223UNIVERSITY OF NIS FACULTY OF MECHANICAL ENGINEERING

THE SIXTH INTERNATIONAL CONFERENCE
TRANSPORT AND LOGISTICS

til 2017

IMPROVING A SERBIAN CITY RAILWAY STATION BY IMPLEMENTING CONCEPT OF INTELLIGENT BUILDINGS

Nemanja MARKOVIĆ[1,2]
Žarko ĆOJBAŠIĆ[2]
Milan RISTANOVIĆ[3]
Nedeljko DUČIĆ[4]

[1)] Philip Morris Operations Serbia, Niš, Serbia
[2)] Mechanical Engineering Faculty, University of Niš, Niš, Serbia
[3)] Faculty of Mechanical Engineering, University of Belgrade, Belgrade, Serbia
[4)] Faculty of Technical Sciences Čačak, University of Kragujevac, Serbia

Abstract

Public buildings such as railway stations display many similar design, operation and maintenance features in most countries. The two most noteworthy similarities amongst these building types are high-energy consumption and necessity for retrofitting many buildings within this sector. This paper presents a concept of improving a Serbian city of Paraćin railway station by implementing concept of intelligent buildings. Improvements are based on introduction of Building Automation System (BAS) with computationally intelligent features, along with HVAC control and LED lighting system. Proposed enhancements are aimed at increase in energy efficiency and user comfort in main railway waiting room.

Key words*: railway station, intelligent building, building automation system, HVAC, LED lighting, computational intelligence.*

1 INTRODUCTION

Buildings are increasingly common form of the spatial planning in modern urban environments as well as railways. Surveillance systems and energy management systems, air conditioning, security systems, fire protection systems, and even systems of protection against earthquake or wind gusts, are now realized as an integral part of individual buildings and are commonly integrated at the level of harmonization of all functional aspects of executing global strategy of "intelligent buildings" [1].

Consumption of energy in the World is increasing fast, and the production capacities are limited. For the transport of passengers and goods at the railways, passengers waiting at the railway stations consume large amounts of energy. European directive 2006/32/EC2 has declared improvement of energy efficiency and cost-effective energy savings in an economically efficient way. Therefore, the rationalization of energy is also necessary at the railway stations.

Energy consumption of railway stations can be rationalized in different segments trough the LED lighting, heating, ventilation and air condition and introduction of computationally intelligent Building Automation System (BAS). Railway station in a Serbian town of Paraćin has two containing buildings (main building and ambulant building) and warehouse. Main building consists two floors - ground and first floor. Ground floor has waiting rooms, public toilets, control tower, ticket office, stationmaster office and boiler rooms. Upstairs stationmaster apartment and meeting rooms are located. In March 2008, railway station has been renovated by doing constriction works and improving heating system and boiler house.

The major construction project was regarding improving of heating system in main building - ground floor by installing of radiator and floor heating in waiting rooms and improving old system. Also, additional ventilation system for public toilets has been installed.

In this paper concept of control of HVAC system, LED lighting and Building Automation System (BAS) is presented through concept of automation of waiting room, which provides for the highest energy efficiency with simultaneous application of intelligent concepts that provide higher comfort during system usage. Required control functions are presented along with description of proposed solutions. Also, use of computational intelligence is foreseen, in order to provide some intelligent functions to the system and further enhance user comfort and efficiency.

2 CURRENT STATE OF CONSIDERED RAILWAY STATION BUILDING

During adaptation, all heating and ventilation installations were renovated at the ground floor in total area of 404 m^2. Considering position of the building the following climate conditions have been adopted:

- Climate zone one;
- The external temperature value t_e = -18°C (JUS U.J5.600);
- The internal temperature according to the purpose of the various rooms: waiting room 18°C, toilets 15°C, other rooms and offices 20°C

