АРХИТЕКТУРА

Moradi Pour Omid
postgraduate student degree
Department of Fundamentals of Architecture and Architectural Design,
Kiev National University of Construction and Architecture

PRINCIPLES OF FORMATION OF ARCHITECTURE OF ENERGY EFFICIENT RESIDENTIAL BUILDINGS OF AVERAGE HEIGHT

Summary. The principles of formation of energy-efficient systems of heating, ventilation and air conditioning of residential buildings of medium height are considered. The analysis of basic requirements to modern systems of climate control of premises is carried out, technical means of their organization and management are defined. The model of control of parameters of heating, ventilation and air conditioning system which includes the analysis of temperature, level of humidity and level of air pollution in a premise is offered. The mathematical apparatus is developed and the basic scheme of cooling and heating of air in the building, which is based on the ideal Carnot cycle, is constructed. The basic approaches of development and adaptation of the model for solving actual problems are indicated.

Keywords: energy efficiency, residential building, heating, ventilation, air-conditioning, mathematical model, Carnot cycle.

1. Introduction

The formation of energy-efficient heating, ventilation and air conditioning systems of buildings, which allow to maintain optimal conditions of microclimate in the room, necessary for the stay of people, placement of technological equipment and storage of products is based on the classification of the type of building and external climatic conditions. ***The analysis of the literature sources*** devoted to this topic showed that within the framework of the standard methodology, heating, ventilation and air conditioning systems can be divided into complexes intended for residential premises [1-3], public buildings [4, 5], industrial premises [6, 7] and medical institutions [8, 9].

To date, there is an increase in requirements for maintaining climate control in the premises when designing heating, ventilation and air conditioning systems. First of all, this is a tightening of safety standards, comfortable organization of work and rest, storage conditions of food products, maintenance of the so-called "clean room" and keeping animals. This is partially offset by the growth of opportunities for the organization of heating, ventilation and air conditioning systems, both heating, air conditioning and ventilation, and automatic control systems in the "smart house" mode [10-12]. However, it should be noted that the problem of optimization of heating, ventilation and air conditioning from the point of view of the need to build energy-efficient systems is a complex and non-trivial task.

Also, important factors influencing the choice of the optimal organization of the heating, ventilation and air conditioning system are the height of the floor and the total number of storeys of the building [13-15]. In the case of heating systems, the highest energy consumption, which can be calculated by determining the specific consumption of thermal energy, it is associated with the height of the floor of the building. The number of storeys of the building is important in establishing the ventilation system, which is based on the construction of common sectional exhaust shafts — this approach allows to reduce heat loss through the ceiling of the upper floor, as well as to reduce the resistance to heat transfer of the attic coating. It is characteristic that in general, these factors have mutual influence, which further complicates the task. Accordingly, when building the basic model of heating, ventilation and air conditioning, it becomes necessary to choose typical options, leaving the possibility of expanding the mathematical apparatus for a wider class of problems.

Thus, in this work it is proposed to confine the study to the construction of the methodological framework that includes the development of principles of formation of architecture and organization in heating, ventilation and air conditioning systems of energy-efficient residential mid-rise buildings, which can be represented as ***the objective of the work***.

2. Basic approaches to energy efficiency of the heating, ventilation and air conditioning system

Assessment of energy efficiency of heating, ventilation and air conditioning systems involves the construction of the mathematical model and the introduction of the following indicators:

- the acceptable temperature range of indoor air;
- the temperature of the air outside ;
- permissible air flow rate in the room ;
- the allowable humidity level for indoor air, according to the air temperature;
- the level of indoor air pollution, which can be expressed in terms of volume fraction, according to typical chemical pollution agent s .

In addition, the temperature level in the premises of the residential complex is correlated with climatic conditions, a significant difference between the indoor temperature and outdoor temperature does not meet both medical standards and energy-efficient approach to heating, ventilation and air conditioning. Thus, an additional standard can be introduced for, which corresponds to the permissible temperature range of the indoor air .

