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Research of Operation of Combined Building-Energy System of Buildings and Equipment

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Abstract: *The paper describes the mobile laboratory and its equipment for measurement of design models. The design models of the new compact station are based on the latest theoretical foundations of building technical equipment and their common control.*
Keywords*: combined construction and energy systems, mathematical and physical models, mobile laboratory, compact station, design models, renewable energy sources.*

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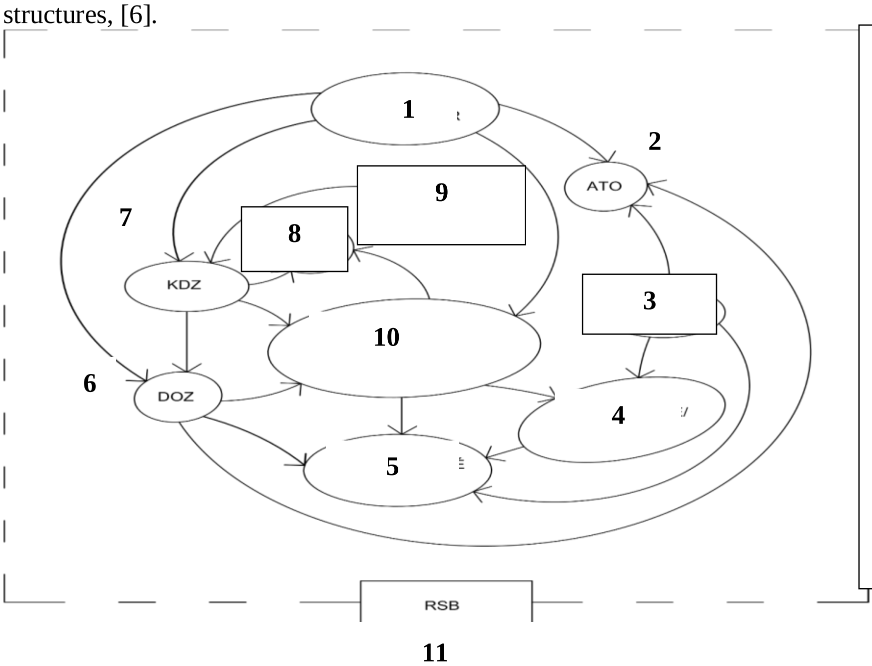
I. INTRODUCTION

Energy systems built into some building structures, which serve to capture solar energy, geothermical energy and external energy, or have the function of end elements of the heating, cooling and ventilation system, are generally called combined energy systems of buildings. We include solar roofs among the combined building and energy systems with built-in tube absorbers, building structures with active thermal protection (ATP) - active control of heat transfer, which have a multifunctional purpose - thermal barrier, low-temperature heating, high-temperature cooling, heat recovery and storage, solar energy and outdoor energy, energy storage, large-capacity storage heat exchangers (underground heat accumulators as part of the foundation structure of a building) or heat exchangers used for recuperative ventilation of buildings built into foundation slabs and wall structures, [6].



THE LEGEND:

1 solar absorber
2 active thermal protection
3 sources of cold
4 heating / cooling
5 recuperative ventilation
6 long-term heat storage
7 short-term heat storage
8 hot water heating
9 heat source (eg heat pump)
10 Measuring and regulation
11 Building control system

FIG. 1 Principle diagram of connection of combined building-energy system [6]

Based on utility model no. 5749 A working laboratory and a series of mathematical and physical models have been developed for the operation of the combined building and energy system of buildings and equipment registered in Banská Bystrica, Slovak republic in April 2011, [6]. The nature of the operation of the combined building and energy system of buildings based on the exchange and / or conversion of energy according to the invention consists in the fact that the complex creation of the indoor environment of the buildings with regard to the seasonal or immediate requirements is accomplished by a combination of controlled processes. These processes include heat absorption, heat production, cold, heat accumulation, use of active heat protection, low temperature, hot air heating, cooling, water heating. With the help of a building control system that actively regulates the temperature of the heating medium and with the help of a heat source, a cold source and a short-term heat reservoir and a short-term cold storage tank, we create the appropriate properties of the indoor environment.