Two boilers houses located in west part of the building are used, with all needed elements, for radiator heating facility. First boiler house, located in room 17a (Figure 1) is used for heating of waiting room (position 9, 10), offices (room 11, 12 and 13) and public toilet. Second boiler house located in room 4 is ensuring heating for other areas in the ground floor which are not covered with boiler house 17a. As the fluid, the hot water 90/70°C is used. Water heating is done with the help of two electric and two gas boilers of power N = 36kW retrospectively located in room 4 and gas and electro boiler power N = 24kW and N = 18kW retrospectively located in room 17a. Each boiler room is equipped with all necessary kits for providing heating (pump, expansion vessel, valves etc.). The boiler water splitter leads to two branches: one branch for radiator heating and second for floor heating of the building, for which supply hot water temperature is appropriately reduced for floor heating by mixing walve in second heating loop.

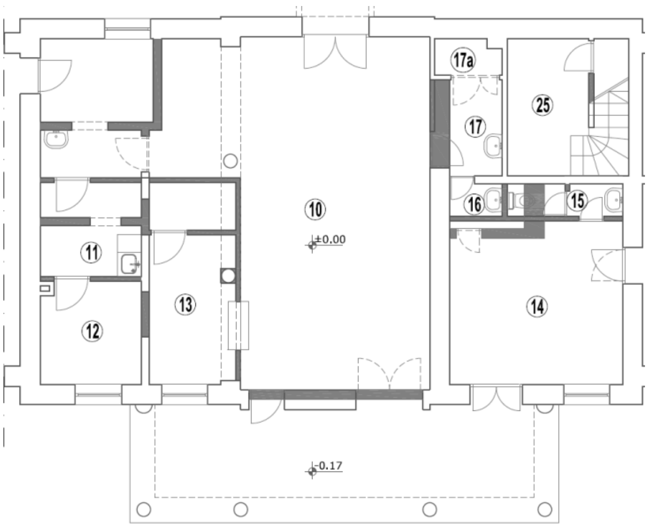

Fig. 1 *Railway station in Paracin*

As the heaters, aluminium radiators GLOBAL type VOX for space heating are used. For the floor heating of waiting room PEX-ALU-PEX pipes are used. Radiators are placed under windows with height according to the height of the parapet. Horizontal pipe network runs partly on the ceiling and in most of the rooms on the floors which are located above boiler room. Piping network for supply of radiators in waiting room 9 & 10, public toilet room 8, as well as offices 11, 12 & 13 is separately heated from the boiler house located in room 17a. This boiler house is used for floor heating in the waiting rooms as well. The pipe network in the boiler is isolated with mineral wool cape with envelope made of aluminium or galvanized steel, sufficiently reducing the cooling of the heating water in the pipes.

The heating fluid is hot water, while the changes in the water temperature depending on external environmental conditions are taken into account. Water heating boiler operates electrical power or gas for boiler house. Each boiler contained 9kW heaters and depends of the power number of heaters can be 2 or 4. Electrical boilers heaters are controlled by relay which is controlling heaters to work 40s and to be switched off 20s. On this way those boilers have annual saving up to 30% of electrical power.

Control of water temperature is done independently of the radiators' supply water temperature control. Supply water temperature is automatically regulated and limited by the boiler control and the process can be monitored at the display.

Heating of the waiting rooms 9 & 10 is performed by radiators installed that are placed under the windows and Pex-Alu-Pex pipes located inside floor. Radiators are placed at the two sides, north and south.

Taking in consideration that even during daytime daylight cannot ensure enough amount of light in the building, lighting is ensured with help of regular incandescent lights which are consuming lots of energy.

3 IMPROVING ENERGY EFFICIENCY AND USER CONFORT BY IMPLEMENTING INTELIGENT RAILWAY STATION BUILDING CONCEPT

Railway stations are categorized as large public buildings that consume large amounts of energy due to their large size and high occupant density. Considering that average number of passenger in Serbian railways is 18 Mio people yearly where 20 % of average energy consumption (296 MWh) is going on lighting and HVAC system in the railway stations, large potential saving can come through optimizing lighting and heating systems in railway stations.

