as follows:

$$y_i = \sum_{j=1}^{m} L_{ij}(u_j), \text{ where } i=1, 2, \ldots j, \ldots, n$$

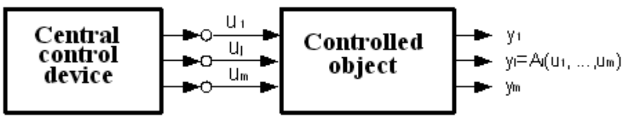

Fig. 2. Multidimensional system [10]

In case of the systems characterized by several impacts, the central control device (Fig. 2) can be substituted by several local devices C_i, i= l, 2,..., n, performing the control functions for individual subsystems. This solution is presented for m=n (Fig. 3).

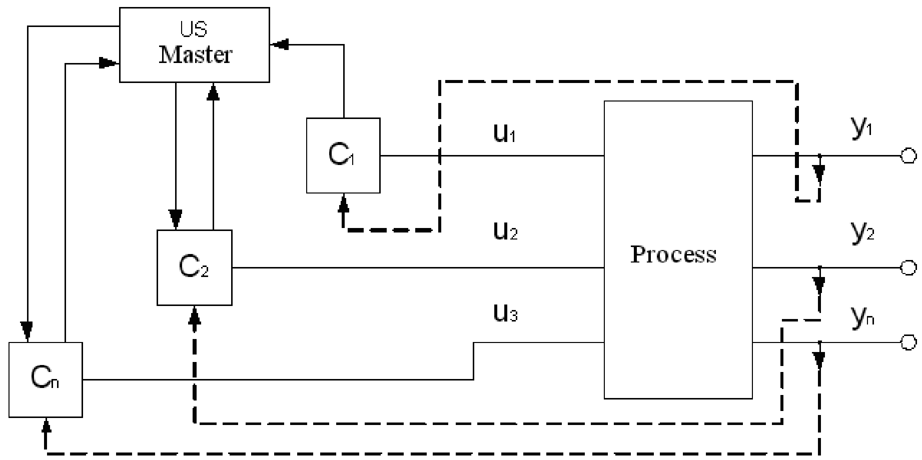

Fig. 3. Multidimensional system control by means of local devices and superior tool [3, 10]

The purpose of the superior control device is to coordinate the operation of local devices in order to subordinate to local objectives of separate subprocesses to the common global objective as well as to consider the interrelation of process outputs and inputs. The coordination is achieved through the continuous data flow between the local control devices and superior control devices.

The systems in accordance with Fig. 2 are called the centralized control systems and the systems in accordance with Fig. 3 are called the decentralized control systems.

The decentralized control systems prevail in the complex system for the processes control. Their role is important in the scope of processes automation in industry, building engineering and in other fields of our life. The principal advantage of these systems consists in their ability to perform rather complex functions by means of relatively simple tools. The volume of data to be processed by the local and superior devices is significantly lower than the volume of data to be processed by means of single control system in the centralized system.

In order to enable the correct functioning of the decentralized system, it is necessary to coordinate the functioning of the local devices and systems through the selection of the efficient links enabling fast data transfer. Unless this requirement is met, the functioning of the decentralized system will be significantly worse than the functioning of the centralized system.

In a majority of control systems, the control devices for individual processes are arranged in the form of pyramid or hierarchical structure (Fig. 4). The hierarchical structure belongs to the group of decentralized structures in case of determined freedom of the individual subsystems containing the decision making members or devices in the decision making process. The hierarchical centralized structure is also possible with all the decisions made by the member situated on the top of the hierarchy and with other members completing the orders issued by the central member. This structure contains the controlled objects O_1,..., O_n, (with interrelations ignored in order to simplify the problem), local control devices C_1^1,..., C_m^1, second level control devices C_1^2 , ... etc. Every set of objects e.g. O_1, ..., O_n and C_1, ..., C_n. C_1^1 can be considered as a subsystem (indicated in Fig. 4 by means of dashed line and letter P_1) controlled by the higher level device (in case of P_1 - C_1^2 performs the role of superior device).

