

are used in energy sectors to solve different tasks such as creating a model of energy consumption, prediction of energy needs in different conditions and optimization of energy system overall, but it needs some adjustments and further researches to be effectively used for diversified systems with large dependency on alternative energy sources.

### **References**

1. Pokryshka D. S. (2024). Review of strategic documents of the European Union in the field of economic security: analytical review., NISD, p. 41.
2. IEA, Share of renewable electricity generation by technology, 2000-2030. URL: <https://www.iea.org/data-and-statistics/charts/share-of-renewable-electricity-generation-by-technology-2000-2030>.
3. Damages and losses of the energy sector of Ukraine as a result of a full-scale Russian invasion exceeded \$56 billion – KSE Institute estimate as of May 2024. URL: <https://kse.ua/ua/about-the-school/news/zbitki-ta-vtrati-energetichnogo-sektoru-ukrayini-vnaslidok-povnomasshtab/nogo-vtorgnennya-rosiyi-perevishhili-56-mlrd-otsinka-kse-institute-stanom-na-traven-2024-roku>.
4. Plosky V. O., Zabarylo P. O. (2024). Current state of alternative energy potential of Ukraine. Materials of the III International Scientific and Practical Conference "Green Construction", p. 118–122.
5. Kudrya S. O. (2024). Atlas of the energy potential of renewable energy sources of Ukraine., Kyiv: Institute of Renewable Energy of the National Academy of Sciences, p. 392.
6. Zabarylo P. O., Zabarylo O. V., Korotkykh J. A. (2024). Application of neural networks for the optimization in using of alternative energy sources processes., Proceedings of XIX international conference on modern achievements of science and education., p. 72–75. URL: <https://elar.khmmu.edu.ua/handle/123456789/16892>

### **FEATURES OF MICROCLIMATE SYSTEMS IN MUSEUM BUILDINGS**

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**Abstract.** *This paper analyzes the creation of integrated microclimate systems for the preservation of cultural heritage in museum buildings. Heating, ventilation, cooling, humidification, dehumidification, and air purification systems*

*are considered as an integrated microclimate control system. The study justifies the need to consider the individual characteristics of buildings and exhibits when designing integrated microclimate control systems and emphasizes the use of modern technologies (CFD air-flow modeling, Intelligent HVAC control systems, Energy-efficient devices, Monitoring of indoor and outdoor microclimate parameters).*

**Keywords:** *museum microclimate systems, heating, ventilation, cooling, humidification, dehumidification, air purification.*

The preservation of cultural heritage in museum buildings requires the use of modern engineering systems, including heating, ventilation, cooling, humidification, dehumidification, and air and water purification [1]. Moreover, each museum building requires an individual approach, which considers the specifics of exhibits, building type, and technical capabilities [2]. Therefore, such facilities should be regarded as technically complex objects, where the efficiency of engineering systems affects not only visitor comfort but also the preservation of collections. Microclimate systems play a key role in maintaining the required indoor environmental conditions: temperature, humidity, air cleanliness, and airflow velocity [3].

The design of engineering systems for museum buildings should be based on a comprehensive, systematic approach that integrates modern technologies and equipment, such as:

- Computational Fluid Dynamics (CFD) modeling;
- Intelligent HVAC (Heating, Ventilation, and Air Conditioning) control systems;
- Energy-efficient devices;
- Continuous monitoring of indoor environment parameters.

Successful examples of the systematic approach to creating effective microclimate systems include the Louvre Museum (Paris, France) and the Getty Museum (Los Angeles, USA) [4, 5].

In the Louvre, a displacement ventilation scheme combined with microprocessor-controlled display cases (climate showcases) is used. Air is supplied from the floor, which reduces air turbulence and ensures stable indoor climate conditions.

In the Getty Museum, natural ventilation systems are implemented, where air exchange is provided by automated windows with special actuators. A backup mechanical ventilation system is also installed. CFD calculations have demonstrated the ability of this system to adjust the indoor microclimate parameters depending on outdoor conditions and visitor load.

