International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

| March 2024 | Issue 58 | Volume 16 | Number 1 | Pages 92-97 |
|---|---|---|---|---|

# MODELING OF AUTOMATIC REGULATION OF A VENTILATION BASED ON FUZZY LOGIC

**G.M. Yeralinova [1] B.B. Orazbayev [1] D.K. Brazhanova [2] S.R. Suleimanov [3]**

*1. Department of Systems Analysis and Management, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan gulmira_9292@mail.ru, batyr_o@mail.ru*
*2. Department of Energy Systems, Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan dana_b.k@bk.ru*
*3. KazTechAutomatics LLP, Temirtau, Kazakhstan, seidamet.s@gmail.com*

**Abstract-** The study will be conducted in order to improve the model of automatic control of supply and exhaust ventilation in the production room using fuzzy logic. The main scientific novelty lies in the fact that the model will control not only the basic parameters of the microclimate, but also the content of harmful substances in the indoor air. To create this model, five main stages of the fuzzy modeling process will be studied and applied. Fuzzy logic will allow the model to adapt to changing conditions, taking into account the fuzziness and uncertainty of the input data. This will help to achieve optimal working conditions in the production room, providing a comfortable and safe environment for employees. As a result of the study, recommendations will be proposed for the development and implementation of similar systems at other production facilities. This will allow the benefits of the developed model to be extended to a wider range of industrial enterprises, ensuring optimal working conditions and increasing employee safety.

**Keywords:** Intelligent Systems, Fuzzy Logic, Air Ventilation System, Controller.

## 1. INTRODUCTION

According to the analysis of the literature [1, 2, 3, 4], modern models based on fuzzy logic cannot always be used to control the microclimate in industrial premises.

In most of the works, the main goal of the authors was to save electricity, this is achieved mainly by controlling two parameters: temperature and relative humidity. As a result, the use of fuzzy logic allows for significant energy savings.

The use of fuzzy controllers in the management of the ventilation and air conditioning system provides a number of advantages:
- selection of the required operating mode depending on the temperature and humidity of the air;
- there is no need for constant reconfiguration, unlike PID controllers, when changing equipment parameters;
- ensuring constant comfort in the room.

However, for industrial premises, not only temperature and humidity control is important, but also the ability to effectively manage emissions of harmful substances into the air [5]. To solve this problem, the task was set to develop control methods and algorithms based on fuzzy logic that would meet the requirements of microclimate control in industrial premises. The main component of such a system is a model that takes into account production conditions and allows maintaining the necessary climatic parameters within specified limits [6].

Thus, the development of a model capable of controlling emissions of harmful substances remains an urgent task. The effectiveness of monitoring the microclimate of industrial premises can be significantly improved with the help of developed management methods and algorithms.

Such a system will take into account production conditions, climatic factors and the concentration of harmful substances, ensuring optimal management of the microclimate in production.

## 2. STAGES OF FUZZY INFERENCE DEVELOPMENT

Let's discuss the stages of creating a fuzzy output:

1. Definition of input and output variables: At this stage, input variables are defined, which represent factors or parameters affecting the system, and output variables, which represent recommendations or control signals that the system should generate. In the context of supply and exhaust ventilation control in a production room, input variables can be temperature, humidity, $CO_2$ level, and output variables can be ventilation rate or air mixture level.

2. Linguistic variables represent various values or terms that are used to describe input and output variables in a fuzzy control system. For each term, an affiliation function is defined, which describes how much a given value corresponds to a given term. The membership function can be, for example, triangular or Gaussian in shape.

Registered: 230801 Article Info: 1704 Accepted: 240224
Reserved: 240116 Available: 240331

3. Creating a rule base: The rule base consists of a set of rules that associate input variables with output variables. For example, the rule may look like "If the temperature is high and the humidity is high, then increase the ventilation rate." The rule base can be compiled by experts who rely on their knowledge and experience, or using machine learning algorithms.

4. Evaluating the activation of rules is an important step in a fuzzy control system. At this stage, the degree of activation of each rule is determined, that is, to what extent this rule is applicable in the current situation based on the values of the input variables. For each rule, the degree of activation is determined, which can be expressed as a numeric value from 0 to 1. The higher the degree of activation, the more applicable the rule is in the current situation. The evaluation of rule activation is based on membership functions, which determine how much each linguistic variable is present in the input data. Membership functions can be specified in the form of graphs or mathematical formulas.