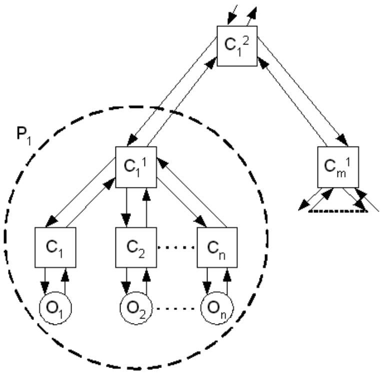

Fig. 4. Hierarchical structure [3]

The integrated systems are characterized by "distributed intelligence". Therefore, the individual devices arranged in the whole building can perform their functions in an undisturbed manner, even in case of interrupted communication with the superior managing units. It is possible, thanks to the controllers equipped with individual microprocessors and memory used for storage of the controller operation data. Therefore, the various systems can be controlled in local mode without necessity of permanent intervention of the system operator. Such solution increases the system reliability and reduces the time of reaction to various hazards and alarm conditions. The possibility of optional modelling of the system shape should also be emphasized, because the system flexibility is ensured – enabling its continuous adaptation to the needs of an organization.

EIB (European Installation Bus) actually called KNX is defined as a bus system with tree structure (the system can be branched but without forming any loops).

The line (branch) is the basic part of the structure used for the connection of system elements (maximum 64), sensors and actuators. Several lines (max 15) can be integrated together to form an area by means of special devices, for instance linear couplings. It is possible to integrate fifteen areas into one system (Fig. 5) by means of individual area couplings.

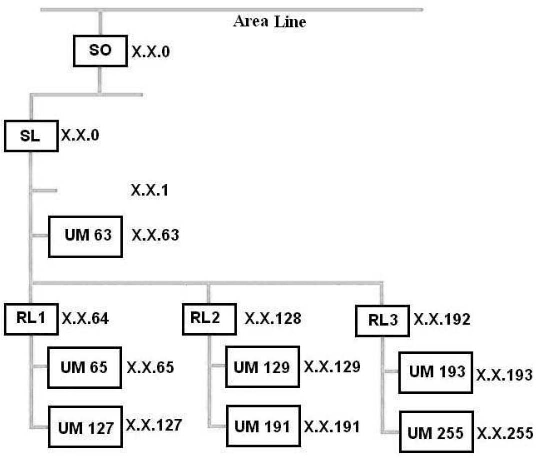

Fig. 5. KNX system: SO – Area coupler, SL – Line coupler, RL - Line Repeater, UM – bus unit [2, 4]

EIB (European Installation Bus) integrates more than 50000 bus elements together; the communication elements can communicate with each other in the form of information exchange irrespective of the location of their connection to the bus.

The system elements communicate with each other usually in local mode [12]. In case of the occurred event, determined commands are issued by the sensor in the form of telegrams transmitted between the sensor and actuator. The Carrier Sense Multiple Access /Collision Avoidance [CSMA/CA] protocol has been applied as the bus access mechanism warranting collision free and equal right access (of BCU module) to the bus [2, 6, 12, 13].

Algorithm of asynchronous CSMA/CA protocol is presented in Fig. 6.

