FRI-10.326-1-EEEA-12

INTELLIGENT MANAGEMENT SYSTEMS POWER SUPPLY AND MICROCLIMATE IN BUILDINGS.ANALYSIS OF THE MAIN TYPES APPLIED TO TECHNOLOGIES AND ALGORITHMS OF MANAGEMENT

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Abstract: *The article analysis the existing methods and algorithms of the automatic control system (ACS) in BEMS-systems (Building energy management system).The purpose of the article is to analyze the existing systems of intelligent management power supply of buildings, their main types and used technologies (sensor networks with IoT (internet of things) and ICT (information and communications technologies), wireless sensor networks (WSN), BIM, etc., as well as the study of the current state of elements of management and the identification of strengths and weaknesses. Special attention is devoted to the most promising methods of management of BEMS-systems.Based on the study of management methods established that methods with the creation of neural networks, fuzzy logic and the application of artificial intelligence are perspective. The analysis shows that the introduction of such systems is currently laborious, requiring large computational power, additional specifications and increases the setup time of the system.*

Keywords: *Building Energy Management system (BEMS), heating, ventilation and airconditioning (HVAC), IoT technologies and ICT, BIM, wireless sensor networks, intelligent systems.*

INTRODUCTION

Over the past decade, the rapid growth in energy consumption and the associated CO2 emissions, with a reduction in the amount of the planet's fuel and energy resources, have led research scientists to pay special attention to finding energy efficiency solutions. Among all sectors of energy consumption, buildings and residential complexes, according to reports by the United States Department of Energy (DOE), more than a third (up to 40%) of total world energy consumption and more than 60% of electricity consumption belong to residential/commercial buildings sector (Farmani,F., Parvizimosaed, M., Monsef H., &Rahimi-Kian A., 2018). About 90% of the total energy consumption by the housing and communal services sector of the Republic of Kazakhstan is spent on building exploitation. Residential buildings are characterized by the highest energy consumption – 50-55%, industrial buildings are somewhat less, 35-45%, and civilian buildings account for about 10%. In housing and civil engineering, energy efficiency reserves reach up to 40% (Toporov, V.,I., &Amirbaev, T., R., 2012). In this regard, measures to reduce heat and energy are of great importance for the Republic.

EXPOSITION

I. Building Energy Management Systems (BEMS). In modern literature, to describe optimal energy management systems for buildings, the generally accepted term is Building Energy Management System (BEMS), which is an integral part of intelligent buildings and smart houses that control not only heating, ventilation and air conditioning (HVAC) systems, but also lighting, monitoring of energy consumption parameters, security system, etc.

BEMS is a comprehensive, multi-level, multi-purpose, integrated, interconnected and fully intelligent information building management system, combining software and hardware to control the activity of any building.

BEMS focuses on four main functions (Park, J.,Y., & Nagy, Z., 2018):

1. Monitoring: continuous monitoring of sensor measurements.
2. Management: algorithms for managing systems of buildings.
3. Optimization: increase system performance.
4. Reporting: documentation of interim and final results.

Research in the field of development BEMS are displayed in the works (Lund, H., Ostergaard, P.,A., Connolly, D., & Mathiesen, B., 2018).

Many scientific papers have noted that in order to effectively manage the power supply system of buildings it is necessary to take into account dynamic environmental parameters (Amin, U., Hossain, M.J., Lu, J., & Fernandez, E., 2017). Thus, authors states that, using the example of office building analysis in a shopping center in Sweden, the load to the heating system can be reduced by more than 40% (Jahedi, G., & Ardehali, M.M., 2011). Such a system is defined by the authors of the work as the BEMS intellectual system, operation model of which includes the operational modules of lower and upper levels (Fig.1). While the lower level module focuses on the operation of HVAC and other engineering systems in order to maintain the internal microclimate within certain limits, the upper level module determines how well the resulting climate control and other loads are satisfactory. As a result of a numerical study, the authors argue that the introduction of intelligent BEMS as compared to standards (which the Austrian state is actively introducing into buildings) is low-cost, more energy efficient and leads to a significant reduction in CO2 emissions.