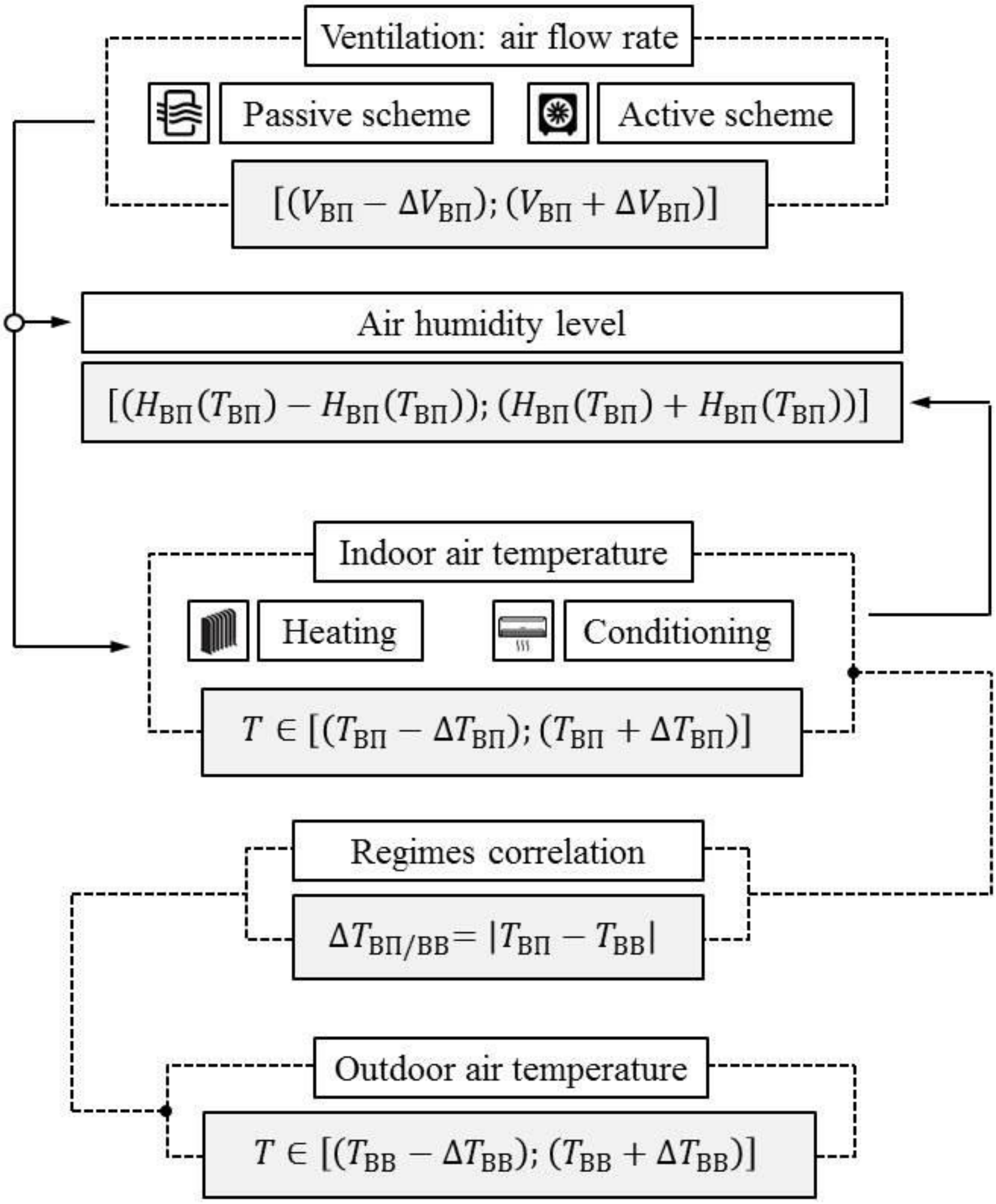

Fig. 1. The basic model of control of heating, ventilation and air conditioning system parameters.

At the level of construction of the mathematical apparatus, the definition of energy efficiency of residential premises can base the concept of heat load for the ideal process of heating and air conditioning. At the same time, in the framework of this study, in order to build a basic model, it is proposed to consider the processes of air conditioning and heating of premises with the possibility of further supplementing the mathematical apparatus with algorithms for controlling humidity and the presence of typical air pollution agents.

3. Modeling of the heating, ventilation and air conditioning system of the premise

The simplified mathematical model of the system maintaining the set temperature mode in premises, which are using the processing mechanisms of ambient air at the level of the Carnot cycle, but does not take into account the energy consumption during transportation and distribution of the coolant and the heat transfer area in the model is considered unbounded, is based on analysis of heat sources (appliances, building residents, etc.), their parameters and the mutual arrangement (Fig. 2).