II. PROGRESSIVE TECHNOLOGIES IN CONSTRUCTION MODELS

Progressive technologies and materials for the application of renewable energy sources in buildings consist of the following basic components [1], [2], [3]:

- Solar collectors (can be combined with solar roofs).
- Long-term liquid-based heat storage units (heat transfer by coil to liquid), solids (heat transfer to eg soil through a pipe register) or phase change (coil transfer eg to paraffin).
- Short-term heat storage tanks based on liquid or phase change.
- Cooling system, which is based on a pipe register located in the non-freezing depth of the soil (may be supplemented by an external cooler and a coolant accumulator).
- A recuperative heating / ventilation system based on a recuperation air-handling unit with preheating or air cooling in single- or dual-pipe counterflow heat exchangers located at the non-freezing depth of the soil. The final heat treatment of the ventilation air is by means of liquid, gaseous or electric heat exchangers (heaters, coolers) integrated in HVAC units or external located in the HVAC distribution system. This system can be complemented by low-temperature heating and high-temperature cooling systems used to temper the interior of the building.
- Of building structures (roof and external walls) with internal energy source - active thermal protection consisting of a pipe system provided with a distribution layer (plaster, thermally conductive foil, thermally conductive coating or spraying) placed between the load-bearing part of building structures and thermal insulation layer.
- Peak (standby) heat source (electric coil in short-term storage tank, electric boiler, gas boiler, heat pump, fireplace, other heat source and combination of multiple heat sources)
- Controller software (measurement and control), which controls all actuators and components of the combined building and energy system of the building.