5. After aggregating the estimates of the activation of the rules, a fuzzy conclusion is obtained, which is a set of recommendations or control signals to achieve the desired microclimate conditions. However, in order to apply these recommendations in practice, it is necessary to convert the fuzzy output into certain values, which is carried out at the stage of defazzification.

6. Defazzification is the last step in the fuzzy inference process, which converts fuzzy inferences into specific numeric values or solutions. In this case, defuzzification is used to convert fuzzy recommendations or control signals into specific values for controlling the supply and exhaust ventilation.

The whole process of developing fuzzy inference requires an analysis of existing data and the expertise of domain experts to determine linguistic variables, membership functions and the rule base, as well as to configure and validate the system.

## 3. METHODS

The Fuzzy Logic Toolbox program is a powerful tool for modeling and developing control systems based on fuzzy logic. It provides a wide range of functions and tools for creating and optimizing fuzzy systems:
- Development of expert systems
- Designing neural networks;
- Using special blocks to build Fuzzy Logic systems in Simulink.

This expansion pack is considered one of the optimal solutions for scientific and technical tasks [7]. Using Fuzzy Logic Toolbox, you can create and optimize a fuzzy control system using specific input and output variables, membership functions, and rules. This system can be tested and evaluated by simulating various scenarios.

## 4. CONTROLLER SIMULATION BASED ON FUZZY LOGIC

To design a ventilation process control system, the first step is to nominate variables: the input variables will be temperature (*T*), humidity ($\varphi$) and the maximum permissible concentration of harmful substances in the air (*MPC*) [8]. The output parameters are signals to the actuators of the ventilation system. Table 1 shows the variables used.

Table 1. Used values of input variables

| Designation | Symbol |
|---|---|
| Negative Middle | NM |
| Negative Small | NS |
| Zero | Z |
| Positive Small | PS |
| Positive Middle [9] | PM |

The temperature membership functions for the 0-25 °C range are described in Table 2, and below is the model in MATLAB in Figure 1.

Table 2. Used values of input variables

| Membership functions | Range (°C) |
|---|---|
| NM | 16-10 |
| NS | 15-18 |
| Z | 17-19 |
| PS | 18-21 |
| PM | 20-25 [9] |

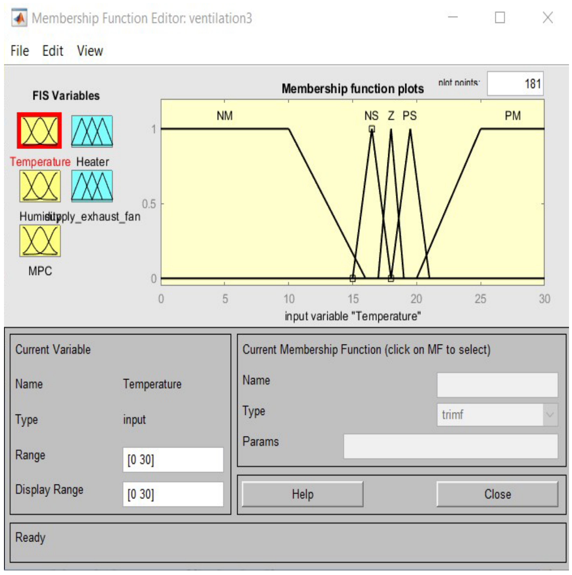



Figure 1. Membership function for temperature

Table 3. Used values for relative humidity

| Membership functions | Range (%) |
|---|---|
| NS | 20-40 |
| Z | 40-60 |
| PS | 60-80 [9] |

The functions of the relative humidity membership for the range 0-100% are described in Table 3 and Figure 2. The functions of the membership for *MPC* are shown in Table 4, and simulation on Figure 3. Figure 4 shown a structure of the fuzzy controller model. Output variables: signal to the actuator of the heater, supply and exhaust ventilation. Table 5 shows the values of output variables used for supply and exhaust ventilation.