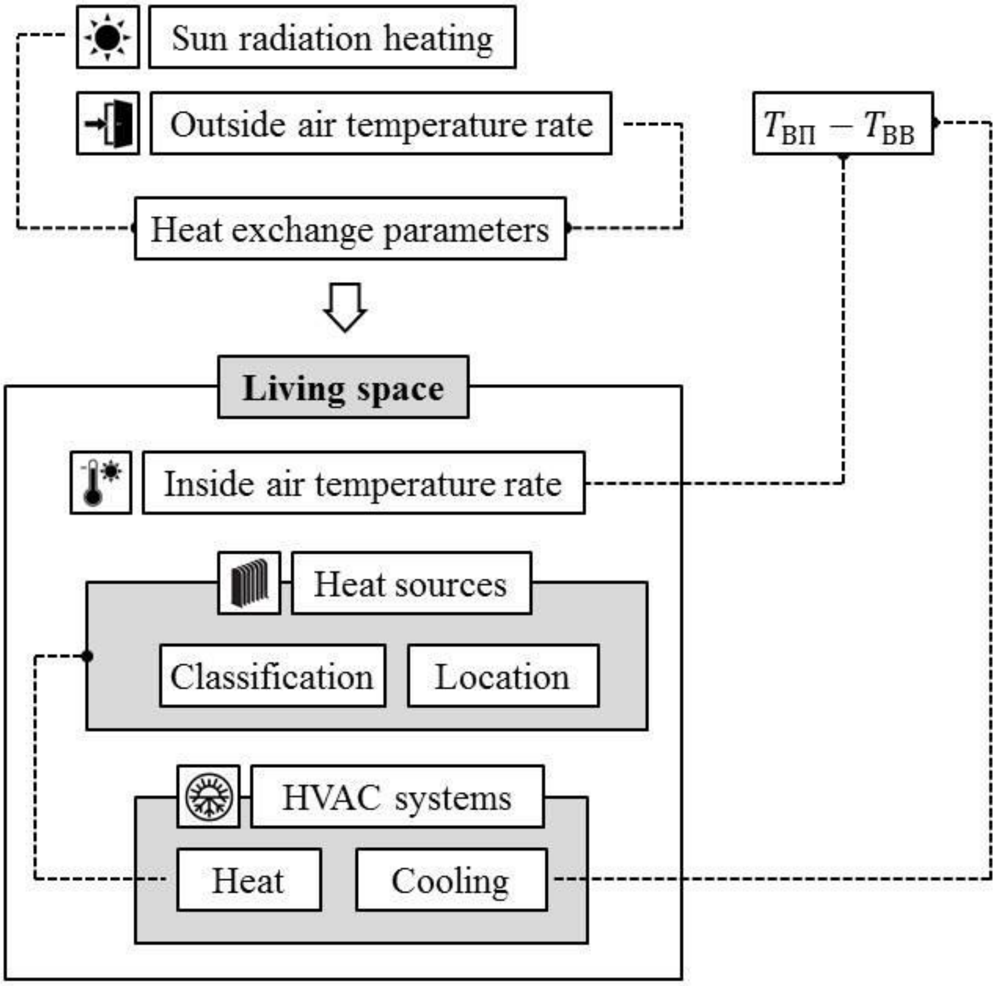

Fig. 2. The basic scheme of cooling and heating of air in the premises.

Under the present scheme it is necessary to introduce variables for temperature heat sources that are present in the premises as a one-dimensional matrix Calculating the difference of and allows selecting the operating mode of the heating, ventilation and air conditioning system in which the external environment can be used to cool the heat source or the heat source be taken into account when heating the premise. For the temperature difference the air conditioning system is activated, which can be described on the basis of the Carnot engine model. Its description considers the absorption of heat load for temperature through power consumption .

Heat load absorption [15-17] is calculated through the total heat dissipation from all sources according to the temperature difference:

moreover, it should be noted that in this case the Signum function should be defined as follows:

To calculate the power consumed by the heating, ventilation and air conditioning system in relation to a single heat source it is necessary to enter the efficiency factor :

and total power consumption calculated for all heat sources:

where

Calculation of energy-efficient heating, ventilation and air conditioning system can be based on obtaining the maximum efficiency in the framework of the developed mathematical model. At the mathematical level this can be formulated as follows:

Substituting in equation (6) the value for the total heat output from (1) and the total power consumption from (4) , the following expression can be obtained:

The development of the model implies its adaptation to solve a wide range of urgent problems. Therefore, in the future it is proposed to carry out the stages of the study presented in Fig. 3, with correlation of modeling results [18].