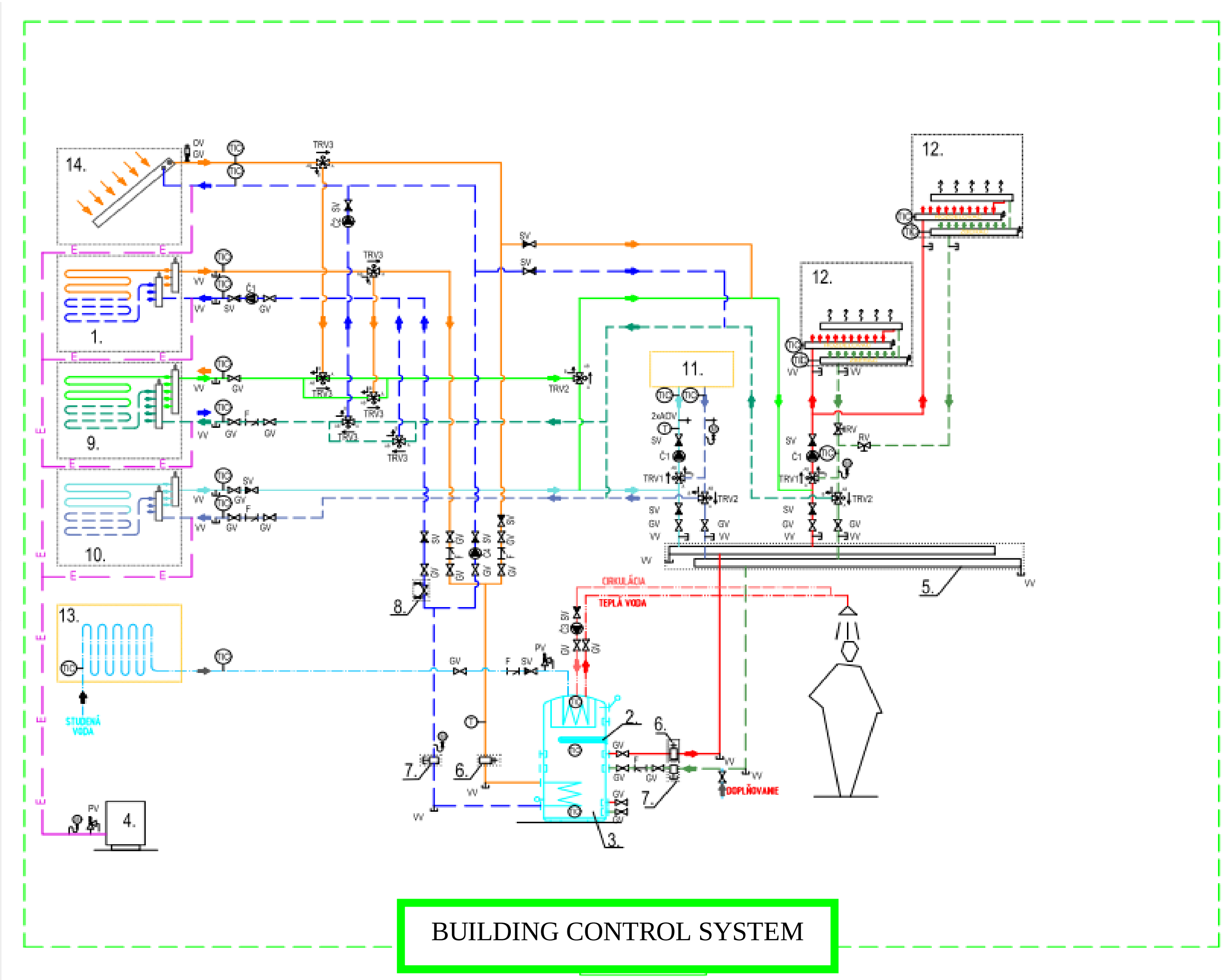
III. MATHEMATICAL-PHYSICAL MODELS OF COMPACT STATION ENERGY SYSTEMS

In accordance with Directive EU 2018/844 (2010/31/EU), [1], on nearly zero energy buildings, the requirement to achieve energy class A0 of the primary energy of the building, the requirement for quality building envelope buildings with target thermal resistance in accordance with STN EN 73 0540, RES were developed technical solutions, which are presented:

a) **Utility Model No. 5749**: OPERATION OF COMBINED BUILDING-ENERGY SYSTEM OF BUILDINGS AND EQUIPMENT, registered in Banská Bystrica, Slovak republic, in April 2011, (author: Kalús) [6].

b) **EUROPEAN PATENT EP 2 572 057 B1:** *Heat insulating panel with active regulation of heat transition.* Date of publication and mention of the grant of the patent: 15.10.2014 In: Bullettin 2014/42 European Patent Office, interantional application number: PCT/SK2011/000004, international publication number: WO 2011/146025 (24.11.2011 Gazette 2011/47), 67 p., (author: Kalús) [3].

When creating mathematical-physical models, we focus on variants of connection with devices offered on the Slovak and Austrian markets. From the variants of research and development involvement we choose the ones that are currently most used in individual housing development. One possible variant is shown in Figure 2, where the mathematical-physical model includes an alternative energy source (solar water heating, PV cells and others), a peak source (heat pump, electric boiler, biomass boiler), two short-term storage tanks, self-heating hot water tank, heat recovery unit, cooling circuit.



VARIANT 21.01.02: ENERGY SYSTEM OF THE BUILDING IN MODIFICATION WITH SOLAR ROOF AND SOLAR COLLECTORS, THE TOP SOURCE IS AN ELECTRIC SPIRAL IN THE COMBINED STORAGE TANK, HEATING IS CARRIED OUT BY UNDERFLOOR HEATING, LONG-TERM STORAGE IS A GROUND STORAGE TANK BELOW THE BUILDING

FIG. 2 Mathematical-physical model - variant 27.02.08 [Kubica]

IV. ADJUSTMENT MEASUREMENTS ON A MOBILE LABORATORY

Adjustment measurements in the laboratory and measurements of design models of compact stations of the new SMART type, will be performed on a mobile laboratory (simulator and optimizer of energy systems), which was designed and produced by REGULTHERM, s.r.o. based on utility model no. 5749 Method of operation of the combined building and energy system of buildings and equipment, [3], [6]. We have been actively involved in the design and implementation of this mobile laboratory and are continuing our continuous research and experimental measurements. Based on the following measurements, we modified the composition of the mobile laboratory and the connection of the future compact device.

a) Starting the system.
b) Calibration of the gauges and sensors.
c) Cooling circuit modification.
d) interventions in the process of operation.
e) Heat pump control.
f) The proposed procedure for the operation of the compact device.
g) Installed power diagnostics.