Increasingly high level of automation of public buildings in world can be observed through fact that 16 % of energy consumption is used for BAS systems in public buildings (Figure 2). Therefore, implemenation of BAS along with integrating computational intelegence features, can provide increased energy efficiency at the same time providing higher user confort and intelligent functions.

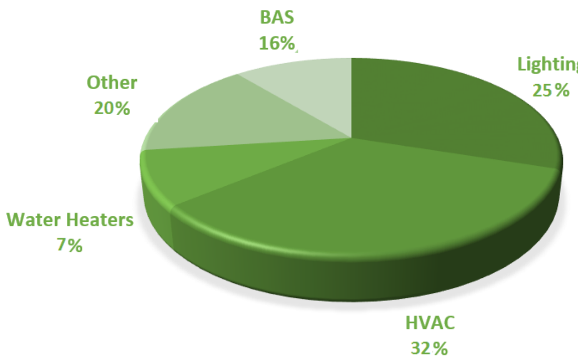

Fig. 2 *Energy consumption in public buildings [2]*

According to the worlwide study [3] intelligent controls can help reduce energy usage by as much as 40% in case of new buildings and Greenfield investments. For existing buildings, energy efficiency this percent may increase significantly by 18% on average after recommissioning.

First design strategy considered here is to adopt active design strategies for highly efficient equipment to provide heating, cooling and ventilation. Second considered improvement is to optimize current lighting system. Third task is to adopt intelligent controls for building envelope and equipment based on actual demand to sustain a safe, comfortable, and energy-efficient building environment.

Finally, in terms of renewable energies, it is necessary to carry out technical and economic assessments to avoid possible failures and long payback periods.

3.1. Advanced HVAC implementation

As strategies to save energy in the railway station HVAC system, the following aspects should be considered:

- Appropriate selection of chiller type
- Appropriate selection of heating source
- Heat recovery on air terminal
- Lover level ventilation and temperature control
- Adjusting of temperature set points

By instaling variable chiller plant, variable frequency control over chilled and cooling water pumps as well as cooling tower fans could be enabled. Pump frequency is dependent on the pressure drop within the closed loop, where the speed of the cooling tower fan is dependent on the chilled water outlet temperature. This can save up to 4% of total energy.

Variable air volume air-conditioning system is enabled by the air-conditioning box in the entrance and waiting areas. The minimum air volume should be set at 60% of the designed value. This measure can save up to 6% of the total energy for every 1° change in temperature.

Heat recovery from fresh and exhaust air enables full heat recovery between fresh and exhaust air in the waiting area with a heat exchange wheel [4]. This can ensure savings of up to 3% of the total energy.

Indoor Air Quaility (IAQ) is also proposed for waiting room, in order to increase comfort while maintaining operational costs as low as possible. Such control has many benefits, from lowering ‘sick building syndrome’ to allowing greater number of people to occupy waiting room. Indoor Air Quaility (IAQ) is expressed through measuring two variables, carbon dioxide (CO_2) concentration and Volatile Organic Compounds (VOC). Typical concentrations of carbon dioxide with relevances are presented in Table 1.

Table 1. CO_2 concentration levels

CO_2 [ppm]	Relevance
330	Normal outdoor concentration
1000	20% of people dissatisfied with IAQ
1500	Limit value according to DIN 1946
2000	Sensitive persons have headache
4000	Max. classroom value at the end of lecture
5000	Maximal acceptable offices concentration
100000	Loss of consciousness

3.2. Improvement of lighting system

Improving of current lighting system should be done by ensuring following criterias:

- Light quality inside building should ensure maximum confort of the users,
- Lamp selection should ensure maximal energy efficiency.

According to European directive EN-12464 reccomendation for light illumination in public buildings is 200 lux.

Considering all of the above, suggested choice is to use LED lights instead of regular incandescent lights. By using LED lights energy saving can be improved up to 80% having in mind that energy consumtion of LED lights is eight times less [3]. In order to ensure right spectre of light for the purpose, LED lights should be chosen with 6500K.