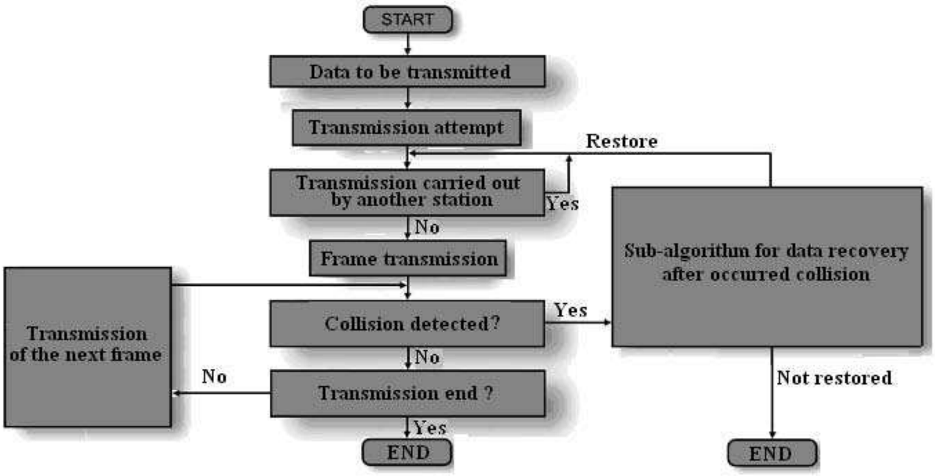

Fig. 6. Algorithm of bus access mechanism in KNX system [2, 11]

Therefore the transmission of messages can be commenced any time by the elements participating in the transmission but they have to verify if the network is not busy by other transmission. The system elements (sensors or actuators) are provided with assigned priorities. In case of transmission process commenced by two sensors simultaneously, the transmission is withheld by the sensor with lower priority and restored after the completion of the transmission by the sensor with higher priority. In case of both sensors with the same priority, the decision on transmission order depends on the physical address. The physical address is a unique number assigned to every element of the system in order to determine the telegram recipient and the localization place of the device. The element with the higher physical address releases the bus for the element with the lower address [12, 13, 14].

The communication telegram sent by the sensor propagates along the whole line. The messages are received by the actuators being the recipients of information; the receipt notification is sent by the recipient to the sender. The telegram must be ignored by other users who are not its recipients. The linear coupling preventing the propagation of information along the whole bus is extremely important in such situations. The coupling performs the role of a filter – amplifier. At the time of the system activation in the coupling, a filtering table is automatically recorded in order to determine the telegrams to be amplified and transmitted and the telegrams to be attenuated. The information flow as well as filtration is possible in both directions.

In case of a telegram sent for example by the sensor from the line 3 and to be received by the actuator situated in the line 13, this telegram is furnished to the linear coupling 3 and passed by this coupling to the main line. Then the telegram is passed through the linear coupling 13 and furnished to the recipient. At this time the telegram is locked by the linear couplings 1,2...14,15 and sent via the main line without reaching these lines. Therefor, the communication is possible within these lines in a parallel mode. Identical filtering tables are incorporated in area couplings in a manner enabling unrestricted information transfer to the elements located in other parts of system structure. The telegram transfer process to other areas is identical.

COMPUTER – AIDED DESIGN

A wide group of programs dedicated for computer – aided design of electric systems in conventional version was available at the time of the creation of intelligent electric systems. Therefore it was obvious that more advanced programs will be developed to facilitate the designing of intelligent electric systems. Furthermore it should be emphasized that the programming by means of the computer is required for some installations of intelligent electric systems.

The designing process of an intelligent system consists of several phases diversified with respect to their degree of difficulty and time consumption. All requirements included in the standards, regulations and recommendations concerning the issue under analysis should be considered and met in every phase. The majority of designing activities can be automated and optimised to a significant degree by means of computer – aided design systems.

The wide spectrum of computers with diversified hardware architecture, functioning in the framework of many various operating systems has been created as a result of intensive development of electronic engineering and information systems. However, the disadvantage of this diversity consists in the fact that the software elaborated for a hardware platform most often will not work on the computer with another platform.

ETS4 SOFTWARE TOOL

ETS4 software tool (European Installation Bus Tool Software) is required for the designing, startup and further servicing of the installations in KNX TP system. ETS4 software tool is distributed by the Association of KNX system devices manufacturers and dedicated for operation in Windows environment as the standard program for EIB systems installations. ETS4 is a modular program consisting of several parts supporting each other. The scope of basic properties of ETS4 program encompasses the automatic creation of the system documentation encompassing the plan of the system, addresses allocation list and the list of applied bus elements. At the installation startup all data and information concerning the installation functioning, diagnostics and service are transferred to the memory of corresponding bus elements.

