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The analysis of the possibilities to control temperature in a building using the TELETASK system automation

Streszczenie. *W pracy przedstawiono rozkład kosztów funkcjonowania budynku na przestrzeni kilkudziesięciu lat jego eksploatacji. Uwzględniono przede wszystkim urządzenia i systemy zużywające energię elektryczną i cieplną. Wyjaśniono konieczność dobrania odpowiedniej metody sterowania temperaturą umożliwiającą osiągnięcie wymiernych korzyści ekonomicznych oraz ich wpływ na komfort życia i pracy użytkowników obiektu. Opisano metody i tryby sterowania temperaturą pomieszczeń w oparciu o rzeczywistą instalację wykonaną przy użyciu system inteligentnego budynku Teletask. Wykonano projekt systemu sterowania temperaturą dla pomieszczenia mieszkalnego oraz biurowego. Przeprowadzono pomiary z wykorzystaniem elementów systemu Teletask w celu wyznaczenia czasu załączenia i wyłączenia systemu grzewczego przy zapewnieniu zadanej temperatury pomieszczenia. Wyznaczono zakres oszczędności dzięki zainstalowaniu systemu inteligentnego budynku do sterowania temperaturą dla pomieszczeń o różnym przeznaczeniu. (**Analiza możliwości sterowania temperaturą w budynku z wykorzystaniem automatyki systemu TELETASK).***

Abstract*. The paper presents the distribution of costs of functioning of a building over a period of several decades of its use. Above all, devices and systems which consume electricity and thermal energy were taken into account. The necessity to select an appropriate method of temperature control in order to achieve measurable economic benefits and the impact of these benefits on the life and work of the building users were clarified. The methods and modes of temperature control in rooms based on real installation made using the Teletask intelligent building system were described. The design of the temperature control system for living and office spaces was prepared. The measurements, using the Teletask system components were carried out in order to indicate the time during which the heating system was to be switched on and off, while ensuring the set temperature in the room. An estimation was made with regards to the possible savings owing to the installation of the building intelligent system for temperature control in rooms intended for various purposes.*

Słowa kluczowe: Teletask, regulacja temperatury, automatyka budynkowa, instalacja inteligentna.
Keywords: Teletask, temperature control, building automation, intelligent system.

Introduction

In times of continuous development of new technologies, intelligent systems play a greater and greater role in designing new buildings. Developers of building automation systems broaden their functionalities in order to provide as great a comfort and safety to their users as possible. One of the basic areas in which building automation elements are applicable is the smart temperature management system. In expanded installations, three separate subsystems such as heating, ventilation and air conditioning which altogether are referred to as the HVAC system, are integrated [4-9,11]. The automatic temperature management in the building contributes to the improvement of quality and comfort of life and work. Furthermore, it leads to the savings of energy (both thermal and electric), i.e. it reduces the financial outlays incurred for the current exploitation of the building. Generally, exploitation costs constitute as much as 70% of the total costs in the life cycle of a building, and the investment outlays amount to only 10%, which was presented in figure 1 [1,12].

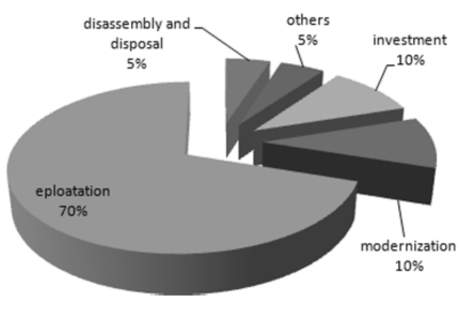

Fig.1. Percentage of costs in the building life cycle [1,12].

The exploitation costs are made up of the electric energy and thermal energy, which constitute, in total, over 80% of total costs (fig. 2). While analysing the consumption of electric energy by different subsystems (presented in figure 3), it must be noticed that as much as 70% of energy is consumed by the lighting and the HVAC system. Therefore, from the economic point of view, each investment should be preceded by analysis of available energy-saving and reliable building management systems [1,3,12,13].