4.1 Technical equipment of mobile laboratory

The laboratory includes vacuum solar collectors, photovoltaic panels, an air-to-water heat pump with the option of producing heat or cold, and a heat recovery ventilation unit and a DHW tank with electric heating. Remote access allows you to monitor and set actual and desired quantities according to the needs of the measurements performed. The software records measured states at five minutes intervals. The software can create various time graphs with temperature, humidity, consumption or battery charge status. If necessary, we can export all values to another calculation program.

FIG. 3 Mobile laboratory - photovoltaic and solar thermal panels, meteorological station [Photo source: authors]

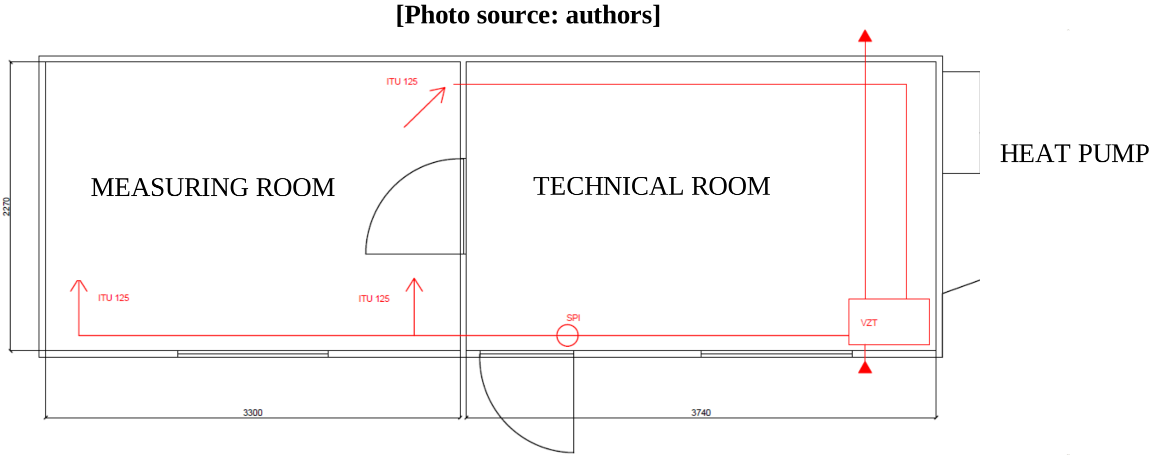


FIG. 4 Floor plan of a mobile laboratory [REGULATHERM]

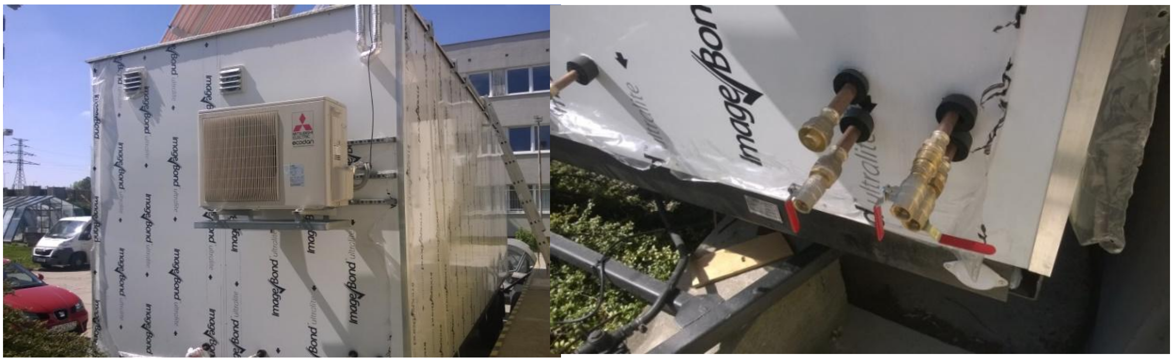


FIG. 5 View of the heat source - heat pump and the possibility of connecting a mobile laboratory to an external heat source [Photo source: authors]

FIG. 6 View at the equipment of technical and measuring micromobility of a mobile laboratory [Photo source: authors]