The special symbols and names of bus elements with various application, established by Konnex Association responsible for the certification of devices in this systems, are used in KNX system designing and automatically entered by ETS4 package into the plans and diagrams of the systems i.e. into its electromagnetic part (230/400V) and bus(24V). After startup, the main window is opened (Fig. 7.) with pushbuttons enabling the access to the next parts of the program.

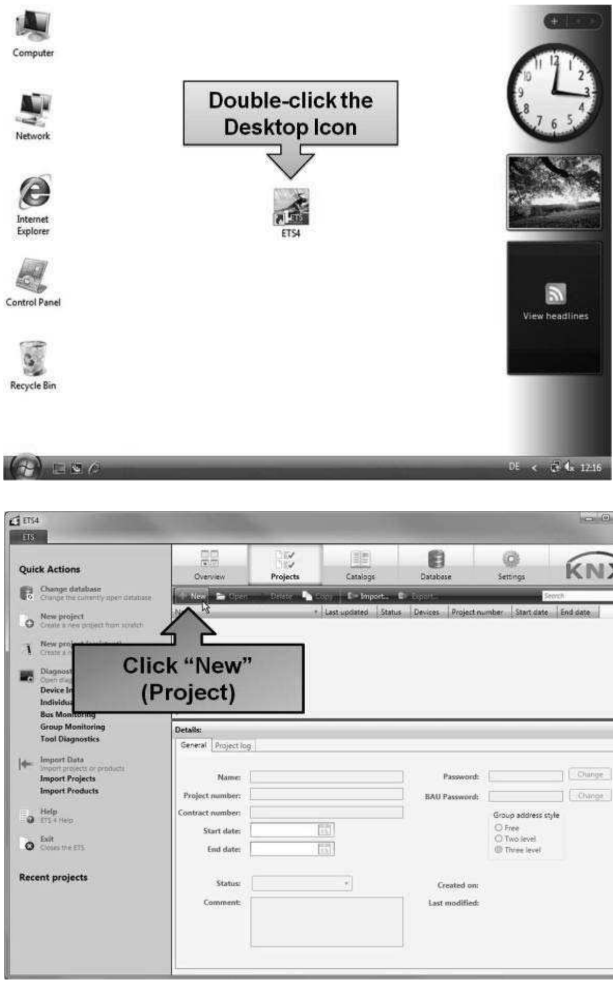

Fig. 7. Starting window of ETS4 program – commencing of the new design creation

The individual program windows contain: the modules responsible for the selection of design saved in the computer or for the commencement of work associated with a new design, designing, installation of KNX TP system apparatuses from the manufacturers in base program if the use of their devices is intended by the designer, program setting, option selection menu; startup and testing.

The devices can be inserted directly into the design or the building structure can be created at the beginning with subdivision into the storeys and rooms.

In the second case the devices are located at the places of their factual installation in the real object i.e. the apparatuses to be installed in switching stations are located in switching stations and control apparatuses in the rooms from which the bus telegrams are sent to the actuators. The designing principle consists in the dragging of individual “building objects” to the design, with logical reservation that the larger object must not be inserted into the smaller object.

The first step of systems designing is associated with the selection and planning of the layout of bus elements in the building. At the selection of the devices for KNX systems the following principles should be adhered to:

- For each bus line, at least one power pack should be selected with the coil with rated current sufficient to provide the power supply for all devices connected to the line.
- The length of the conductors for single line should not exceed 1000 meters. For more complex topological structures (containing the level higher than basic) one linear coupling should be selected for each subordinate line.
- When designing the line routes in the building, the quantity of devices to be directly connected to this line should be considered in order to not exceed their permissible quantity determined by the address space.

The simplest KNX system able to function in the building consists of one power pack with coil, two – wire bus cable, one actuator and one sensor as well as KNXnet/IP router coupling KNX system with the computer network of the building in order to enable the communication by means of IP network.