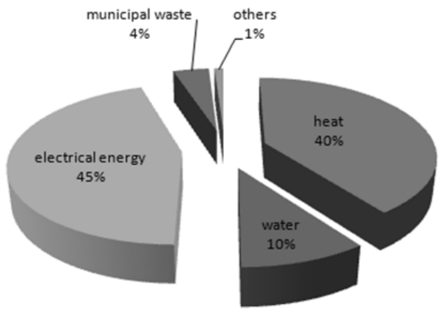

Fig.2. Distribution of costs of exploitation among the respective elements [1,12,14].

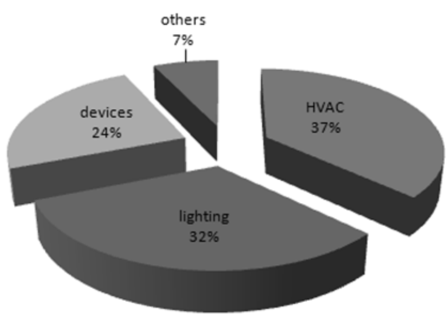

Fig.3. Division of consumption of electric energy into different domestic subsystems [1,14].

The automatic control of the lighting intensity using light sensors and the turning of the light on and off by means of motion sensors will allow for the generation of energy savings at the level of about 40%. On the other hand, the automatic control of the HVAC system based on temperature sensors, reed relays and time schedules will contribute to the reduction of costs by about 10% [1,3,7]. However, it must be remembered that the whole system also needs energy for its current operations. However, this consumption is very small in comparison to savings which can be generated owing to the automatic control [2]. What is also important is that the building heating/cooling schedules should match the set zone temperatures properly to the presence of users, taking into account the times of heating and cooling of the space. Fig. 4 presents the comparison between the graph for the set temperature vs. the real temperature in a room, when at t_0, the value of the required temperature was changed and the radiator valve was closed.

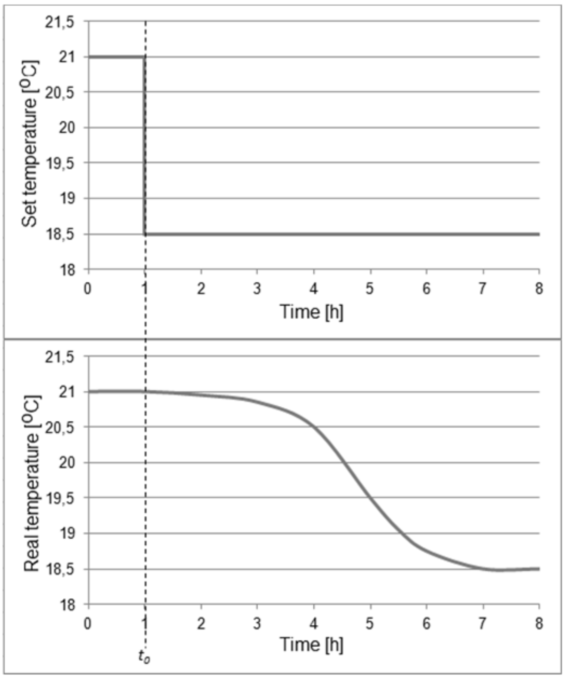

Fig.4. Graph which presents changes in the set and real temperatures in a room [1].

Based on analysis of curves presented in fig. 4, it can be noticed that the process of cooling of a room by about 2.5°C may last even 6 hours (depending on many factors such as e.g. insulation of partitions, external conditions, presence of people and devices, etc.) [1]. Furthermore, for about 3 hours, the users should not feel any temperature changes. This shows unambiguously that instead of continuous heating of the rooms, it will be more economical to use the algorithm of periodical activation of the heating in order to maintain the permanent temperature value. Also, knowing the schedule of stay of the users in the given zone, its heating may be stopped earlier before the planned longer period of non-use. A similar situation will refer to the room ventilation and air conditioning systems. Therefore, the automatic room temperature adjustment and control may bring energy savings, i.e. measurable economic benefits.

