9. Building management system solutions for the public nZEB

9.1. Introduction to building management systems

The most common current industry term for building management and automation is Building Management System (BMS) or Building Management and Control Systems (BMCS). BMS systems are "Intelligent" microprocessor-based controller networks installed to monitor and control a buildings technical systems and services such as heating, air conditioning, ventilation, lighting, hydraulics, etc.

Generally, the signals are sent to the actuators from the controllers depending on the data from the sensors (see Fig. 9.1.1.) after the processing with different algorithms. More specifically, they link the functionality of individual pieces of building equipment so that they operate as one complete integrated system. Now installed in every major building or facility with the availability of direct integration into all other building services such as security, access control, CCTV, fire, lifts and other life and safety systems. Commonly BMS systems are internet-enabled allowing integration of systems from multiple system vendors and access from anywhere in the world.

BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using specific protocols as C-Bus or Profibus. Vendors are also producing a BMS that integrates the use of Internet protocols and open standards such as DeviceNet, SOAP, XML, BACnet, LonWorks, Modbus. Building management systems are most commonly implemented in large projects with extensive mechanical, HVAC, and electrical systems. Systems linked to a BMS typically represent 40% of a building's energy usage; if lighting is included, this number approaches to 70% [9.1]. BMS systems are a critical component to managing energy demand.
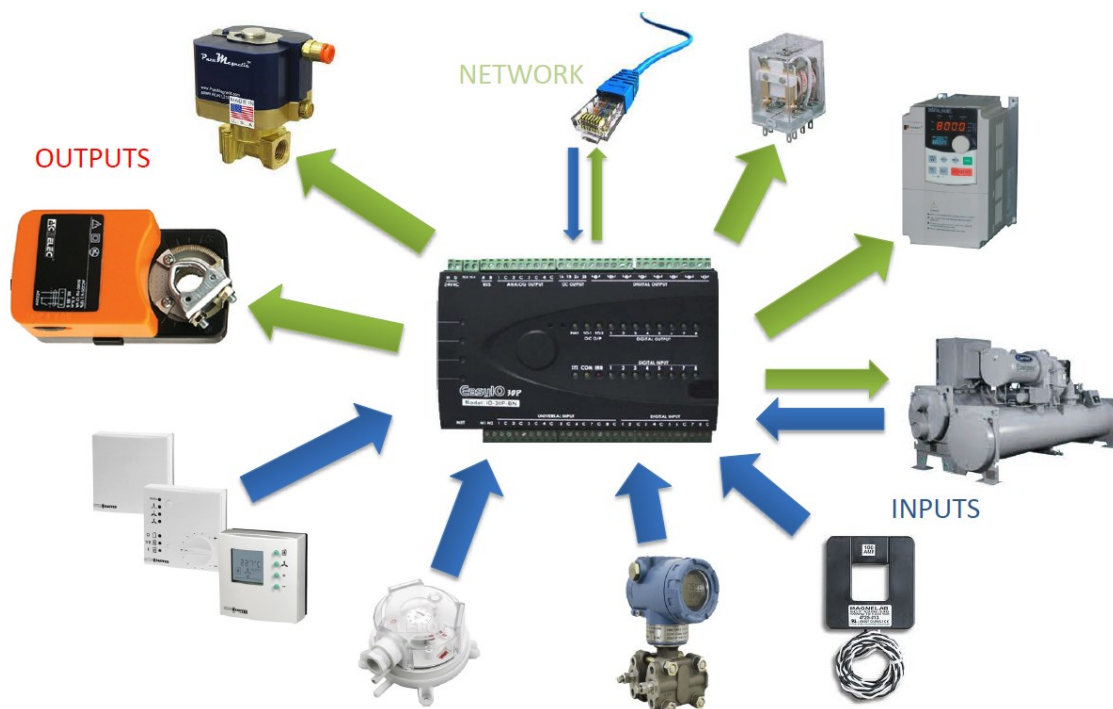
Figure 9.1.1. *Principle of BMS controller – outputs are depending on inputs.*

Typical system components used in BMS can be divided to tree groups: hardware, field devices – sensors/actuators and communications or networking. As BMS systems can be controlled by the technical or some of parameters monitored by ordinary user without any special education, there is wide range of user interfaces available for different BMS hardware and filed device components – from the basic LCD built-in display through to full graphic operator workstations with the web servers.