OPERATING PRINCIPLE OF VISUALIZATION SYSTEMS

The operation of the visualization and control systems is determined through the so called Objects determining their types, functions and interrelations [3]. The following items can be classified as the objects; editable data from panel, symbolic names of programmable controllers supporting the system, buffers of messages. The objects can be also created in the form of graphical elements, icons, windows and alarm messages pages as well as elements located on the screens. The objects enabling the control system support and its visualization are a very important group of the objects. The system support is possible by means of the following objects: virtual switches (pushbuttons, switches), real pushbuttons and input fields used for data entry. The objects enabling the visualization encompass the following scope: binary states displays, output fields (text and numerical fields) as well as virtual meters.

Analysing the hardware and software mechanisms used for the control over the object automation system on the levels of individual tiers of hierarchic model of information exchange in the object, we can find that on the level of direct control tier in KNX TP standard, the simple optical and audible signal devices as well as liquid crystal displays (LCD) and HMI panels are very often used as the system status visual presentation mechanisms.

In case of hardware elements used for the visualization and control purposes in residential objects, the aesthetical feature of the component, possibility of its integration with interior design as well as the manner of the presentation of automatic control system devices status are principal criterion for the selection of proposed solution.

The communication protocols are another criterion essential for the applications area of a visualization component.

In case of automatic control system based upon KNX standard, the elements dedicated for the visualization of and control over the system operation are usually characterized by very limited possibility of extension and their implementation in other automatic control systems. The visualization devices (mainly HMI panels) are equipped with additional interfaces (e.g. RJ-45, USB) enabling the achievement of their objective on the level of higher control tiers (mainly in superior control tier).

The interfaces applied in this standard constitute in a way the equivalents of external communication cards. The information received from the bus or sent to the bus (occurring as a result of the telegrams with the queries concerning the address group status or as a result of bus watching) is copied to the cache of KNX interface and sent to visualization system after its conversion. In order to enable data exchange with KNX system bus, one communication program constituting and integral part of communication system is usually used. This program is completely independent of the hardware elements used in the automatic control system owing to complete standardization of BCU units construction.

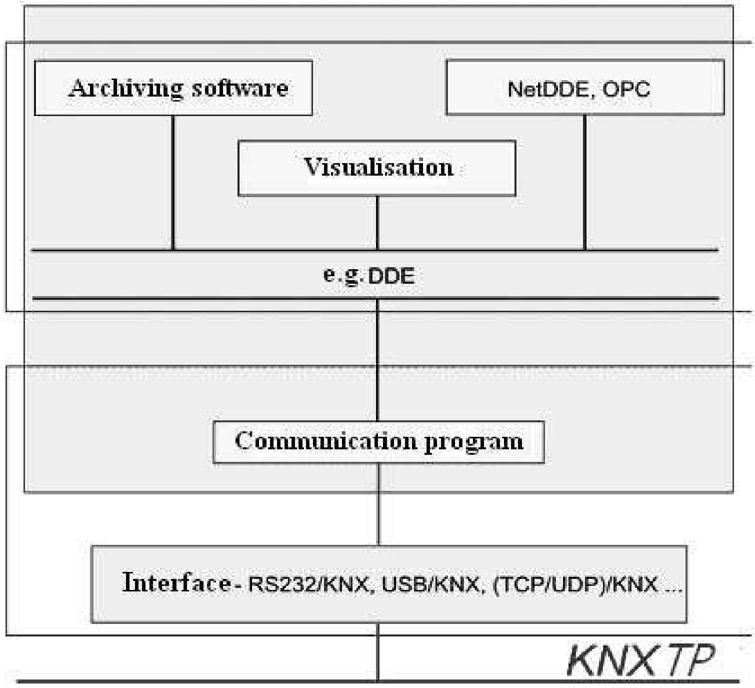

Fig. 8. Data exchange mechanism in visualisation application in KNX system [11]

In case of KNX automatic control system, the application of superior Building Management Systems (BMS) is not obligatory [8]. This type of systems is usually applied in large objects characterized by significant topological span of the automatic control system. The aim of the achievement of economical benefits associated with savings by the users in the scope of electric energy, heating medium energy etc. as well as increased comfort of object use is the principal factor contributing to the application of the Building Management System in an object. An example of such management completed by means of WinSwitch 3 program is presented in the diagram below (Fig. 9).