TELETASK system

In view of the multitude of cooling and heating systems available on the market, their integration is difficult without using specialised automation supported by software. The manufacturer of the Teletask intelligent building system offers several products and solutions, owing to which the automatic adjustment of the HVAC system equipment is possible. The user, in order to control and change the presets, has standard buttons, touch panels and visualisation screens at their disposal, and also through remote access (mobile or computer applications, use of the Ethernet or Internet networks). The system is programmed (connection of the system elements and creation of functions and schedules) by means of the PROSOFT company application. It was divided functionally into 5 areas, i.e. [10]:

- Prosoft: allows for the identification of rooms and building zones, connection of input and output interfaces of the system, creation of functions;
- Timesoft: the creation of clocks and time schedules;
- Cardsoft: the operation of key fobs, proximity cards and readers;
- GUISoft: the creation of visualisations for touch screens and mobile applications;
- AV-Soft: operation of audio devices.

In order to pre-programme the functions which serve the purpose of ensuring comfortable living conditions to building users, the appropriate implementation of system equipment is necessary. In the case of the HVAC system equipment control, which consumes the largest amount of electric energy and thermal energy in the building, it is necessary to pre-programme the input devices (such as temperature sensors, reed relays, buttons or touch panels) as well as output elements, i.e. the executive elements (such as, e.g. radiator electrovalves, fans and air handling units connected to relays and analogue outputs). After the devices are configured appropriately, it is possible to proceed with the creation of the automatic temperature adjustment in the building.

Possibilities for setting the temperature sensor

The temperature sensor, in accordance with the instructions of the manufacturer, should be mounted at the height of about 1.5 m from the floor, at a distance of at least 0.15 m from the door, windows and outer walls, sources of heat or cold (radiators or air conditioners) [10].

In general, the temperature control algorithm in the Teletask system covers:

- the temperature measurement in the zones by means of sensors,
- the comparison of the current temperature value measured with the values set in the programme by the user, and its possible correction in accordance with the assumed programme,
- the periodical temperature measurement for the purpose of further correction.

The cooling system functions in an identical manner as the heating, but it is activated in the case of a temperature increase above an assumed value.

The general settings regarding the temperature sensors will determine their possible presets in the specific operating modes. In the programme window visible in fig. 5, it is possible to distinguish the following settings, important from the point of view of temperature control [10]:

- *heating system type*: the configuration of the heating cycle (refers only to the zone of sensors with the following control methods: “relay”, “flag” or “local mood”). The default setting identified as “no cycle and hysteresis 0.5°C” means that the heating will be started when the temperature falls by 0.5°C below the preset and will switch off when the set value is reached. This will allow for the optimal maintenance of the required temperature and for the reduction in the energy consumption;

– *cooling system type (air conditioning)*: similarly as above, in the case of heating;
– *temperature/10V or 100% time*: it refers only to the heating system with the multi-step adjustment, analog control and other control methods with adjusted cycles. It identifies the maximum difference between the measured temperature and the adjusted temperature of the heating/cooling mode;
– *enable auto modus*: the selection of this programme option will cause the automatic switching of the system between the heating mode and cooling mode depending on the value of the measured and set temperatures. It is also possible to change the modus from *AUTO* to *HEAT* or *COOL* manually, however, then the system will respond to the temperature changes and the activation of the equipment only in the set mode, until the time of repeated manual change to the AUTO modus by means of e.g. the touch panel or the application;
– *delta heat/cool*: specifies by how many degrees the measured temperature may be higher than the set temperature. When the measured temperature is higher than the sum of the set temperature and *delta*, the system will switch to the *AUTO* modus and start the cooling of the zone;
– *frost protection temperature*: specifies the minimum temperature to be achieved in the zone in order to provide protection against the excessive cooling and danger of freezing, when e.g. a window is open or when the heating system is off.

Each installed temperature sensor has individual properties regarding the control methods and the activation thresholds, as has been shown in figure 6.

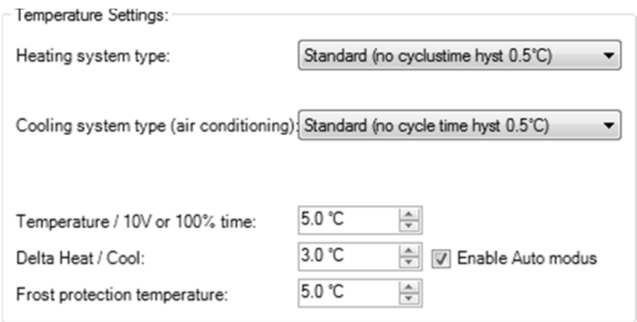

Fig.5. View of the window of general temperature sensor settings.