These examples highlight the necessity of applying Building Information Modeling (BIM) for integrated design and the importance of building layout.

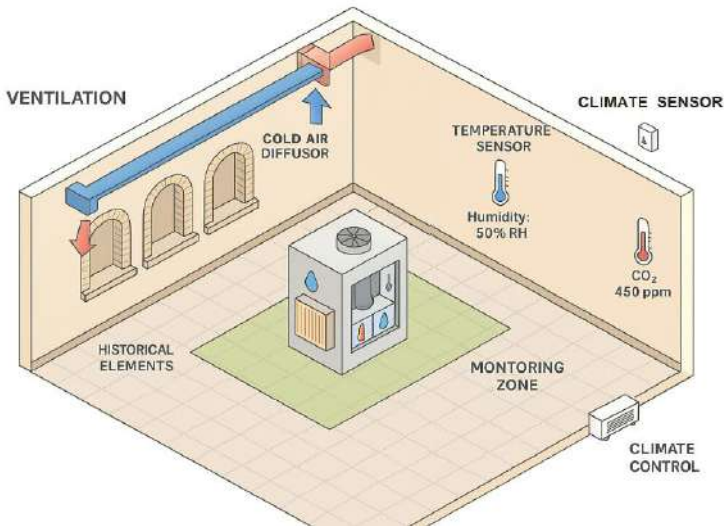
The operation of microclimate systems in such buildings should be based on monitoring both internal and external microclimate parameters, which ensures stable temperature and humidity, crucial for exhibit preservation.

Considering the typical layout of museum buildings, two main types of exhibition halls can be distinguished:

- halls with external walls and windows;
- internal halls without external walls and windows.

The organization of microclimate systems in these spaces differs.

Halls with windows require reserve system capacity to compensate for rapid changes in external conditions (temperature, solar radiation, air velocity, humidity). In such halls, it is advisable to place heating-ventilation units with integrated humidifiers under the windows (Fig. 1).

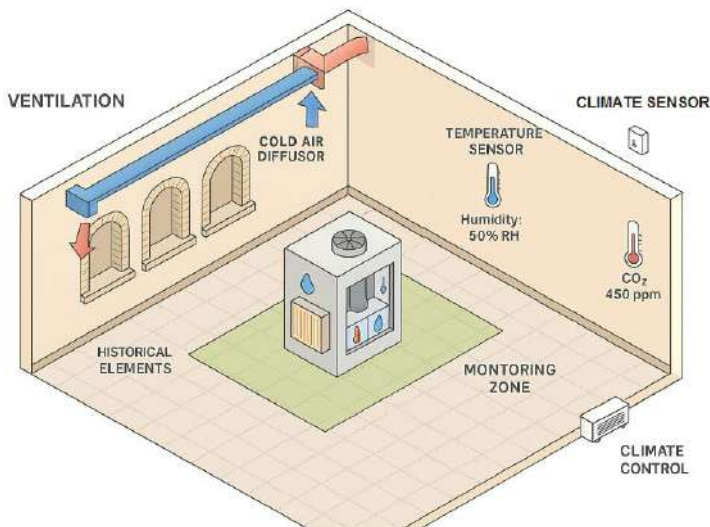


**Fig. 1. Schematic diagram of the arrangement of microclimate systems for outdoor museum premises**

The ventilation unit (in the mechanical room) should include a dehumidifier, which provides flexible response to changes in indoor and outdoor air parameters.

For internal museum halls (without external walls and windows), the use of a “climate island” is recommended – a structural unit combining several devices, such as heating elements, a humidifier, and a dehumidifier.

Efficient air distribution from the “climate island” is ensured by an axial fan, integrated with the microclimate monitoring system (Fig. 2).



**Fig. 2. Schematic diagram of the arrangement of microclimate systems for indoor museum premises**

Fresh air is supplied by a central supply-and-exhaust ventilation system, which should preferably include humidification and dehumidification sections.