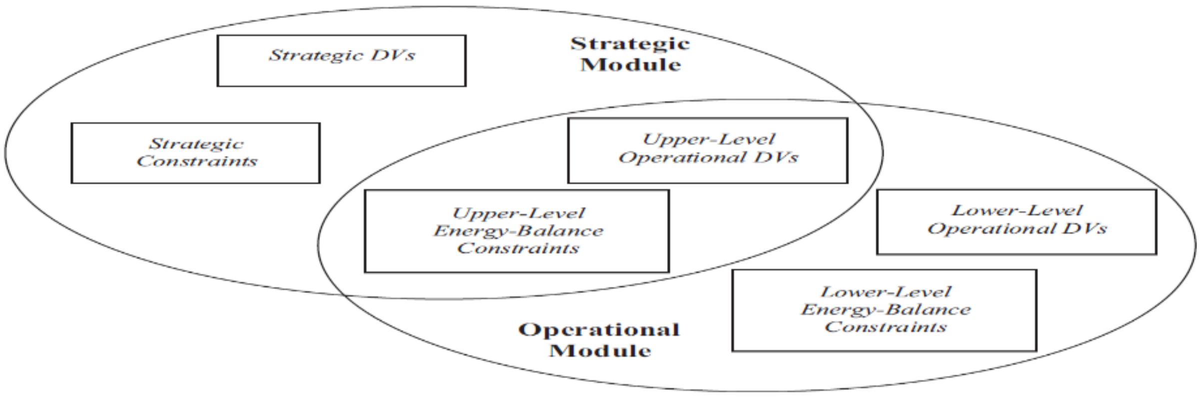

Fig.1. Scheme of BEMS (Jahedi, G., & Ardehali, M.M., 2011)

In the works (Ibragimova, M.V., Stoyak, V.V., & Kumyzbaeva, S.K., 2016), (Ibragimova M., Stoyak V.V., Kambourova V., & Streicher, W., 2017), the authors apply the methods of dynamic simulation modeling of the energy balance of buildings for more efficient and energy efficiency using of the power supply system.

The authors of (David, M., Aubry, A., & Derigent., W., 2018) payspecial attention to the correct designing and qualitative development of BEMS, and also found that the amount of energy consumed by the building exceeded the expected figures calculated at the time of designing. The main reasons for high consumption include the low performance of solar panels and the inefficient operation of the BEMS due to its incorrect designing.

II. Algorithms and methods of ACS in BEMS. Below is an analysis of the methods and algorithms used in building energy management systems, as well as modern achievements in information and computational methods that have attracted the greatest interest of research scientists in this sphere (Kim, A., Han, J., Yu, T., & Kim, D.S., 2014).

Classic controllers:

Binary controller. In cases where the search for output modulation is not required, binary or on / off is widely used for small systems in buildings, in particular for controlling room temperature using standard thermostats; this mechanism is prone to hysteresis and overshoot. In basic form, the binary temperature controller also gives a deviation from the setpoint, which requires more complex controls.

PID controllers. It is known, that careful adjustment of the controller and selection of the coefficients is necessary for a perfect system operation with a PID controller. However, the problem lies in the non-linearity of operation of all HVAC systems, as a result of which the system can be precisely tuned in one part of the operating range (for example, at full load). To solve this problem, researchers have proposed several methods of auto-tuning: retransmission an automatic tuning, step tests with an open loop, or a combination of them.

Computational control methods. Scientific researchers are currently actively proposing the replacement classical elements of management on some hybrid solutions that contain elements of classical controls. Below are some of the most well-known methods.

Supervisory Method. Over the past two decades, the collection of large amounts operational data of online mode along with the growing integration system of software security building automation has allowed the development of optimal management strategies to find the optimal solution for the building's energy supply system, with considering the carbon and cash costs of electricity and gas (Peng, C., & Qian, K., 2014). It is important to note that the supervisory method includes many methods that often include training methods (such as artificial neural networks, fuzzy logic, or genetic algorithms).

Method of stimulated learning. In this case, the management system improves work by analyzing previous actions, i.e. performs automaticalautocalibration of control parameters and used in conjunction with the neural network of artificial intelligence and fuzzy logic methods (Plageras, A., Psannis, K., Stergiou, C., Wang, H., & Gupta B., 2017).

Control method with fuzzy logic. This method resembles the process of human thinking, since it can deal with partial truth (ordinary binary variables are either true or false) (Lizanaa, J., Friedrichb, D.,Renaldib, R., & Chacartegui, R., 2018). Consequently, the fuzzy logic method is able to work more effectively with uncertainties in multivariate control systems.

Artificial neural networks. The ability self-learn an artificial neural network to determine the relationship between input and output parameters, aimed initially at predicting (behavior) and, ultimately, optimized system management.Examples of recent modeling attempts include the adaptation of artificial neural networks to control the temperature inside a building with a double fencing insulation system, the operation of a hybrid ground-based heat pump and the optimization of the power supply system and maintaining comfort in the house. Within all of these attempts, the artificial neural network performs the predictions that are used to make a decision about the next control action.

Agent-oriented management. Agents (in the form of electronic devices) are deployed and placed mainly in process automation systems and electronic equipment, which provides management flexibility and system reliability. These are interactive, automatic, and flexible components that are widely used in extremely complex systems. According to the results of the analysis performed, it can be concluded that the most promising control methods BEMS are methods with the creation of neural networks, fuzzy logic and the use of artificial intelligence. However, the introduction of such systems is currently laborious, requiring large computational power, additional specifications and increases the setup time of the system, so PID controllers still occupy a large share of automation, both in the industrial sector and in home automation systems.

