Project name: IRN AR14869386 "Research, development of a set of structures and creation of an experimental sample of an automatically controlled sailing wind power plant with a swinging working body".

Relevance. The problem of widely used turbine wind farms is the unpredictability of wind gusts, speeds that often change in short periods of time and hurricanes. In addition, the lower limit of the wind speed range, at which the output power of turbine wind farms is usually 30% of the nominal more than 10 m/s. This circumstance determines the territorial restriction on the use of turbine wind farms. For example, vast territories of Kazakhstan and other countries have average wind speeds of about 3 m/s and effective use of turbine wind farms is impossible in these territories. Thus, the project solves the urgent problem of expanding the territory of using wind sources of renewable energy, since the automatically controlled sailing wind power plants (SWPP) proposed in the project are designed to generate electric energy at wind speeds of 2.5 m/s, regardless of the random nature of changes in wind direction and speed. Therefore, all consumers of these territories will be able to have access to inexpensive energy from an inexhaustible source - wind. Manufacturing of own products (licensed) in the form of automatically controlled sailing wind farms will allow Kazakhstan to take its place in the global renewable energy market.

The project offers a new technology and technical means for the effective conversion of wind energy into electrical energy by using: a spatially moving sail in the form of an umbrella, with automatically adjustable sailage, perceiving both lifting force and wind resistance force; using parallel manipulator actuators to control the movement of the working body using a controlled damper and to generate electric energy using built-in power take-off system and built-in electric current generator. This technology will allow: firstly, to develop a new direction in the world for converting wind energy into electric energy; secondly, it will create more efficient and reliable small wind farms that generate electric energy at an affordable price for consumers.

The global wind farm market will receive new high-performance automatic controlled wind farms at a cost-effective price.

Goal: to investigate and develop a set of designs for creating an experimental sample of an automated small sailing wind power plant with a swinging working body using technology, technical and hardware means for effectively converting wind energy into electrical energy when wind speed changes in a large range, starting from 2.5 m/s, regardless of the direction and nature of the wind speed change.

Expected results. Based on research, calculations, and design developments of a set of structures, an experimental sample of an automatically controlled small sailing wind power plant with a capacity of 5 kW will be created that meets the requirements and makes it possible to further commercialize the project.

Based on the results of the work, 2 articles will be published in rating journals and in scientific journals of the Republic of Kazakhstan. A monograph will be published and reports will be made at international conferences.

In 2023, the following works were completed

• A device has been developed for conducting meteorological studies and monitoring the environment of exposure. The analysis and selection of technical means for measuring wind speed and direction are carried out. Experimental studies of wind dynamics and characteristics for a month in Karaganda were conducted.

• A section of the sail model with an aerodynamic profile was made, and the design documentation of the mast was prepared.

• The equations of the dynamics of the control system by linearization and the results of the stability analysis of the system for the analysis of the control system are obtained. The analysis of the dynamic working body (WB) is carried out taking into account the random nature of changes in wind speed and direction and the nonlinearity of controlling the movement of the WB using spring preload.

• The hardware and software parts of the subsystems and the control system of the SWPP have been developed. A test bench for the actuator has been designed together with a control automation system.

• The scheme and algorithm of automated control of the system are constructed.

• * An analysis of the dynamics of a manipulator converter (MC) at a power of 5 kW SWPP was carried out. The calculation and design of the mast with elements of connecting umbrellas and fastening to the MC was carried out. The initial data for the design of actuators with the possibility of scaling have been obtained. The design documentation for the manufacture of the mast has been prepared.

• The design documentation of the actuators and the manipulator converter (MC) has been prepared, taking into account the previously created prototype of the actuator. The calculation and design of the mast with elements of connecting umbrellas and fastening to the MC was carried out.

• A test bench for the actuator has been created.

According to the results of the conducted research, published:

1. Sholanov K.S., Omarov A.S. Description of the design and technology of wind energy conversion by an umbrella sail power plant. Bulletin of the Toraighyrov University. Energy series. - 2022. – No. 3. – pp. 211-223. doi: 10.48081/OBSP7632

2. Sholanov K.S., Omarov A.S. Modification of Wind Power Plant with an Umbrella Sail // Reviews of Modern Science. Proceedings of the 1st International Scientific Conference. Technical Science section. Zurich, Switzerland. – 2022.

3. Sholanov K.S.,Kabibulatov A.A. The manipulator actuator of a sailing wind power plant. PCT/KZ2023/000010 Patent application for a WIPO sailing wind power plant. Reg. No. 2022/065 dated 11/16/2022

4. Sholanov K., Omarov A., Ceccarelli M. IMPROVING EFFICIENCY OF CONVERTING WIND ENERGY IN MODIFIED SAIL WIND POWER STATION // International Journal of Mechanics and Control. Vol. 23, No. 02, 2022.

5. Sholanov K.S., Omarov A.S. Investigation and selection of parameters of a modified wind power plant with an umbrella sail. In the journal Bulletin of the Toraighyrov University. Energy series. – No. 4. – 2022, – pp. 211-223.

6. Sholanov K.S.,Kabibulatov A.A. The manipulator actuator of a sailing wind power plant. PCT/KZ2023/000010 WIPO Patent Application.

Members of the research group:

The project leader is Academician of the National Academy of Sciences of the Republic of Kazakhstan and the Kazakhstan National Academy of Natural Sciences, Doctor of Technical Sciences, Professor **Sholanov Korganbai Sagnaevich**, h-index2, Scopus Author ID 56258478400, ORCID 0000-0002-2077-7883.

research group:

Lead Researcher **Marco Ceccarelli**, Phd, professor, University of Rome Tor Vergata, LARM2, Director, h-index 30, ResearcherID AAK-9020-2020, ORCID 0000-0001-9388-4391, Scopus Author ID: 7102783688.

Deputy Scientific Supervisor researcher **Abzhaparov Kuanysh Almabekovich**, PhD, h-index 1, Researcher ID AAY-6133-2020, Scopus Author ID 57189640775.

Researcher **Omarov Anuar Serikovich**, PhD, ORCID 0000-0001-9602-2770.

Junior Researcher **Mirzabaev Berik Islambekov**, PhD, ORCID 0000-0003-1430-741X.

Information for potential users.

During the implementation of this project, it is planned to solve the following scientific issues:

- Monitoring of the impact environment by experimental investigation of wind dynamics and characteristics;
- Investigation of the aerodynamic characteristics of an umbrella sail using Solid Works and Flow Simulation software and a parallel experiment on an aerodi-namical tube;

- Generalization of the algorithm of force analysis of a manipulator converter for scaling and propagation to SWPP of various capacities;
- Formation of a dynamic model of the actuator and a block diagram of a nonlinear control system for the movement of the rotor by changing the preload of the springs of the damping system;
- Investigation of the dynamic properties of the RO motion control system using the statistical linearization method.

The consistent solution of these interrelated issues within the framework of this project will ensure the development of the concept and principles of construction, the structure of the automated control system of the SWPP and obtain technical solutions for the creation of sets of structures and an experimental sample of the SWPP. The research strategy is based on the initial structuring of the scientific tasks of the project, the allocation of the above five local tasks and their solution. At the next stage, the integration of these tasks is ensured for the creation and manufacture of sets of structures, the assembly of an experimental sample of SWPP and conducting field tests. Types of research: descriptive and experimental. The research strategy is based on a consistent transition from theoretical calculations, the use of computer modeling, experimental research to the creation of prototypes and testing in real conditions.