Approximate estimated lifecycle for the main components of BMS is as follows:
- BMS field controllers – 15 to 20 years
- Field devices – 15 to 20 years
- BMS computer hardware – 3 to 5 years
- BMS software – major releases 3 to 5 years

9.2. Most popular BMS protocols

BACnet® (Building Automation and Control networks) protocol is focused exclusively on building automation. It was created in 1987 at Cornell University, Ithaca, New York, and became an ANSI standard in 1995 under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). BACnet is a worldwide standard used by more than 800 vendors across hundreds of devices. BACnet clients must be backward compatible to ensure interoperability with multiple generations of devices within an installation. BACnet supports most building operations, including HVAC, lighting, fire protection, and physical security (access control, intrusion) devices. This protocol is supported and maintained by ASHRAE Standing Standard Project Committee 135.

Modbus® is a serial communications protocol developed by Modicon (now Schneider Electric) in 1979. Originally created for use with Modicon's programmable logic controllers (PLCs), it was released as an open protocol in 2004 and has become a *de facto* standard for connecting a wide range of industrial electronic devices. The Modbus protocol uses a client/server architecture to manage communication between a host and intelligent devices, especially sensors in data acquisition systems. In building automation, it is used to control equipment such as chillers, boilers, and fans. Modbus is used to communicate between intelligent devices and sensors and instruments, and to monitor field devices using PCs and human-machine interfaces. Modbus is most widely used as an industrial protocol, but is also popular in building, infrastructure, transportation, and energy applications. Noted for its flexible and open communications, Modbus is one of the most widely used protocols in the world.

M-Bus (meter-bus) is a European standard for the remote readout of consumption meters (water, heat, gas, electric meters, as well as valves and actuators) in homes and buildings. It was developed in the 1990s at the University of Paderborn, in conjunction with Texas Instruments Deutschland GmbH and Techem GmbH, and is now widely used in many European countries for smart metering. M-Bus makes it possible to read meters remotely from a host computer or handheld device. In building automation, M-Bus can be linked to the building system to provide integration with other systems such as HVAC and lighting. It is also sometimes used for alarm systems and flexible illumination systems.

KNX is a worldwide communication standard for home and building control. It was created in 1999 by Konnex Association (now KNX Association), and is a combination of three previous standards: European Home Systems Protocol (EHS), BatiBUS, and European Installation Bus (EIB or Instabus). The KNX Association administers the standard, providing vendor- and product-independent commissioning software for standardized commissioning procedures (ETS). KNX Association has about 400 member companies in 38 countries, offering more than 7,000 certified products for building automation, which are handled by approximately 48,000 certified KNX-partners in 138 countries. KNX Association is a non-profit organization governed by Belgian Law. KNX is used in residential and commercial building automation for HVAC, lighting, security, remote access, blind and shutter control, visualization, and energy management.

DALI (Digital Addressable Lighting Interface) is the leading protocol for the control of lighting in building automation. Developed by a group of manufacturers led by Phillips, the protocol was first drafted as an open standard in 2000 as an alternative to Digital Signal Interface (DSI). DALI 2 replaced the original DALI protocol in 2014 and is backward compatible with it. DALI provides exceptionally fine-grained control over lighting, with each device being separately addressable. 256 levels of brightness are possible. Features include remote control, integration with fire and emergency lighting systems, balancing of light output as LEDs age, and the ability to adjust lighting load based on electricity demand. DALI is used exclusively for lighting and related controls. DALI devices include fluorescent HF ballasts, low voltage transformers, PE cells, motion detectors, wall switches and gateways to other protocols. The protocol is administered by the DALI working party (AG DALI), ensuring that DALI compliant products will have the highest levels of interoperability with other DALI products. Testing can be done either by an approved test house or by DALI members themselves using DALI software.