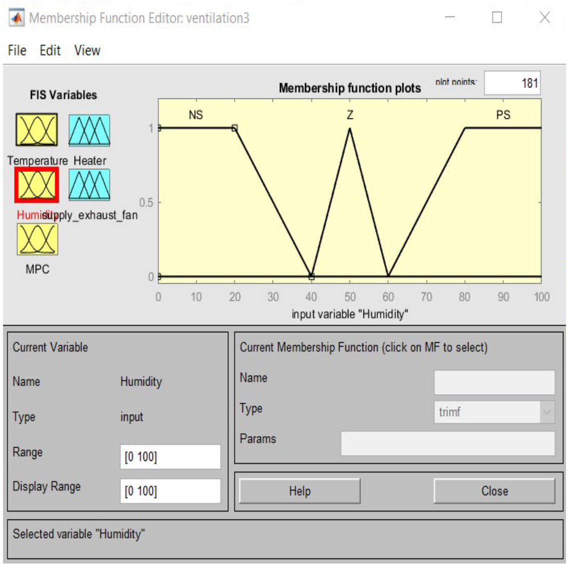



Figure 2. Membership function for relative humidity

Table 4. The values used for *MPC*

| Membership functions | Range |
|---|---|
| NS | 0-0.35 |
| Z | 0.35-0.70 |
| PS | 0.70-1 [9] |

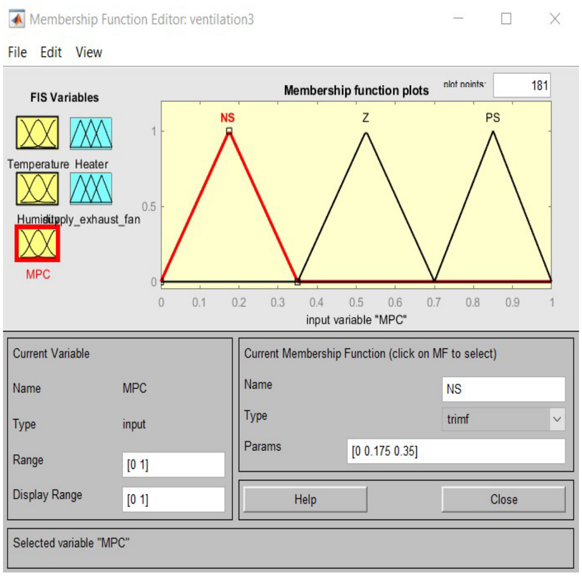



Figure 3. Membership function for *MPC*

The fuzzy controller uses linguistic variables and fuzzy inference based on a set of fuzzy rules "IF AND THEN". If the temperature is low, the heater turns on depending on the desired room temperature. Humidity and MPC is controlled by the same rules as temperature [11].

For example, if the room temperature is 15 °C, the relative humidity is 50%, and MPC is 0.5, then the heater will work in MDP (MEDIUM) mode, supply-exhaust fan in MNP (MINIMUM) mode.

Figures 5 and 6 shown operating modes of heater and supply and exhaust fan in MATLAB [11]. Table 6 shows the values of the heater.

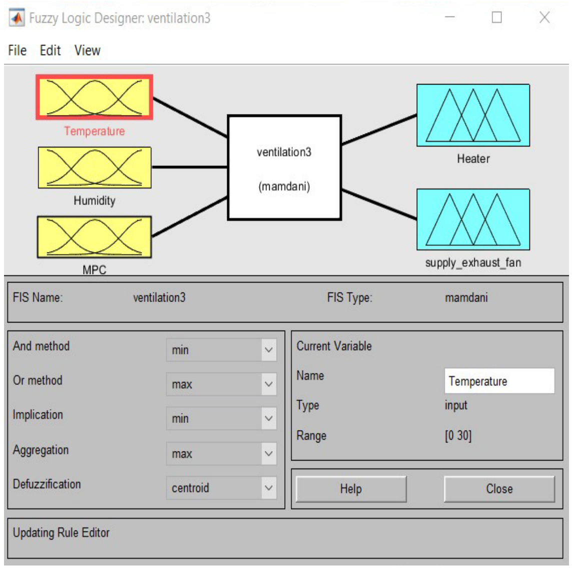



Figure 4. Structure of the fuzzy controller model

Table 5. Used values of output variables

| Membership functions | Symbol | Range (%) |
|---|---|---|
| Maximum Power | MX | 70-100 |
| Medium Power | MD | 30-70 |
| Minimum Power | MN | 15-30 |