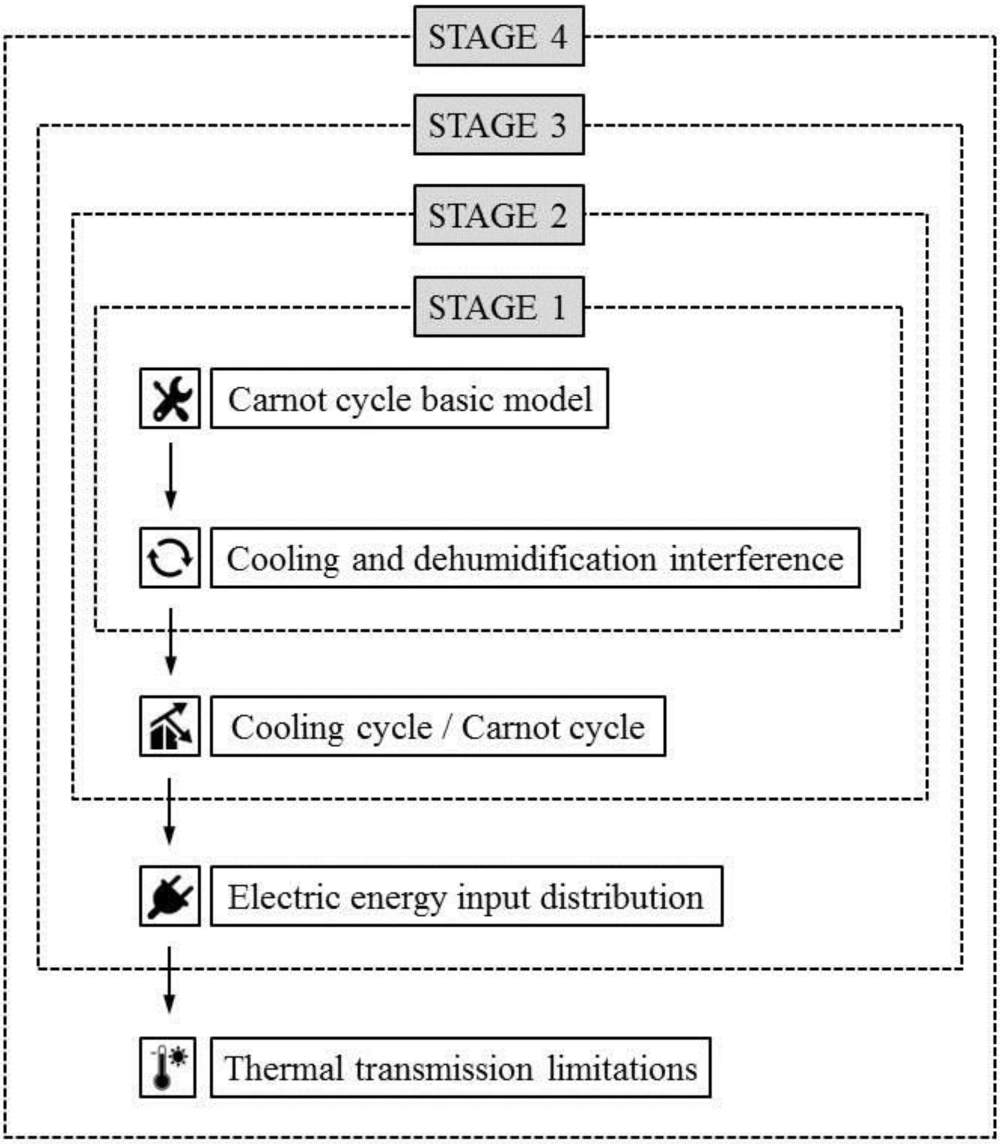

Fig. 3. Stages of development of the mathematical model of heating, ventilation and air conditioning.

This approach to the development and adaptation of the proposed mathematical apparatus allows developing a holistic methodology for the construction of a mathematical model used in the calculation of energy-efficient heating, ventilation and air conditioning systems.

4. Summary

In the course of the study, the principles of formation of energy-efficient heating, ventilation and air conditioning systems were considered and the classification of requirements for these systems was carried out. The model of control of parameters of heating, ventilation and air conditioning system which includes the analysis of temperature, level of humidity and level of air pollution in a premise is offered. The mathematical apparatus is developed and the basic scheme of cooling and heating of air in the building, which is based on the ideal Carnot cycle, is constructed. It is shown that the calculation of energy-efficient heating, ventilation and air conditioning system can be based on obtaining the maximum efficiency, taking into account the consideration of all heat sources located in the premise. The basic approaches of development and adaptation of the model for solving actual problems are indicated.