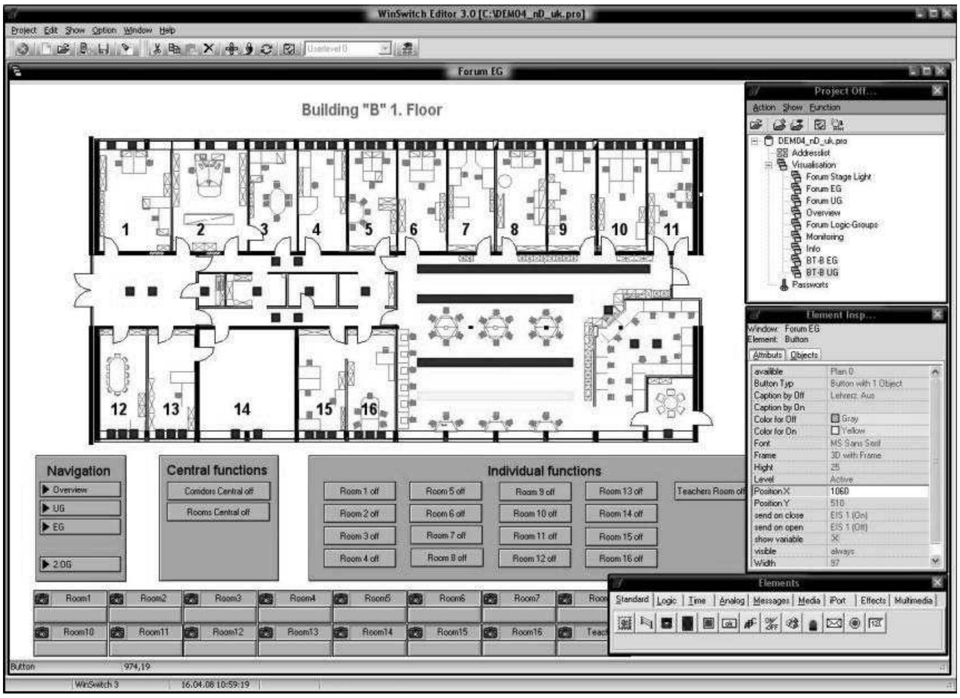

Fig. 9. Intelligent systems management by means of WinSwitch 3 program

CONCLUSIONS

The electric systems are an inherent element of every contemporary building. Initially their sole task was to provide the power supply for electric energy receivers. Owing to technology progress, the automatic control elements occurred in the systems in order to increase their safety, functionality, comfort and electric energy saving. The information systems in intelligent buildings are their indispensable component, irrespective of its scale, advancement degree and applications area. More than 20 years ago a communication standard has been created to enable the communication between distributed BMS devices. Initially called EIB and after conversions known as KNX - this open standard makes it possible that the devices from various manufacturers support each other. The application of IP network for communication between KNX system devices has been launched in recent years. This solution creates huge opportunities for the electric energy management via the Internet.

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KOMPUTEROWE WSPOMAGANIE PROJEKTOWANIA WIRTUALNYCH SYSTEMÓW NADZORU INSTALACJI ELEKTRYCZNEJ WE WSPÓŁCZESNYCH BUDYNKACH

Streszczenie. W artykule omówiono rolę systemu informatycznego w systemach automatyki budynkowej oraz wykorzystanie komputera do wspomagania projektowania i uruchamiania inteligentnych instalacji elektrycznych we współczesnych budynkach. Główną uwagę poświęcono systemowi KNX TP, jednemu z najpopularniejszych systemów stosowanych w automatyce budynków. Podano podstawowe zasady tworzenia projektu instalacji KNX TP w programie narzędziowym ETS oraz procedurę jej uruchamiania.

Słowa kluczowe: inteligentne instalacje elektryczne, projektowanie, integracja, nadzór, wirtualny.