Table 6. Used values of the heater.

| Membership functions | Symbol | Range (%) |
|---|---|---|
| Maximum Power | MXP | 100-70 |
| Medium Power | MDP | 70-30 |
| Minimum Power | MNP | 0-30 |

Table 7. Used values of the supply and exhaust fan for relative humidity

| Change in relative humidity | Then the supply and exhaust fan in the mode of | |
|---|---|---|
| | Supply | Exhaust |
| NS | Maximum Power | Minimum Power |
| Z | Medium Power | Medium Power |
| PS | Minimum Power | Maximum Power |

Table 8. Used values for *MPC*

| Changes in *MPC* | Then the supply and exhaust fan in the mode of | |
|---|---|---|
| | Supply | Exhaust |
| NS | Minimum Power | Minimum Power |
| Z | Minimum Power | Maximum Power |
| PS | Minimum Power | Maximum Power |

The generated base of fuzzy controller rules for this model is shown in the Figures 7 and 8. The fuzzy controller rule base for this model consists of 16 rules that will be resolved in the future, taking into account additional parameters. Rules Viewer shown in Figure 9. The display of the dependence of the output variable on the output variable can be viewed on the response surface in the Figure 10.

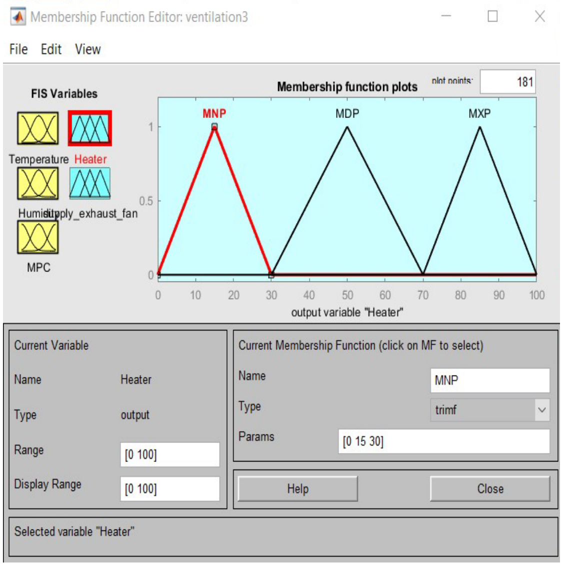



Figure 5. Accessory function for the heater

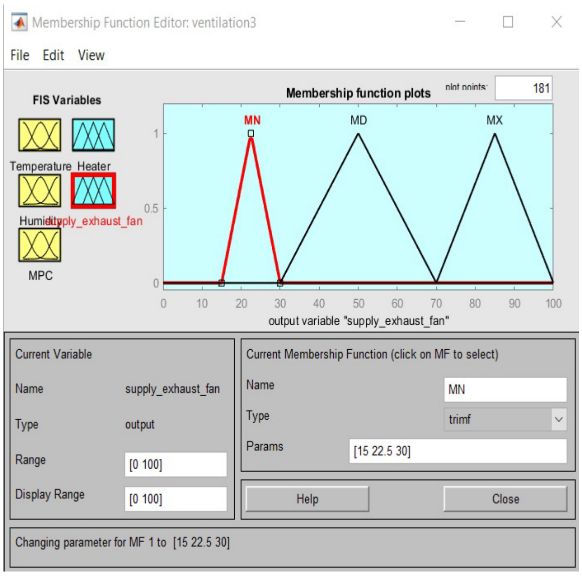



Figure 6. Supply and exhaust fan accessory function