References

1. Yoon, S., Yu, Y., Wang, J., & Wang, P. (2018). Impacts of HVACR temperature sensor offsets on building energy performance and occupant thermal comfort. Building Simulation, 12(2), 259–271. doi: 10.1007/s12273-018-0475-3.

2. Abramski, M., Friedrich, T., Kurz, W., & Schnell, J. (2011). Innovative Shear Connectors for a New Prestressed Composite Slab System for Buildings with Multiple HVACR Installations. Composite Construction in Steel and Concrete VI. doi: 10.1061/41142(396)9.

3. Hernandez, A. (2012). HVAC & Building Management Control System Energy Efficiency Replacements. doi: 10.2172/1063877.

4. Schijndel, A. W. M. V., & Schellen, H. L. (2006). Application of a Combined Indoor Climate and HVAC Model for the Indoor Climate Performance of a

Museum / Anwendung eines Modells für die Kombination des Innen klimas mit dem Heizungs-, Belüftungs- und Temperatur kontroll system (HBT; HVAC) zur Simulation des Raumklimas in einem IVIuseum. Restoration of Buildings and Monuments, 12(3). doi: 10.1515/rbm-2006-6052.

5. Wright, J., & Zhang, Y. (2008). Evolutionary Synthesis of HVAC System Configurations: Experimental Results. HVAC&R Research, 14(1), 57–72. doi: 10.1080/10789669.2008.10390993.

6. Silberstein, E. (2012). Residential construction academy: HVAC. Clifton Park, NY: Cengage Learning.

7. Muthuraman, S. (2016). Careers in HVACR: heating, ventilation, air conditioning, refrigeration. Chicago: Institute for Career Research.

8. Sezdi, M., & Uzcan, Y. (2016). Clean room classification in the operating room. 2016 Medical Technologies National Congress (TIPTEKNO). doi: 10.1109/tiptekno.2016.7863107.

9. Varghese, A. C., & Palmer, G. (2016). Chapter 23 Clean room technology for low resource IVF units. Clean Room Technology in ART Clinics, 345–352. doi: 10.1201/9781315372464-24.

10. Domb, M. (2019). Smart Home Systems Based on Internet of Things. IoT and Smart Home Automation [Working Title]. doi: 10.5772/intechopen.84894.

11. Balasubramanian, K., & Cellatoglu, A. (2010). Selected Home Automation and Home Security Realizations: An Improved Architecture. Smart Home Systems. doi: 10.5772/8408.

12. Saito, N. (2015). The concept of an ecological smart home network. Ecological Design of Smart Home Networks, 3–16. doi: 10.1016/b978-1-78242-119-1.00001-1.

13. Abad, J. M. N., & Soleimani, A. (2016). A neuro-fuzzy fan speed controller for dynamic management of processor fan power consumption. 2016 1st Conference on Swarm Intelligence and Evolutionary Computation (CSIEC). doi: 10.1109/csiec.2016.7482121.

14. Li, Y. L., Zhao, C. L., Liu, Y. Y., Peng, Q., & Li, C. J. (2014). The Research of the Power Capsule Fan Energy Consumption in Thermal Balance Test Method. Applied Mechanics and Materials, 490-491, 902–909. doi: 10.4028/www.scientific.net/amm.490-491.902.

15. Simic, D., Kral, C., & Pirker, F. (2005). Simulation of the cooling circuit with an electrically operated water pump. 2005 IEEE Vehicle Power and Propulsion Conference. doi: 10.1109/vppc.2005.1554567.

16. Quan, H. T. (2014). Maximum efficiency of ideal heat engines based on a small system: Correction to the Carnot efficiency at the nanoscale. Physical Review E, 89(6). doi: 10.1103/physreve.89.062134.

17. Feidt, M. (2017). From Carnot Cycle to Carnot Heat Engine: A Case Study. Finite Physical Dimensions Optimal Thermodynamics 1, 75–97. doi: 10.1016/b978-1-78548-232-8.50003-0.

18. Liu, X., Jiang, Y., & Zhang, T. (2016). Temperature and Humidity Independent Control (Thic) of Air-conditioning System. Berlin: Springer Berlin.