Among the temperature sensor control methods, both for the heating algorithm (the '*Heat*' tab) and cooling algorithm (the '*Cool*' tab), it is possible to select one out of several control options, presented in figure 6. The control methods implemented in the system include [10]:
– *standard relay*: the basic form of control based on control of the activation and deactivation of one relay output to which both the electrovaves of radiators and circultion pumps or fans, etc. can be connected;
– *analog control*: the option of smooth control by means of the analog output of the system (dimmer) within the voltage range between 0-10 V, which allows for operation within the maximum temperature difference that amounts to 5°C;
– *4 step (OR)*: this mode is used to control the operation of fans with the set speed (off/low/medium/high). The '*OR*' mode means that only one out of four relays will be switched on, depending on the difference between the set and real temperatures:
  • *off* – in the case of heating, when the set temperature is lower than the real one, there is no need for adjustment;
  • *low speed* – for a temperature difference up to 0.5°C;
  • *medium speed* – for a temperature difference between 0.5°C and 2.5°C;
  • *high speed* – for a temperature difference between 2.5°C and 5°C, when the fan is switched to the highest speed;
– *4 step (AND)*: this mode operates in a manner which is close to *4 step (OR)*, but the difference is that the consecutive relays are connected as the temperature grows which causes the simultaneous operation of one, two and three systems accordingly;
– *local mood*: only for special applications, the triggering of the local mood will cause the activation of many outputs at the same time;
– *flag*: for special applications, the flag which is responsible for the controlled temperature in the given zone will be on or off.

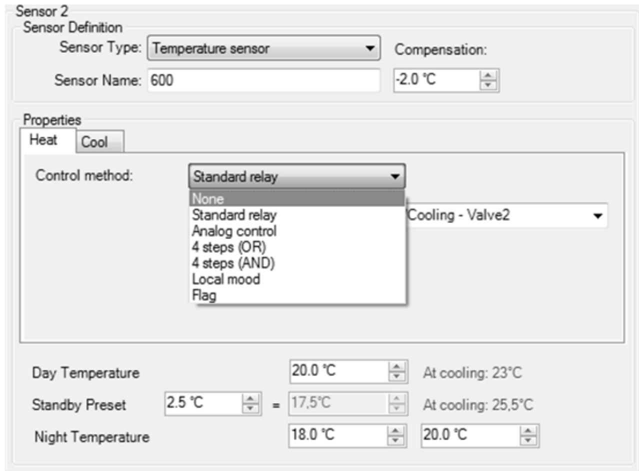

Fig.6. View of the setting window for control methods and presets of the temperature sensor.

Other sensor parameters have the following meaning [10]:
– *compensation*: a calibration parameter of the device which allows for taking into account the necessity of a permanent change in the value of an indicated temperature; it can be changed within the range between -5°C and +5°C with a step every 0.5°C;
– *day temperature*: the threshold temperature value in the '*DAY*' mode, which the system will strive to reach. The possible range of changes is between 5°C and 30°C with a step every 0.5°C. In the cooling mode, the value is increased by the "*delta heat/cool"* parameter,
– *standby temperature*: this is the temperature value in the standby mode (savings), dependent on the "*DAY"* preset; the changes are possible within the range of values between 0.5°C and 5°C with the step every 0.5°C. For the heating algorithm, the "*DAY"* temperature is decreased by the set value, and for the cooling algorithm – it is increased by this value and by the *"delta heat/cool"* parameter.
– *night temperature*: the threshold temperature value in the "*NIGHT"* mode, which the system will strive to reach. The possible range of changes in the heating algorithm is between 5°C and 30°C, and for the cooling - between 20°C and 30°C. The value of this preset can be established separately for the heating and cooling

algorithms with a step every 0.5°C. However, the temperature value for the cooling may not be lower than the night temperature preset for the heating, increased by the *"delta heat/cool"* parameter.