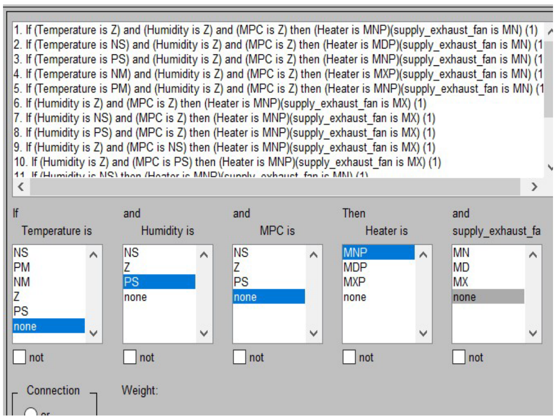



Figure 7. Formed rules base in Rules Editor

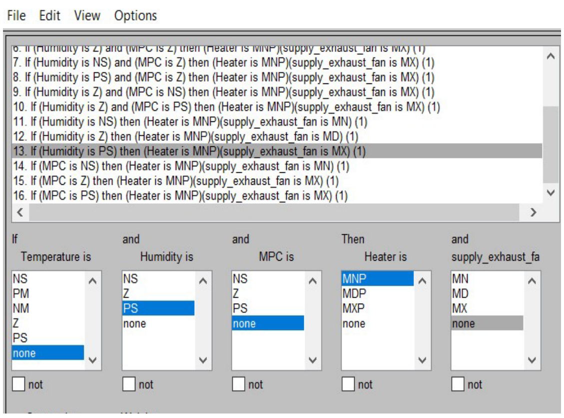



Figure 8. Formed rules base in Rules Editor

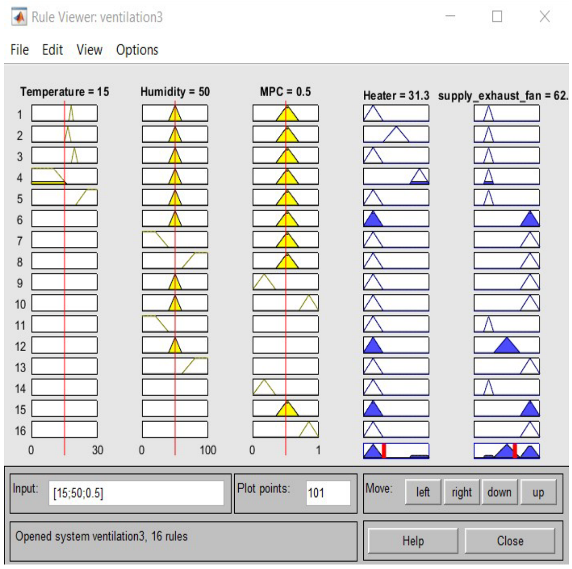



Figure 9. Rules viewer

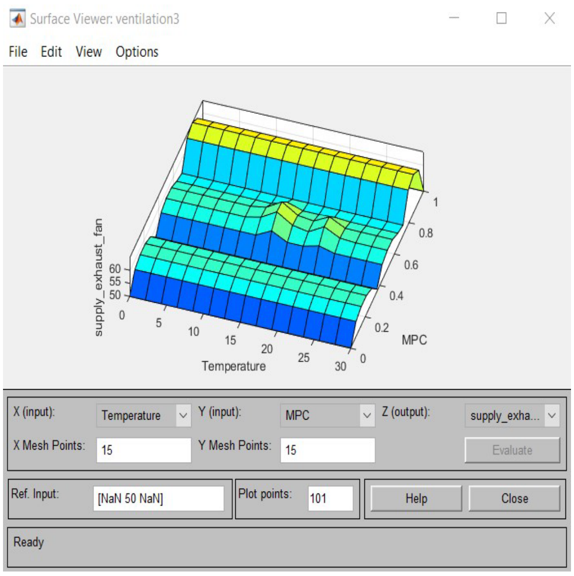



Figure 10. Surface

The model was built considering the permissible temperature, relative humidity and maximum permissible concentration of harmful substances in the air of the production room. In comparison with the works [1, 2, 3, 4], where the main task was to reduce energy costs, in the proposed model, in addition to the main parameters, the concentration of harmful substances in the air is monitored.

This makes it possible to use this model in industrial premises, which is the main difference between the developed model and the above ones. This method of fuzzy control and the algorithm implementing it, in addition to economically maintaining the climate in industrial buildings, will allow you to continuously select and implement the necessary operating modes of actuators.

## 6. CONCLUSIONS

The research conducted based on the development of a model based on fuzzy logic has both scientific novelty and practical significance [12]. This model allows you to take into account the uncertainty and fuzziness of the input data, as well as adapt to changing conditions.