9.3. An examples of systems and software use in a public nZEB

As an example of public nZEB, building ""SALA", which is a business support centre and a library in the Aloja county was chosen. The building in relatively new, it was built in 2016 (see Fig. 9.3.1.). The main building parameters are summarized in Table 9.3.1. Systems used in this nZEB and controlled by BMS system are:

- Heating and cooling, which is provided by the geothermal heat pump with borehole heat exchanger and underfloor heating system.
- Domestic hot water (DHW), which is provided by the same geothermal heat pump and partly by the solar collectors placed on the roof.
- Ventilation, which is provided by the compact HVAC unit with a counterflow heat recovery exchanger with efficiency 93% and efficient EC fans.
- Lighting, which is provided by the electricity and partly by the PV panels placed on the roof with batteries for energy storage

General scheme of combined heating/cooling systems in studied building is shown on Fig. 9.3.2. – as it seen, it integrates different technologies, energy exchangers and control points, as well as dozens of sensors. All the systems are managed by the BMS system, which is based on *Niagara* framework [9.2], which provides also data logging and visualization with built-in web server (Fig. 9.3.3). The BMS system is created to help not only show, but also analyse and predict the interconnection between different systems, thus increasing the efficiency of the whole building. The biggest challenge during the

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planning and integration of the BMS system for this building was a connection of all the existing and newly installed systems, sensors and actuators in one place. The protocols used to connect all the systems are: *BACnet*, *KNX*, *Modbus* and *M-Bus*, some additional drivers and hardware adapters were installed to ensure the operation in one system.
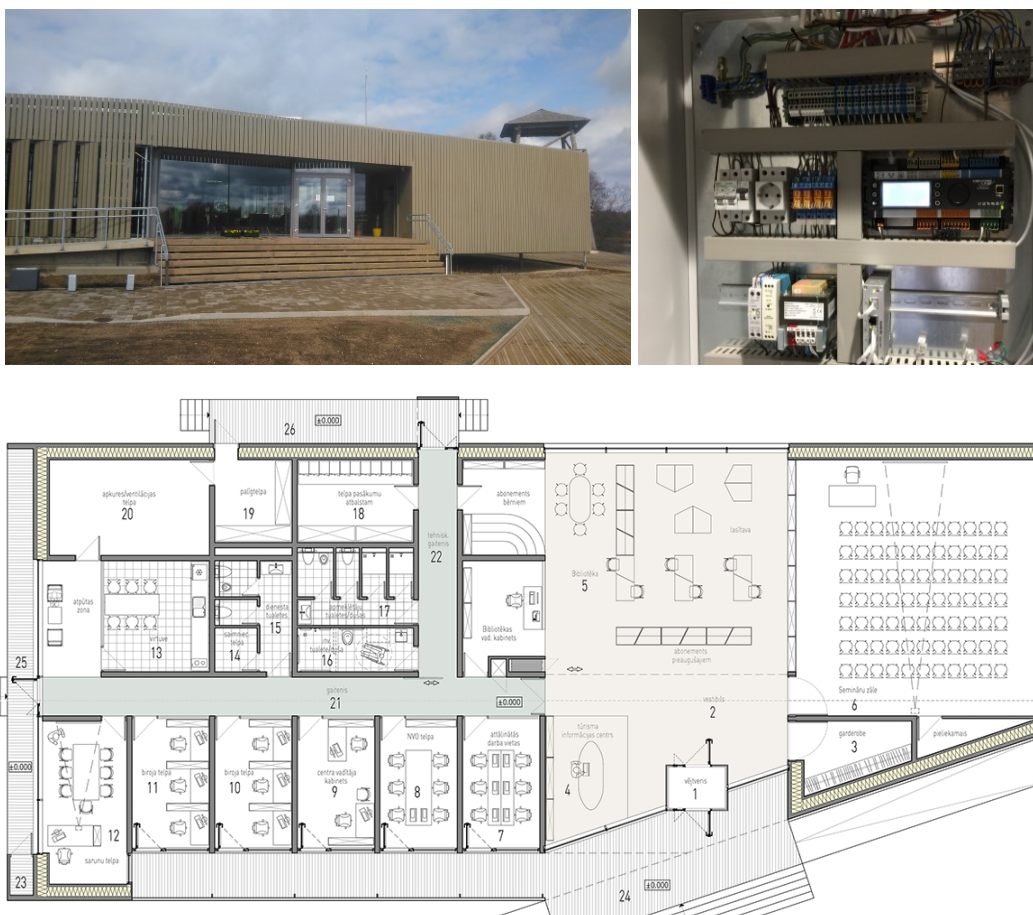