Sensor, conditional and process functions

The process of automatic temperature control can be extended using integrated functions such as [10]:

- sensor functions: they are used to create conditions based on the sensor mode preset, its measured value level, etc;
- conditional functions: the fulfilment of a condition causes the execution of a pre-determined action, and failure to fulfil it leads to another pre-defined action;
- process functions: The function monitors the status of the element/function being the condition on a current basis, and automatically switches on/off the executed function.

Particular attention must be paid during the process of defining conditions and functions (above all the process functions), as there is a possibility of an interplay between different elements of the system and their incorrect functioning (e.g. while using one element in several functions/operating modes of sensor).

View of settings and manual control

The change in the settings and temperature control in the Teletask system is possible both from the level of traditional buttons and also from touch panels or visualisation screens. Figure 8 presents one of four screens of the AURUS touch panel, on which it is possible to manipulate sensors.

The available panel buttons (fig.7) are responsible for the change in the preset of the required temperature, the change in the *DAY/NIGHT/STANDBY* presets, the change in the *AUTO/HEAT/COOL* operating modes, the switching between the sensors and their activation/deactivation. Also the value of the current temperature from a selected sensor is visible.

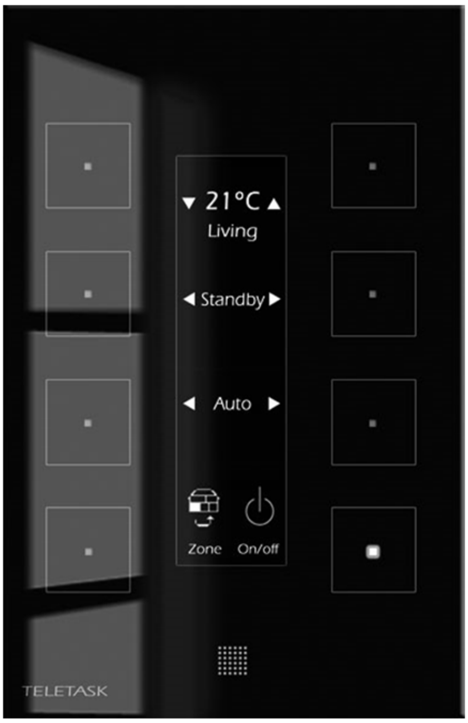

Fig.7. View of sensors of the AURUS touch panel of the Teletask system.

The panel has a number of other capacities such as control of all elements of the system or display of messages (programmed messages or information about present risks). It is also possible to visualise various parameters on screens such as consumption/production of energy, temperature changes, etc. on a daily, weekly, monthly or yearly basis. The graphs are presented as linear or bar graphs, depending on the type of the sensor. Additionally, it is possible to generate a graph from any time interval on visualisation screens. The data from the sensors are stored in the central processing unit memory, which allows for their accessing from any actuator or handling device. The exemplary graph for the monthly room temperature is shown in figure 8.

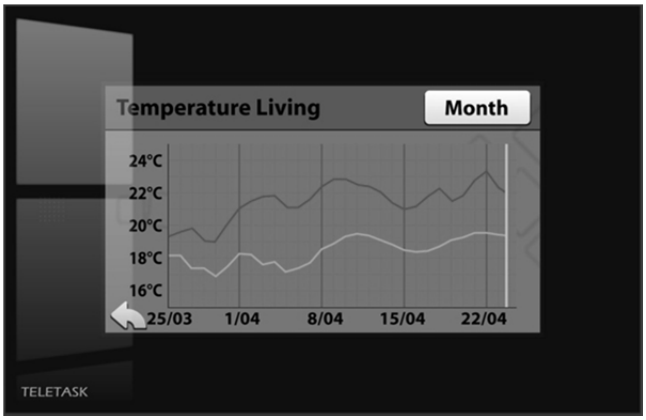

Fig.8. View of the temperature sensor graph window on the touch panel of the Teletask system [9].

Time schedules

As well as the control methods in the configuration settings of temperature sensors, there are still other adjustment options. One of them is the use of time schedules based on different clocks (daily, working days, weekends, special clocks) in the TIMESOFT tab of the Prosoft application. The view of the schedule setting window is presented in figures 11 and 12 in the next chapter which concerns the performed system design.