Illumination daylighting control can improve energy consumption by integrating such system which controls lighting power. When illumination reaches 200 lux, lighting control would switch them off. This measure saves up to 5% of the total energy according to simulation results. It is noted that if a dimming system is used, the saving rate could be higher [5].

However, dimming systems require electronic dimmable ballasts and are therefore more expensive than a switching system, especially in retrofitting existing lighting systems that do not have electronic dimmable ballasts. However, dimming systems achieve the highest savings and do not have the abrupt changes in light level characteristic of switching systems.

3.3. Implementation of BAS enhanced with computational intelligence

Success of BAS implementation comes from true integration of all building systems. Furthermore, intelligent BAS control is the interaction between building envelope, building services, and human factors, and it means the fundamental integration of all systems. It requires careful checking and verification throughout the design, installation, and commissioning stages and operation. Intelligent controls not only require hardware to be installed but also rely on accurate control strategies set up by software. An international case study [3] shows that integrated hardware and software control systems are required as a platform to monitor and control all building equipment as well as an integrated energy management platform to monitor all energy consumption to achieve the proclaimed objectives.

Summarized, many of intelligent building technologies that are already used in commercial buildings can also be suitable for railway station buildings. However, the implementation of these technologies requires more detailed consideration. International experience shows [6] that integrative design is essential for an integrated system to work rather than technologies being simply stacked together.

The purpose of a building management system (BMS) is to ensure station comfort through maintenance of a range of systems, such as temperature, humidity, air quality, and lighting illumination; when setting up a BMS, the first step is to define the correct comfort requirements, and balancing comfort levels with energy consumption levels [7]. The criteria can be classified into the following categories:

- The indoor dry bulb temperature index: in the station temperatures need to be set for winter and summer months.
- The indoor relative humidity index: seasonal changes in humidity need to be determined.
- The indoor air quality index in station: carbon dioxide concentration is mostly used as a measurement [7].
- Indoor air-conditioning air speed and wind noise index: these indexes measure the quality of design and installation and are hard to achieve by simply relying on BMS [8].
- Lighting system should be adjusted according to number of users and day period

Besides this, additional high level control computational intelegence can be applied trough temperature controllers which have internal temperature sensors and control loop. Controller generates control signal based on deviation of the measured temperature form the desired reference in the waiting room. Valve is controlling the volumetric flow rate of the warm water, i.e. heating power. Implemented control algorithms could in principle be various control laws.

By means of calorimeter, which should be installed on radiators, instantaneous heat power is constantly measured, as well as supply and return temperature, flow rate and cumulative energy.

System measures all values and they are available. Data acquisition of values that are measured throughout system can be used for modelling, identification and verification of the heating system performance, as well as for optimizing control in terms of improving energy efficiency [9].

System can be also designed to operate in two heating modes: winter and summer mode. Pre-defined heating modes provide high user comfort and energy efficiency.

In addition, to increase comfort and add autonomous behaviour, presented heating control is empowered with additional intelligent functions:

- Intelligent fuzzy controlled temperature set point correction in the comfort heating regime and lighting based on the current occupancy.
- Implementation of intelligent optimum start controller.

Fuzzy supervisory temperature set point correction [10] is an intelligent system function aimed at improving thermal comfort and lighting of the waiting room audience. Namely, normal occupancy in the waiting room, requires that temperature setpoint is set as 20°C with normal lighting, while low occupied waiting room during busy periods means that temperature setpoint should be somewhat increased to improve user comfort. To provide information of occupancy level, signal is sent by using several occupancy sensors.

Occupancy is estimated during five consecutive five minute samples, then fuzzy supervisor exhibits the following rules:

R1: If occupancy is normal then temperature_setpoint is default and lighting is defauilt

R2: If occupancy is low then temperature setpoint is slightly increased and lighting is slightly decreased

R3: If occupancy is high then temperature setpoint is slightly decreased and lighting is slightly increased

For example, if system default temperature setpoint for comfort regime is set to 20°C and lighting 200 Lux, then fuzzy supervisor is allowed to change setpoint in the interval (±2°C, ±40 Lux).