Fig. 9.3.1. *Pictures and floor plan of the public nZEB building.*

Table 9.3.1. *Main parameters of studied nZEB building.*

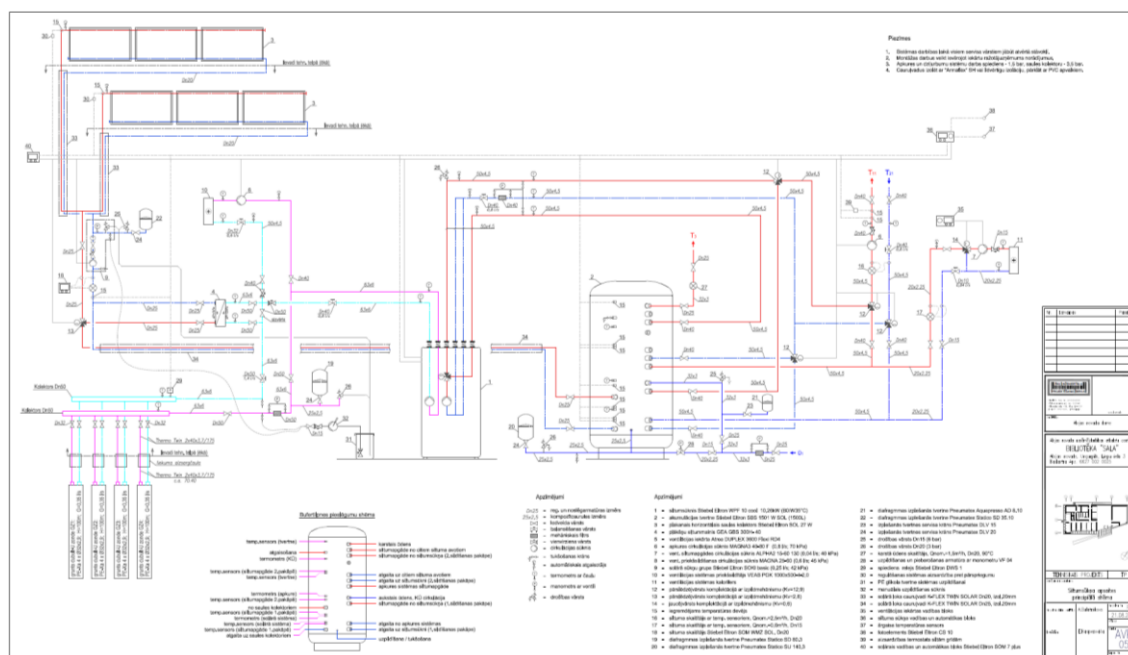| Parameter	Value
Location	Ungurpils, Latvia (57°46′19″N, 24°48′46″E)
Year of construction	2016
Threated floor area	521 m^2
No. of occupants	25
Building volume	1569 m^3
Airtightness	0.3 h^{-1}
Indoor temperature*	18°C (summer) / 25°C (winter)
Heating demand*	15.1 kWh/m^2
Cooling demand*	2.2 kWh/m^2
Heating load*	19 W/m^2
Primary energy*	51 kWh/m^2