The use of time schedules allows for the obtaining of the optimal temperature in the respective zones, depending on the destination of rooms and the needs of the users, maintaining the appropriate comfort.

Temperature control simulation design

In order to examine the thermal energy savings, resulting from the use of the Teletask building automation, the design of the system which would allow for the temperature control was prepared at the Intelligent Building Laboratory of the Institute of Electrical Engineering and Electronics - Poznan University of Technology. The following equipment of the Teletask system was used for this purpose:

- the NANOS central unit,
- the interface of eight 8x10A relays TDS13502,
- the 8-fold analog input interface - 0-10V TDS12309,
- the 8-fold digital input interface - TDS16015.

The view of the electric cabinet including the control elements is presented in figure 9, while the model with actuators, sensors and buttons is presented in figure 10.

Fig.9. Cabinet with the TELETASK system modules used to control the temperature

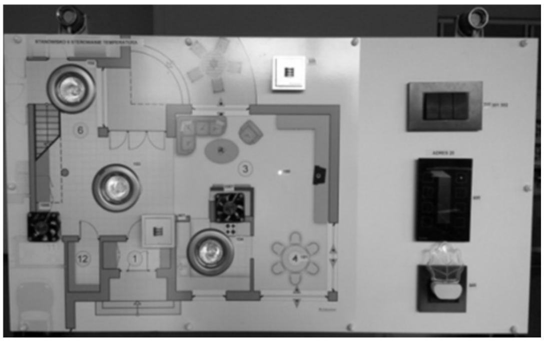

Fig.10. Model of a laboratory station for temperature control

The model of the building includes 2 electrovalves and 2 fans which fulfil the function of actuators of the HVAC system. The temperature is controlled by means of two TDS12310 temperature sensors (marked as sensors 600 and 601). The settings may be manipulated by means of monostable buttons and the AURUS 8OLED touch panel. On top of this, additional elements were integrated such as the electrical socket, lighting fixtures, LED's (which are used for the purpose of lighting and simulation of operation of window roller blinds). In order to control the temperature of the office space on a real basis, the electrovalves from the model were installed on radiators in the laboratory. The room is located on the second floor of the building and has windows coming out in the eastern direction. The second group of tests was performed in the living room of a private single-family house with the cubic volume similar to that of the laboratory.

The simulation of the operation of the heating system was carried out on the basis of the assumed programme of minimum temperature values in the living and office spaces. The set temperature in the '*DAY'* mode was 21°C, and in the *'NIGHT' mode, it was reduced to* 19°C. The time schedule setting windows are shown in figures 11 (for the single-family house) and 12 (for the office). The graph, which shows changes in the set temperatures is presented in figures 13 and 15, for the living room and for the office respectively. On the other hand the statuses of electrovalves of radiators at home and in the office are shown in figures 14 and 16.

One of the considered cases was the living room of a single family house. During the working days, when the first dweller gets up at 6 o'clock a.m., the daily temperature was set by one hour earlier so as to heat the room appropriately. On the other hand, at 8 o'clock (an hour before leaving the house by the last dweller) the operating mode was switched to the night mode with the temperature set to 19°C. Between 1.00 p.m. and 9 p.m. the system operated again in the daily mode. In the evening, at 9 p.m., the '*NIGHT'* mode was switched on again. Similar measurements were performed for a selected weekend day, however, the difference was that the control programme was set to the daily operating mode in the hours between 7 a.m. and 10 p.m. (fig.13). The 600 temperature sensor monitored the value of the current room temperature on an ongoing basis. Based on the measured temperature value, the automatic adjustment system chose to open or close the radiator electrovalve (in the case of a difference between the real and set temperatures amounting to 0.5°C). The graph which presents changes in the room radiator valve statuses on a selected working day and a weekend day is shown in fig.14.