Effective management of the microclimate in industrial premises has a number of advantages, such as increased comfort and safety for employees, improved productivity and quality of work, as well as reduced energy consumption.

In addition, the model can be applied to control technological schemes and premises where it is important to maintain certain conditions to ensure the quality of work and processes.

Further improvement of the model, taking into account additional parameters, will expand the possibilities of its application and increase the flexibility and accuracy of microclimate control. This will allow the model to be adapted to different production conditions and requirements. Thus, the implementation of the developed model based on fuzzy logic has an important impact on the control and management of microclimate parameters in industrial premises, which is important for industry and environmental protection.

## NOMENCLATURES

**Symbols / Parameters**

$T$: The room temperature

$\varphi$: The relative humidity in the room

*MPC*: Maximum permissible concentration

°C: Temperature on the Celsius scale

## REFERENCES


[1] I.M.A. Al Dzhuburi, "Mechatronic Microclimate Control System in Buildings Based on Fuzzy Logic", Author's Abstract. Dis. Ph.D. Tech. Sciences, p. 188, Novocherkassk, Russia, 2010.

[2] D.A. Bobrikov, "Multilevel Automated Microclimate Control System Based on Fuzzy Logic", Author's Abstract. Dis. Ph.D. Tech., p. 154, Moscow, Russia, 2017.

[3] S.I. Yuran, M.N. Vershinin, "Improving the Microclimate Regulation System Based on Fuzzy Logic", Vestnik NGIEI, Issue 9, Vol. 100, pp. 33-45, Izhevsk, Russia, 2019.

[4] A.H. Attia, S.F. Rezeka, A.M. Saleh, "Fuzzy Logic Control of Air-Conditioning System in Residential Buildings", Alexandria Engineering Journal, Vol. 54, No. 3, pp. 395-403, Alexandria, Egypt, March 2015.

[5] A.V. Karpenko, I.Yu. Petrova, "The Conceptual Model of Neuro-Fuzzy Regulation of the Microclimate in the Room", IFAC-PapersOnLine, Vol. 51, Issue 30, pp. 636-640, Astrakhan, Russia, 2018.

[6] G.M. Yeralinova, B.B. Orazbaev, D.K. Brazhanova, "Research and Development of an Automatic Control and Air Conditioning System Based on Fuzzy Logic", Bulletin of the Almaty University of Power Engineering and Telecommunications, No. 60, Ed. 1, pp. 29-44, March 2023.

[7] V.S. Velikanov, G.G. Safin, A.A. Abdrakhmanov, A.A. Shabanov, S.N. Makhmudova, R.A. Abdullin, A.S. Tuguzov, "Development of a Fuzzy Model in the MATLAB Fuzzy Logic Toolbox Environment for Assessing Working Conditions in the Workplaces of Mining Workers", Modern High-Tech Technologies, Vol. 1, Issue 2, pp. 19-24, 2015.

[8] A. Terziev, V. Stoyak, V. Ushakov, D. Brazhanova, S. Suleimanov, "Analysis of the Opportunities for Improving Energy Efficiency in Public Buildings", IOP Conference Series: Materials Science and Engineering, Vol. 13, Issue 4, pp. 238-242, December 2021.

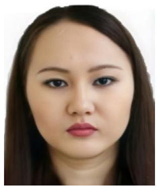
[9] L.Zh. Sansyzbay, B.B. Orazbayev, "Modeling the Operation of Climate Control System in Premises Based on Fuzzy Controller", Journal of Physics: Conference Series, Vol. 1399, Issue 4, pp. 1-7, 5 December 2019.

[10] https://adilet.zan.kz/rus/docs/V2100023852

[11] A.B. Balametov, E.D. Halilov, A.K. Salimova, F.G. Iskenderov "Algorithm and Matlab-Based Program for Modeling the Nodal Electricity Prices", International Journal on Technical and Physical Problems of Engineering (IJTPE), Vol. 12, Issue 42, pp. 20-24, March 2020.

[12] H. Shayeghi, H.A. Shayanfar, "PSO Based Neuro-Fuzzy Controller for LFC Design Including Communication Time Delays", International Journal on Technical and Physical Problems of Engineering (IJTPE), Vol. 2, Issue 3, pp. 28-36, June 2010.