* - data from PHPP calculation

Fig. 9.3.2. S*cheme of combined heating/cooling systems in studied nZEB building.*
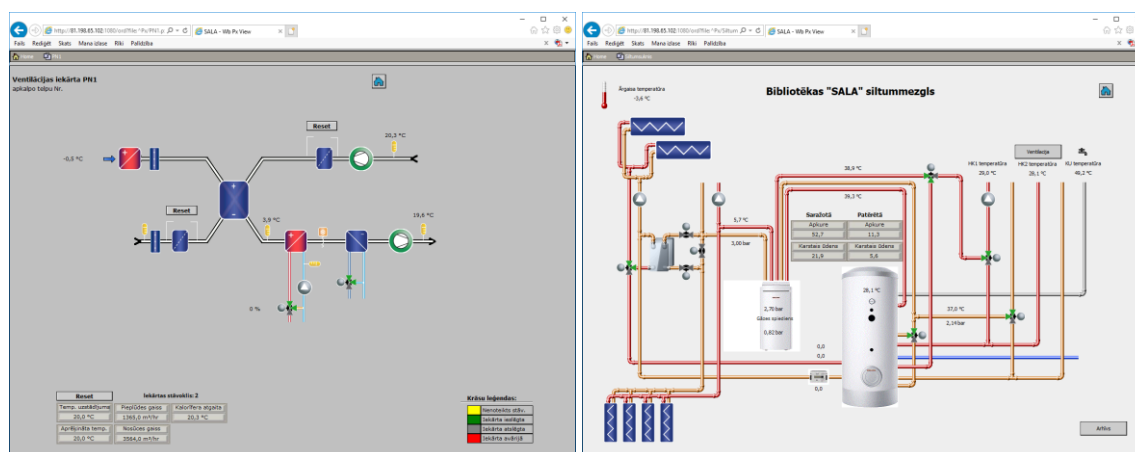

Fig. 9.3.3. *Web interface of the BMS system installed in "SALA" (left - ventilation system, right – heating/cooling/DHW unit).*

Another example of public nZEB, where complex BMS system is planned to install and use, is "*Philanthropy house*" at the University of Latvia, which is currently only in the design stage (Fig. 9.3.4.). It will be relatively small building (heated floor area about 150 m²) with three significantly different zones – office part, seminar room and winter garden. The office space is used regularly – five days a week with corresponding thermic comfort conditions. Usage of the seminar room is irregular; it depends on the events schedule and the number of people using it varies (up to 30 people). The challenge of the winter garden is to ensure appropriate conditions for plants energy efficiently considering that external glass constructions dominate in the space.

A significant aspect of choosing this type of nZEB is the potential opportunity to monitor the building in long-term and to test the chosen building management system