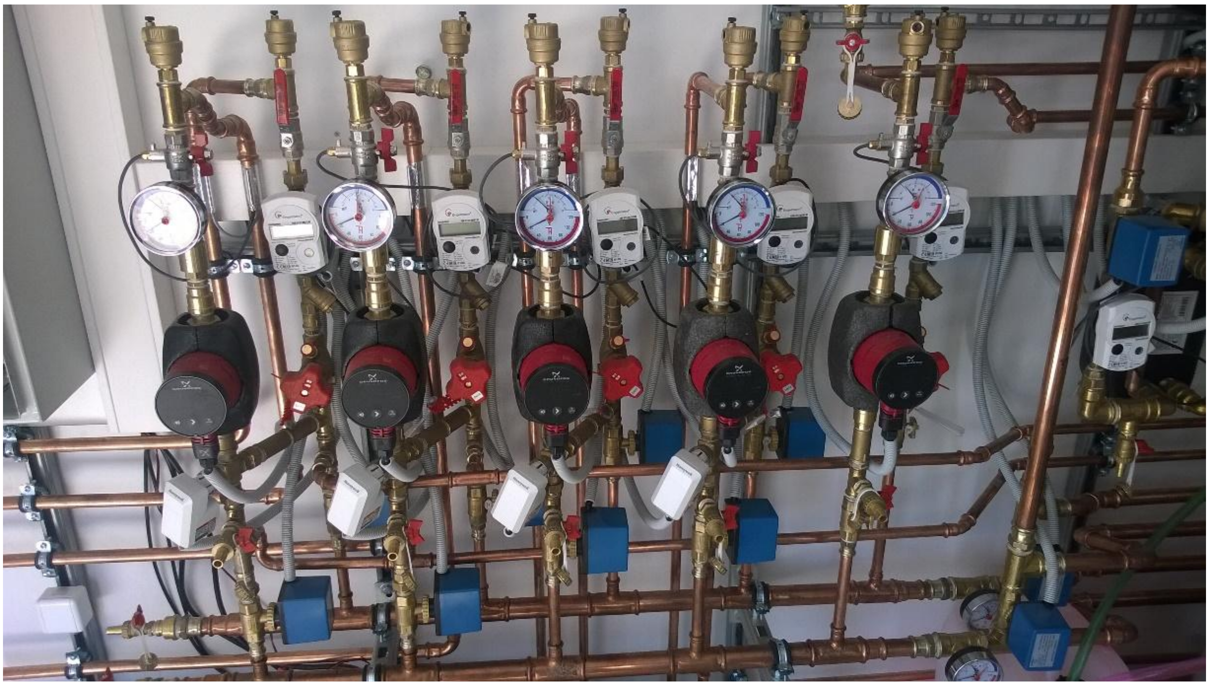


FIG. 7 Distributor and collector with measuring instruments on the heat transfer side [Photo source: authors]

FIG. 8 View of the recuperation ventilation unit and air ductwork in the measuring room [Photo source: authors]

V. CREATION AND MEASUREMENT ON CONSTRUCTION MODELS

The newly created design models will be applied in the mobile laboratory. After configuring the wiring, we will start with field measurements.

5.1 Design model with heat production – tepor

Design of compact station without reversible heat pump and without ability to produce cold. The compact station has three outputs for the source, two with exchanger and one without exchanger. Due to the lack of cooling circuit, the compact station has only one short-term storage tank. This type of compact station can also be connected to a heat pump with production of cold, but it will have its own cooling circuit and will not be controlled by the compact station.