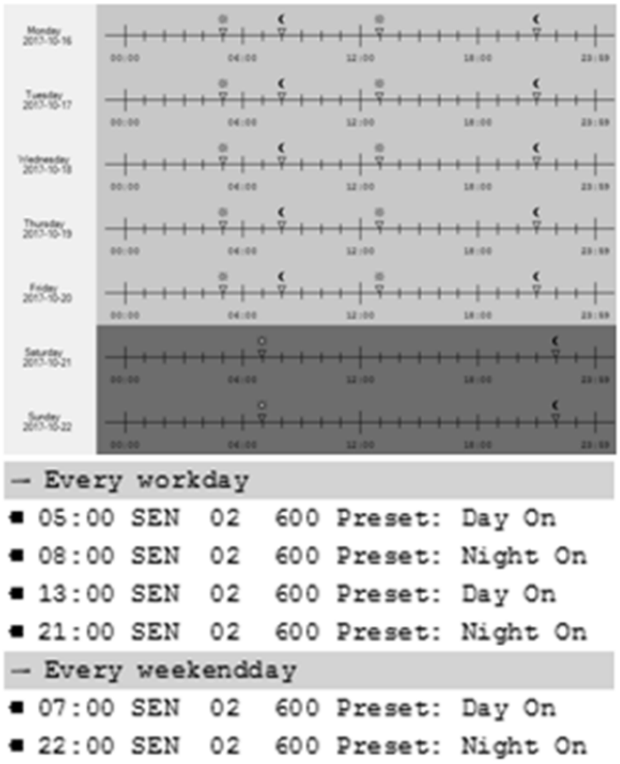

Fig.11. View of the TIMESOFT window including work schedule settings for the heating of the living room

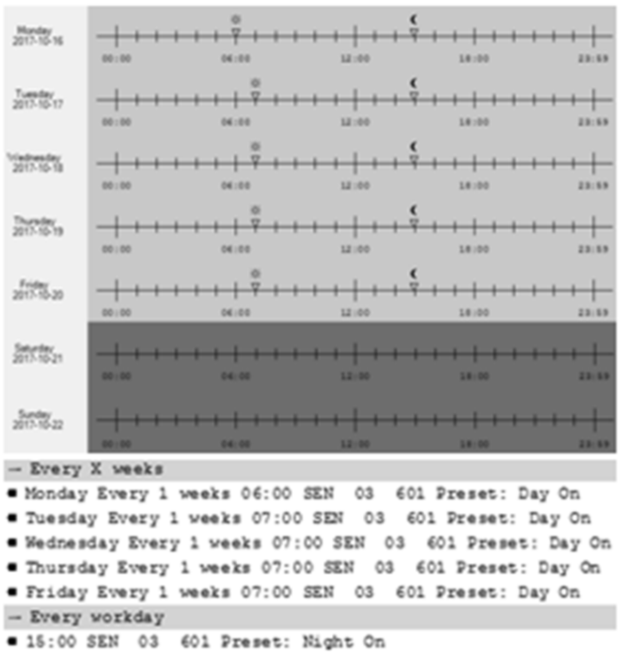

Fig.12. View of the TIMESOFT window including work schedule settings for the heating of the office building

The second case under consideration was the daily mode of functioning of a public facility (laboratory of the Poznan University of Technology) in the 8-hour work system in the hours between 8 a.m-4 p.m. Each working day, the control system set the heating devices to the daily mode at 7 o'clock a.m., activated the night mode at 3 p.m. and lasted throughout the weekend until Monday 6 a.m. An exceptional earlier increase in the temperature only on Monday was caused by the necessity to heat the room after the weekend, so that the users would not feel any thermal discomfort.

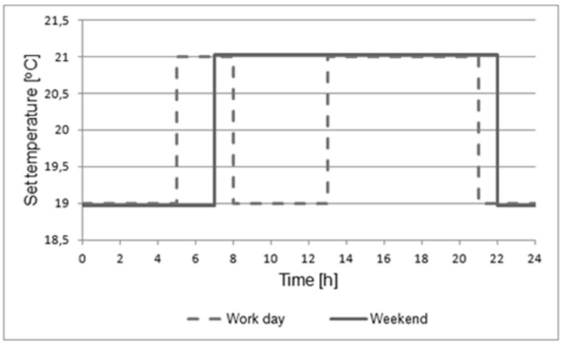

Fig.13. Graph, which shows the temperature set in the room of a single-family house