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(BMS) solutions. A specific opportunity, related to the location of the building, is its usage for demonstration of energy efficient nZEB building technologies and BMS, as well as the usage of the planned renewable energy resources, for example, sun collectors to prepare warm water for the nearby greenhouses.
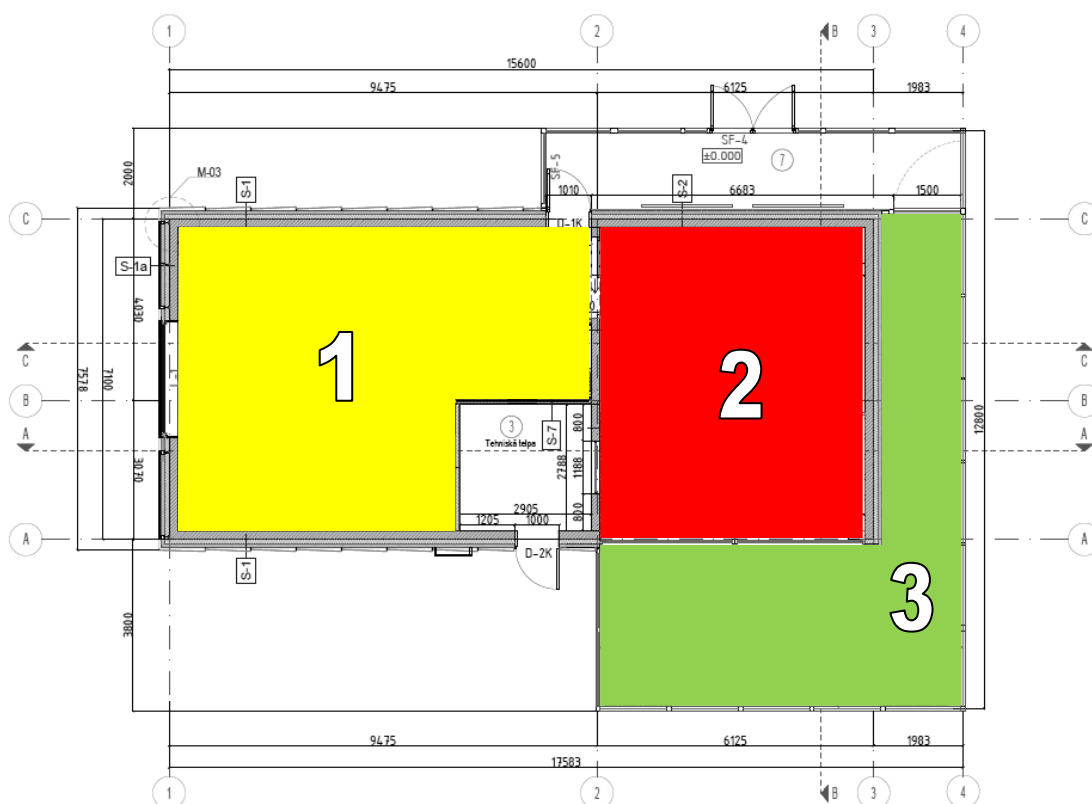

Figure 9.3.4. *Floor plan of the nZEB Philanthropy house" (currently in the design stage): 1 – office part, 2 – seminar room, 3 – winter garden.*

9.4. Conclusion

Use of building management system for nZEB buildings with several interconnected complex systems is an absolute necessity not only to register and analyse the physical measured data, it allows also to develop and optimize the approach for improving of building's energy efficiency. Only by getting a comprehensive information about all the measurements and system operation together it is possible to realize a really smart management of the building, avoiding conflicts between different systems and providing the increasing of overall energy efficiency.

Thus, for example opened window decrease the temperature near it during a winter and heating system (or local heater) will increase the power in this room or even in all the building, at the same time, if the BMS receives the signal from the window open/close sensor (e.g. [9.3]), it will not affect the functioning of the heating system until window is opened or even couple of minutes later. Or, the long-time opening of the window when mechanical ventilation system is operating will cause minimizing or even stop the ventilation system to decrease uncontrolled convective heat losses and to exclude

possible inflow of any outdoor chemical and microbiological contamination; a message to cell phone can be sent too.

The "smartness" of the building can be reached when all the essential parameters – both environmental and measurements from the running systems can not only be measured and recorded, but also used to analyse, control and manage all the important systems (for example, strong wind induces the opening of external window blinds or heating/lighting power depends on occupancy in the room). Intelligent programming of BMS response action using maximum possible actuators (e.g. airflow, heating power, lighting, shading), forecasting of all possible scenarios is absolutely necessary to achieve this goal.

Most of the above listed BMS-controlled situations are especially important in case of public buildings, where some basic parameters used for control of the building systems may be changed unpredictable and in wide range (for example., number of visitors and their behaviour, changing purpose of public rooms – seminars/sporting activities/catering, different climatic conditions needed for exhibits etc.).

Literature

[9.1] A.H. Buckman, M. Mayfield, Stephen B.M. Beck, (2014) "What is a Smart Building?" Smart and Sustainable Built Environment, Vol. 3 Issue: 2, pp.92-109, https://doi.org/10.1108/SASBE-01-2014-0003
[9.2] https://www.tridium.com/en/products-services/niagara4
[9.3] https://www.smarthome.com/insteon-2843-222-wireless-open-close-sensor

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