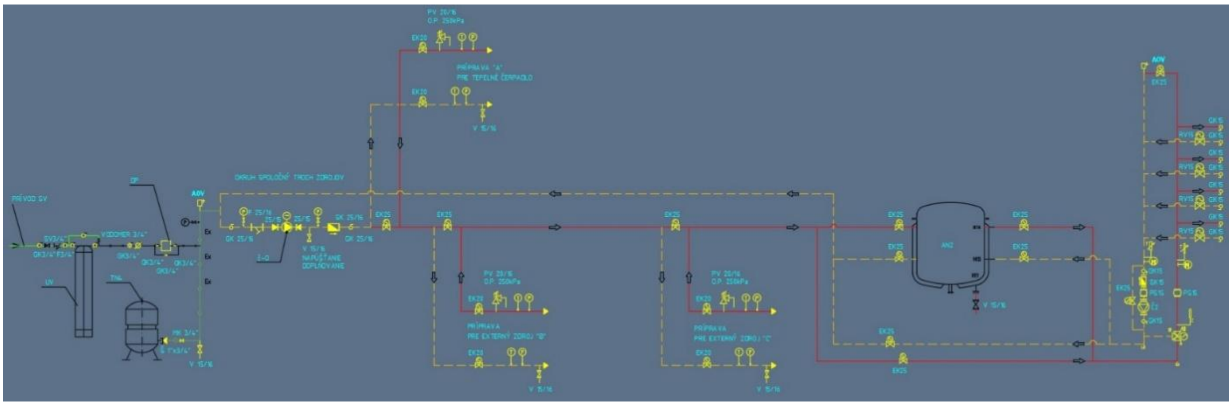


FIG. 9 Construction model of a compact station with heat production [Kubica]

5.2 Design model with heat and cold production

Compact heat pump station with reversible heat production capability, switching between heat and cold production. In this case, the compact station has a three-way valve system that divides the production of cold and heat into two circuits, allowing the heating system to use both cold and heat simultaneously. The heat and cold preparation itself takes place by switching the heat pump running.

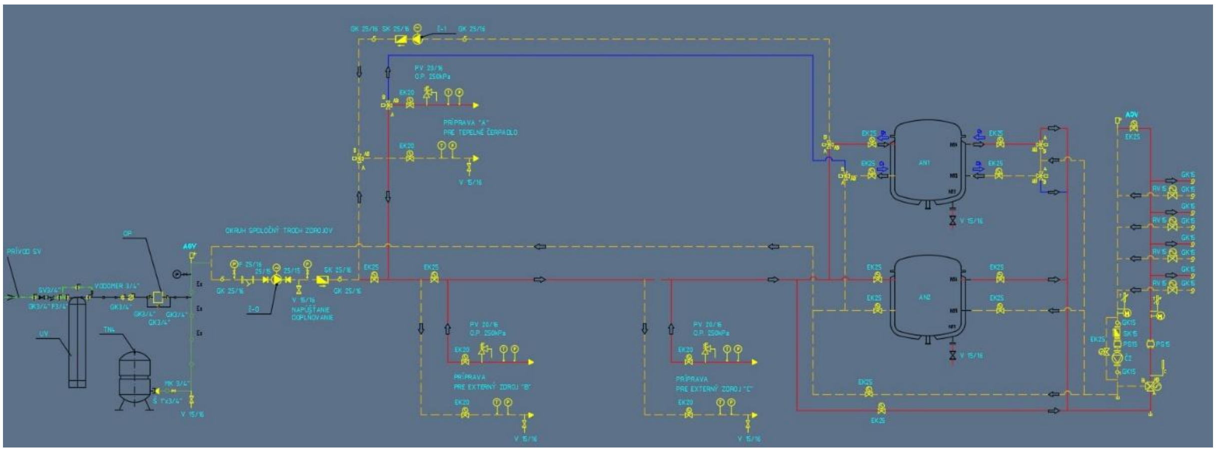


FIG. 10 Design model of a compact station with heat and cold production [Kubica]

VI. CONCLUSION

Pre-installed and pre-programmed ultrasonic heat meters make it possible to create new ways of acquiring data and to compare design and actual conditions. Two sets of ultrasonic heat meters are installed in the compact station. The power pack can detect instantaneous power and the amount of energy stored in the heat and cold store. The set of heat meters recognizes the installed capacity of heating systems.

The measurement and control system is crucial for the proper functioning of the heating system. In addition to the qualitative and quantitative way of adjusting the power, the progressive measurement and control systems can also adjust the pressure conditions in the heating system. In addition to adjusting the operating characteristics of the system, the measurement and control system provides protection against damage to heating systems. Measurement and control monitors and sends feedback so that the software is updated in time for the next action.

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