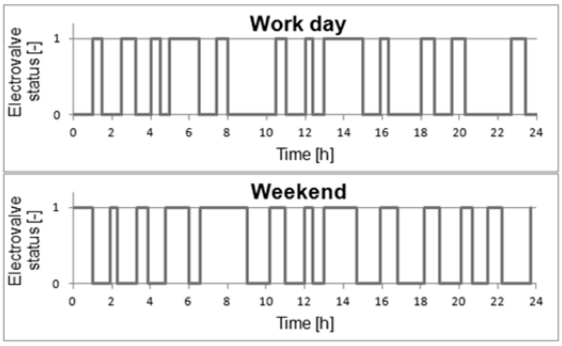

Fig.14. Status of the radiator electrovalve in the room of a single-family house (0 – OFF, 1 – ON)

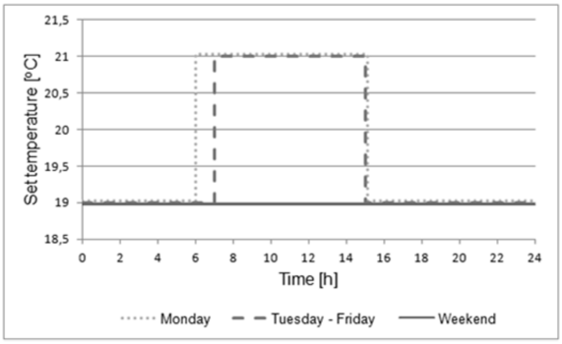

Fig.15. Graph which shows the temperature set in the office space

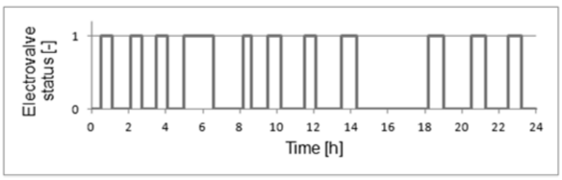

Fig.16. Status of the radiator electrovalve in the office space on a selected day from Tuesday to Friday (0 – OFF, 1 – ON)

The tests were performed for a period of 7 days for each of the rooms in the month of October 2017, when the daily external temperature changed within the range between 5 and 18°C. The graphs which show the operating times of the electrovalve can be used to calculate the savings resulting from the automatic temperature adjustment in the rooms intended for various purposes.

The conducted measurements showed that during the analysed autumn period, the actuators managed to maintain the constant temperature in the room, operating for only 40% of the time in the case of the living room in a residential building and about 30% of time in the case of the office room. By comparing such a system of operation with continuous operation, we are able to achieve the savings at the level of even 60-70% of the total energy used for the correct functioning of the heating system and the provision of the required thermal comfort to the users.

The room in the single-family house was subject to a decelerated process of cooling caused by the presence of persons and activities performed by them (watching TV, preparing and consuming meals, etc.). In the office, on the other hand, the longer breaks in the functioning of the heating during the working day were influenced by the continuous presence of persons and the used equipment (mainly computers). Such big savings also result from fairly high external temperatures, which contributed to the cooling of the rooms and loss of the heat through external walls. During the wintertime, at negative temperatures, the breaks between the respective periods when the valves are open, will surely be shorter than those measured during the studied period.

Conclusions

The options available in the Teletask system with regards to sensor settings and temperature preset control offer a wide range of options for the system design depending on the intended use of the building (houses, office buildings, hotels, manufacturing plants, etc.).

While analysing the consumption of electric energy and thermal energy by the heating systems and the lighting, both of which constitute the largest part of exploitation costs of the building, it is necessary to take into account the use of the building automation systems in order to reduce the energy consumption. The incurred investment outlays may be compensated owing to the generated energy savings, and even bring profits in the later perspective (owing to the periodical, and not permanent heating/cooling of the rooms and reduction of presets in the absence of persons in controlled zones). An unmeasurable element is also the comfort of work and life of the users, which will be improved in view of ensuring constant temperature conditions.

The conducted tests have confirmed that the use of the building automation system to control temperatures will generate savings related to the reduction in the use of the thermal energy. During the autumn period under consideration, it is possible to obtain even 60-70% of gains depending on the type and use of the room. The savings on an annual basis may reach about 30-40%, which is confirmed by numerous literature sources. [1,13,15].

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