III. Wireless sensor networks, IoT and ICT in BEMS. Wireless sensor networks provide low-power, energy-efficient solutions for building extensive networks with continuous measurements of the parameters of buildings any purpose, providing low cost and detailed monitoring of the internal environment (Lizanaa, J., Friedrichb, D.,Renaldib, R., & Chacartegui, R., 2018).

Currently, wireless sensor networks are widely adapted to areas such as aviation, automotive, agriculture, security, home automation, etc. It should be noted that, for the most part, the problems of data transmission and interference associated with wireless sensor networks have been solved, and underway further standardization to support their greater adaptation in the industry.

In addition to the work on the development of thermal monitoring systems and the management of HVAC systems for buildings based on wireless sensor networks, there are several works aimed at creating hybrid systems (Jradi, M., Arendt, K., Sangogboye, F.C., Mattera, C.G., Markoska, E., Korgaard, M.B.,Veje, C.T., & Jorgensen, B.N., 2018). For example, the authors of (Juan, A. Gomez-Herrera, Miguel & AnjosF., 2018) proposed an approach of cyber-physical systems for integrating the building information model of BIM (Building Information Modeling) and wireless sensor networks. In the proposed structure, wireless sensors are deployed in the building to monitor the thermal regime, after which data from wireless sensor networks are collected and transmitted to BIM, where the building model parameters are specified and used as input parameters for continuous modeling (Figure 2). This integration of BIM wireless sensor networks contributes to more rational management power supply of buildings by predicting the load on the system and the ability to manage in real time.

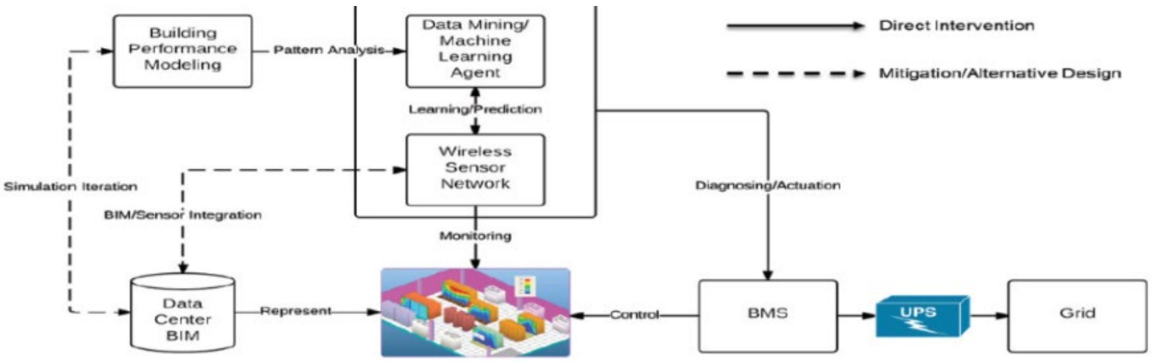

Fig.2. The integration structure of BIM wireless sensor networks
(Lizanaa, J., Friedrichb, D., Renaldib, R., & Chacartegui, R., 2018)

The deployment architecture and tools of wireless sensor networks make it easy to integrate into various Internet protocols. Nowadays a dominance of applications of web solutions or IoT technologies in BEMS (Yua, N., Salakijb, S., Chaveza, R., Paoluccia, S., Sena, M., & Antsaklis, P., 2017) is observed. The peculiarity of IoT technology is that it connects devices via the Internet, allows them to communicate with each other and with users, ensuring the achievement of specific goals such as energy efficiency, monitoring conditions and predicting service of engineering systems. The authors explore the functionality and the possibility of combining such technologies as big data processing, cloud computing and building monitoring using wireless sensor networks into one system in order to improve the energy efficiency of buildings. The analysis shows that the system proposed by the authors includes a network of sensors operating in the IoT environment, a cloud server analyzing the data obtained from the sensors and remote control of HVAC systems by users.

Another possible way to reduce the energy consumption of a building is the use of information and communication technology. According to the International Panel of Experts, (Wang, S., & Ma, Z., 2008) on climate change, by 2030 a reduction in energy consumption can be achieved of more than 30% by use of ICT solutions. In support of this statement, experts believe that ICT-based solutions may allow a (50–80)% reduction of greenhouse gases globally. In this regard, innovations in the field of ICT open up prospects for developing a range of new services that are highly affordable, flexible, secure, easily integrated and convenient for user.