In a central air-handling unit (AHU) humidification can be achieved either by water spray (adiabatic) or steam humidification (Fig. 3).

In the spray method, air moisture is increased by mixing fine water droplets with supply air in a special chamber (Fig. 3, a).

In the steam method, steam from a generator is delivered to a distribution pipe with injection nozzles. During the operation of the steam generator, it is necessary to monitor the operating time of the steam cylinder (Fig. 3, b) and temporarily replace it.

Dehumidification can be performed using adsorption-rotor regenerators, which can reduce absolute humidity to 0,1 g/kg and ensure stable operation at low outdoor temperatures. In some cases, condensation

dehumidifiers (when RH exceeds the dew point) or precision humidifiers with closed-loop dehumidification can also be used.

To ensure constant monitoring of indoor microclimate parameters, it is advisable, in addition to the sensor system integrated with HVAC (heating, ventilation, and air conditioning) systems, to have a separate monitoring system with control sensors.



*a*



*б*

**Fig. 3. Equipment for humidifying air:  
*a* – irrigation chamber; *b* – steam cylinder**

A review and analysis of museum buildings show that indoor microclimate is the key factor for the preservation of museum exhibits. The fundamental principles for designing effective microclimate systems are an individual approach to HVAC system design, integration of systems based on BIM and CFD tools, use of intelligent, energy-efficient equipment with environmental monitoring.

### **References**

8. Thomson, G. The Museum Environment (2nd ed.). – Butterworth-Heinemann, 1986.

9. EN 15757:2010. «Conservation of cultural property – Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials».

10. ДБН В.2.5-67:2013 Опалення, вентиляція та кондиціонування PDF. URL: <https://dbn.co.ua/load/normativy/dbn/1-1-0-1018>.

11. ASHRAE Handbook – HVAC Applications. Chapter 23: Museums, Galleries, Archives and Libraries. – American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019.

12. Camuffo, D. Microclimate for Cultural Heritage: Conservation, Restoration, and Maintenance of Indoor and Outdoor Monuments. – Elsevier, 2019.

## ВПЛИВ ФАЗОВОЇ МОДУЛЯЦІЇ КОДОМ АДАМАРА НА ФУНКЦІЮ НЕВИЗНАЧЕНОСТІ КОГЕРЕНТНОЇ ПОСЛІДОВНОСТІ ІМПУЛЬСІВ

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***Анотація.** В роботі наведені результати дослідження складних сигналів, що являють собою послідовність когерентних імпульсів. Одним із методів обробки таких послідовностей імпульсів є фазова модуляція комплементарними кодами. На прикладі коду Адамара за допомогою математичного моделювання визначено вплив такої обробки на кореляційні властивості послідовності і її функцію невизначеності.*

***Ключові слова:** кореляційна функція, комплементарні коди, фазова модуляція, функція невизначеності.*

У сучасній радіолокації застосовується багато різних типів складних сигналів [1, 2]. Досить розповсюдженими є когерентні послідовності імпульсів. Такі послідовності дають змогу використовувати різні методи модуляції окремих імпульсів, що вносить певне різноманіття між імпульсами сигналу. В свою чергу, це дозволяє покращити кореляційні властивості сигналу – зменшити рівень бічних пелюсток, знизити рекурентні сплески, і більш того, добитись майже рівномірного розподілу функції невизначеності в зоні ненульових доплерівських зміщень. Крім того, когерентність імпульсів в послідовності дозволяє збільшити ефективну тривалість сигналу, наслідком чого є покращення роздільної здатності за доплерівським зміщенням.

Досить розповсюдженим методом обробки когерентних послідовностей імпульсів є фазова модуляція комплементарними кодами [2, 3]. Комплементарними називають дві послідовності, якщо сума їх автокореляційних функцій дорівнює нулю для будь яких зміщень окрім нульових. З огляду на те, що комплементарні послідовності