Replacement of existing fixed start time control with optimum start/stop control can generate 10% energy savings for heating systems operating single shift. In addition to delivering energy savings, optimum start control would substantially improove comfort preventig under-heating at time of occupancy and by shutting down the heating system during the day if the external temerature rises. Optimum start controls have the capacity to greatly improve the environment and comfort within the building and deliver substantial carbotn and cost savings.

Such features can increase user comfort while reducing energy consumption compared to mannualy operating facilities, based on reported research [2][3][6][10].

4 CONCLUSIONS

Intelligent or smart buildings encompass a broad range of fields and providers, including those related to electrical systems, installation, computer science, and software engineering. The design of the building, lighting, HVAC, and control systems are put together by individual firms and outsourced contractors who do not have incentive or knowledge to integrate these different systems [9]. Lack of integration presents a challenge to green buildings as a platform for integrated systems to work together to increase efficiency, and ensure the comfort and safety of occupants.

Proposed building automation in Serbian city of Paraćin railway station is intended to be easily monitored during the operation of all considered systems. Biggest improvement of energy saving and confort index in considered railway station can be done by replacing existing systems and by introduction of BAS systems described in this paper, which also makes prerequisites for applying additional intelligent system functions.

ACKNOWLEDGMENT

Research has been supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under Grants TR35016, TR35005 and TR33047.

This study was done within project No.574591-EPP-1-2016-1-RS-EPPJMO-MODULE "Sustainable, Intelligent and Environment Friendly Transport and Logistics in Urban Context: Promoting EU Standards and Principles in Southeast region of Serbia", co-financed by ERASMUS+PROGRAMME JEAN MONNET.

REFERENCES

[1] Ćojbasić, Ž., Ristanović M., Marković N., Tešanović S., 2016, *Temperature Controller Optimization by Computational Intelligence*, THERMAL SCIENCE 2106, vol. 20, pp. S1541-S1552.

[2] US dept. of Energy, 2010, *Energy Efficiency Trends in Residentials and Commercial Buildings*, Energy Efficiency & Renewable Energy.

[3] Asian development bank, 2015, *Improving energy* efficiency *and reducing emissions through intelligent railway station buildings*, Research, China.

[4] Guy W. Gupton, Jr, *HVAC Controls Operation & Maintenance*, Fairmont Press Inc, Liburn, 2002.

[5] Pandharipande, A., Caicedo D., Wang X., 2014, *Sensor-Driven Wireless Lighting Control: System Solutions and Services for Intelligent Buildings*, IEEE SENSOR JOURNAL, vol. 14, issue 12, pp 4207-4215.

[6] Shengwei W., *Intelligent Buildings and Building Automation*, Spon Press, New York, 2010.

[7] SRPS EN 15232:2014 – Energy performance of buildings – Impact of Building, Automation, Controls and Building Management.

[8] Mirinejad, H., Conn Welch K., Spicer L., 2012, *A review of Intelligent Control Techniques in HVAC Systems*, Energytech IEEE.

[9] Yudong, M., Kelman A., Daly A., Borelli F., 2012, *Predictive control for energy efficient buildings with thermal storage: modelling, simulation and experiments*, IEEE CONTROL SYSTEM MAGAZINE 2012, DOI:10.1109/MCS.2011.2172532.

[10] Ćojbašić Ž., Ristanović M., Nikolić V., Stojiljković S., Marković N., *Intelligent contemporary heating control of an amphitheatre*, Proceedings of 16th Symposium on Thermal Science and Engineering of Serbia, ISBN 978-86-6055-043-1, pp 634-639, 2013.

Contact address:
Žarko Ćojbašić,
University of Niš, Mechanical Engineering Faculty
18000 Niš, Serbia
Aleksandra Medvedeva 14
E-mail: zcojba@ni.ac.rs