CONCLUSION

The article provides a comparative analysis of more than 17 scientific publications, monographs, theses and reports of research work of students in the field of research and development of intelligent control systems for building energy supply and maintaining comfortable conditions of the internal environment. Based on the results of the theoretical studies, the following main conclusions can be drawn:

1. Many scientific papers note that in order to effectively manage the power supply system of buildings, it is necessary to take into account the dynamic parameters of the external and internal environment, which will reduce the load on the heating system by 40%.
2. A modern intelligent building energy management system is based on hybrid systems, which include the integration of wireless sensor network technologies, BIM, IoT and ICT, each of which is responsible for a separate sector BEMS.

REFERENCES

Amin, U., Hossain, M.J., Lu, J., & Fernandez, E. (2017). *Performance Analysis of an Experimental Smart Building: Expectations and Outcomes.* Manuscript. - 2017. - p.23.

David, M., Aubry, A., & Derigent., W. (2018). *Towards energy efficient buildings: how ICTs can convert advances?.* IFAC PapersOnLine. - p. 758-763.

Farmani, F., Parvizimosaed, M., Monsef H., & Rahimi-Kian A. (2018). *A conceptual model of a smart energy management system for a residential building equipped with CCHP system./* Electrical Power and Energy Systems. - 2018. - p. 523-536.

Ibragimova, M., Stoyak, V.V., & Kumyzbaeva, S.K. (2016). *Dinamicheskaya model' vliyzniyz klimaticheskih parametrov na energobalans zdanii.* Vestnik Almatinskogo universiteta energetiki I svyzi. - №4 (35). -2016. s.14-26.

Ibragimova M., Stoyak V., Kambourova V., & Streicher, W. (2017). *Simplified dynamic model of the building energy balance for the energy audit results interpretation.* 6th International Conference on Thermal Equipment, Renewable Energy and Rural Development TE-RE-RD 2017, Proceedings. – 2017. – p. 51-56.

Jahedi, G., & Ardehali, M.M. (2011). *Genetic algorithm-based fuzzy-PID controlmethodologies for enhancement of energy efficiency of a dynamic energysystem.* Energy Convers. Manage. 52 (1) (2011) 725–732.

Jradi, M., Arendt, K., Sangogboye, F.C., Mattera, C.G., Markoska, E., Korgaard, M.B., Veje, C.T., & Jorgensen, B.N. (2018). *ObepME: An Online Building Energy Performance Monitoring and Evaluation Tool to Reduce Energy Performance Gaps.* Manuscript. - 2018. - p. 16.

Juan, A. Gomez-Herrera, Miguel & Anjos F. (2018). *Optimal collaborative demand-response planner for smart residential buildings.* Manuscript. - 2018. - p. 14.

Kim, A., Han, J., Yu, T., & Kim, D.S. (2014). *Hybrid wireless sensor network for building energy management systems based on the 2.4 GHz and 400 MHz bands.* Information Systems. - 2014. - p.1-7.

Lizanaa, J., Friedrichb, D., Renaldib, R., & Chacartegui, R. (2018). *Energy flexible building through smart demand-side management and latent heat storage.* Applied Energy. - 2018. - p. 471-485.

Lund, H., Ostergaard, P.A., Connolly, D., & Mathiesen, B. (2018). *Smart Energy and Smart Energy Systems.* Manuscript. - 2017. - p. 21.

Park, J.Y., & Nagy, Z. (2018). *Comprehensive analysis of the relationship between thermal comfort and building control research - A data-driven literature review.* Renewable and Sustainable Energy Reviews. - 2018. - p. 2664-2679.

Peng, C., & Qian, K. (2014). *Development and Application of a ZigBee-Based Building Energy Monitoring and Control System.* Scientific World Journal. - Volume 2014. - p. 1- 13.

Plageras, A., Psannis, K., Stergiou, C., Wang, H., & Gupta B. (2017). *Efficient IoT-based sensor BIG Data collection-processing and analysis in Smart Buildings.* Manuscript. - p. 18.

Toporov, V.I., & Amirbaev, T., R. (2012). *Razrabotka issledovanie apparatno-programnogo kompleksa teplotehnicheskogo monitoring municipal'nyh obektov.* Otchet o nauchno-issledovatel'skoi rabote, Tovarishestvo s ogranichennoi otvetstvennost'u "Sistemotehnika"-2012. – s. 87.

Wang, S., & Ma, Z. (2008). *Supervisory and optimal control of building HVAC systems: a review.* HVAC&R Res. 14, (1) 2008, 3–32.

Yua, N., Salakijb, S., Chaveza, R., Paoluccia, S., Sena, M., & Antsaklis, P. (2017). *Model-based predictive control for building energy management: Part II – Experimental validations.* Energy and Buildings. - 2017. - p. 19-26.