## BIOGRAPHIES




Name: **Gulmira**
Middle Name: **Maratovna**
Surname: **Yeralinova**
Birthday: 04.06.1992
Birthplace: Karaganda, Kazakhstan
Bachelor: Instrument Engineering, Department of Instrumentation, Faculty of Information Technologies, Karaganda State Technical University, Karaganda, Kazakhstan, 2014
Master: Faculty of Information Technologies, Karaganda State Technical University, Karaganda, Kazakhstan, 2016

Master: Instrument Making, Department of Instrumentation, Institute of Non-Destructive Instrument Making, Tomsk Polytechnic University, Tomsk, Russia, 2016
Doctorate: Student, Automation and Management, Department of Systems Analysis and Management, Faculty of Information Technology, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan, Since 2020
Research Interests: Automation and Control, Instrumentation, Artificial Intelligence, Telemedicine
Scientific Publications: 3 Papers, 1 Patent,1 Thesis

Name: **Batyr**
Middle Name: **Bidaibekovich**
Surname: **Orazbayev**
Birthday: 12.03.1959
Birthplace: Astana, Kazakhstan
Bachelor: Engineering, Department of Technical Cybernetics, Faculty of Automation and Information Technology, Kazakh Polytechnic Institute, Almaty, Kazakhstan, 1985
Master: Engineering Cybernetics Department, Faculty of Computer Science, ACS Moscow Institute of Steel and Alloys, Moscow, Russia, 1992
Doctorate: ACS Moscow Institute of Steel and Alloys, Moscow, Russia, 1996
The Last Scientific Position: Prof., Doctor of Technical Sciences, Department of System Analysis and Control, Faculty of Information Technology, L.N. Gumilyov Eurasian National University, Astana, Kazakhstan, Since 2015
Research Interests: Mathematical Modeling, Optimization and Decision-Making Fuzzy Environment, System Analysis and Management, Intelligent Systems, Expert Systems
Scientific Publications: 580 Papers, 26 Books, 1 Patent, 5 Projects

Name: **Dana**
Middle Name: **Korabaevna**
Surname: **Brazhanova**
Birthday: 23.01.1990
Birthplace: Karaganda, Kazakhstan
Bachelor: Instrument Engineering, Department of Instrumentation, Faculty of Information Technologies, Karaganda State Technical University, Karaganda, Kazakhstan, 2012
Master: Instrument Engineering, Faculty of Information Technologies, Karaganda State Technical University, Karaganda, Kazakhstan, 2016
Master: Instrument Engineering, Department of Instrumentation, Institute of Non-Destructive Instrument Making, Tomsk Polytechnic University, Tomsk, Russian Federation, 2016
Doctorate: Heat Power Engineering, Department of Thermal Power Plants, Institute of Thermal Power Engineering and Control Systems, University Almaty of Power Engineering and Telecommunications, Almaty, Kazakhstan, 2021
The Last Scientific Position: Lecturer, Energy Systems Department, Faculty of Energy, Automation and Telecommunications, Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan, Since 2016
Research Interests: Instrumentation, Automation and Internet of Things
Scientific Publications: 20 Papers, 5 Patents

Name: **Seidamet**
Middle Name: **Rishadovich**
Surname: **Suleimanov**
Birthday: 24.04.1990
Birthplace: Temirtau, Kazakhstan
Bachelor: Heat Power Engineering, Energy Department, Faculty of Energy and Telecommunications, Karaganda State Technical University, Karaganda, Kazakhstan, 2011
Master: Power Engineering, Energy Department, Faculty of Energy and Telecommunications, Karaganda State Technical University, Karaganda, Kazakhstan, 2013
Doctorate: Electrical and Thermal Engineering, Department of Electric Power Engineering, School of Energy, National Research Tomsk Polytechnic University, Tomsk, Russian Federation, 2020
The Last Scientific Position: Head of Scientific Project, KazTechAutomatics LLP, Temirtau, Kazakhstan, Since 2016
Research Interests: Electronics, Lighting Engineering, Energy, Automation
Scientific Publications: 15 Papers, 19 Patents, 7 Projects