ABSTRACT

of the dissertation work on the topic:

«DEVELOPMENT OF AN INTELLIGENT DIAGNOSTIC SYSTEM AND OPTIMAL CONTROL OF THE WIND POWER COMPLEX»

submitted for the degree of Doctor of Philosophy (PhD)

in the specialty 6D070200 – «Automation and Control»

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The aim of the thesis work is to develop and improve a wind turbine with vertical axis location, by developing and implementing additional nodes and mechanisms, regulated by the method of intelligent control.

The main idea of the work is to improve the wind power plant by creating new nodes and mechanisms that increase the efficiency and stability of wind energy conversion into electricity under different conditions of wind power plant operation. Development of an intelligent system for diagnostics and optimal control of a wind power complex based on the determination and regulation of key process variables using intelligent algorithms. The proposed system is able to integrate with current automation systems in the energy sector of the Republic of Kazakhstan.

Object of the study. The object of the study is a wind power plant Wind Rotor Turbines Bolotov, developed and patented, which has technical documentation.

Objectives of the study. Taking into account the set goal, the scientific tasks requiring solution within the framework of the dissertation work are highlighted:

– to analyze the current state of existing control systems of wind power plant;

– to investigate the process of wind energy generation and peculiarities of the wind energy plant as a control object;

– to carry out research, determination of key variables and implementation of necessary units and mechanisms improving the main parameters of electric power generation;

– development of mathematical models of various nodes of the wind power generation system;

– development of the control system structure of various nodes, mechanisms of the wind energy plant and development of an intelligent control system based on neural networks;

– regulation of key variables of the developed nodes of the wind energy plant on the basis of the developed intellectual control system;

– checking the adequacy of the developed intellectual system and testing it on the real operating object.

Research Methods. Theories of automatic control, methods of data acquisition and processing, mathematical and physical formulas for calculating wind power plant parameters, methods of intelligent control systems were used in the course of problem solving. The basics of aerodynamics theory, theoretical

mechanics and electrical engineering theory were also applied. Modeling was performed using the modern Matlab/Simulink software package. AutoCad automatic design program was used to create drawings of the wind power complex structure and automation schemes in the intelligent control system. MS Office software was used for calculations and design of the thesis.

The proposed calculations and algorithms are based on the real operating installations of wind power plants and are designed for conditions in the area of «Dzhungar Gate» of Almaty region.

The main provisions (proven scientific hypotheses and other conclusions that are new knowledge) put forward for defense:

– a universal model of a wind power system with power generation to the grid operating in different modes;

– an intelligent system of diagnostics and control based on neural networks for optimal control of the wind power complex;

– stator guide control mechanism with an intelligent system that takes energy of the wind flow into the turbine rotor depending on its speed coming from an anemometer;

– automatic speed shifter box with calculated gear ratio steps to decrease or increase, depending on the turbine shaft speed and excitation current frequency, the link of transferring the speed of rotation from the turbine shaft to the generator shaft, which is controlled by an intelligent system;

– an automatic generator excitation regulator system with generator excitation current variation depending on the high-speed shaft speed, also controlled by the intelligent system;

– a diagnostic system that prevents critical situations and restarts the operation of the wind power plant.

Description of the main results of the study

– The analysis of the current state of control systems for wind power plants and complexes was carried out, where control systems oriented only to separate categories of installations and units were used, which did not show significant improvements for the wind power plant and the shortcomings of these systems were revealed. This served as a basis for the creation of a new, universal regulation mechanism, diagnostics and intelligent control system for vertical wind turbines, which excludes dependence on wind speed. The relevance of the research topic is substantiated;

– The wind potential of the Republic of Kazakhstan, Dzungarian Gate region is analyzed, the need for efficient wind power plants for wind energy generation is revealed. Also considered the technological aspects of energy generation from wind, analyzed the features of wind power plants;

– A mathematical model of a complex wind power plant is developed, describing aerodynamic, mechanical and power components. The key mechanisms and assemblies required for the full operation of the wind turbine are identified;

– The modeling of the wind power generation system has been carried out, allowing to consider the energy system in dynamics. Output characteristics of the model correspond to the characteristics of the real wind turbine MITSUBISHI

MWT 92. Parameters reflecting the energy behavior of the wind turbine and its basic mechanical and electrical dynamics are presented, where the control and regulation system is based on classical controllers;

– After identifying the shortcomings of traditional wind power control systems, control strategies for aerodynamic, mechanical and complex electrical components of the wind power generation system are revised. A new diagnostic and optimal control system structure including new control systems is developed. Intelligent algorithms using neural network are synthesized. Based on these results, an intelligent diagnosis and optimal control system including the regulation of the excitation current of the generator, automatic gearbox and turbine stator guide mechanism in dynamics is established. The system monitors the wind speed, reacting quickly to its changes, eliminating dependence on the variable nature of the wind. The developed diagnostic system prevents emergencies and, in case of their occurrence, promptly restores the operation of the wind power complex. The analysis of various models of the wind power plant confirms the effectiveness of the developed system;

– The adequacy of the developed intellectual model of the wind power complex was verified with respect to the object on the basis of which it was built. The developed model was tested at the production site of TELMZ LLP together with Future Power Solutions LLP. The results confirmed the effectiveness of the developed system and recommended for further implementation in production.

Justification of the novelty and importance of the results obtained

The results of the thesis represent a significant contribution to the development of the field of renewable energy and energy system management technologies:

– the methods of intelligent control and diagnostics for wind power plants proposed in this paper differ from traditional approaches. The use of neural controllers to determine the stator guide angle, the adjustment of the automatic gearbox and generator excitation current based on wind speed data, and the MPPT (maximum power point tracking) control method are innovative and effective approaches that can significantly improve the efficiency and stability of wind turbines;

– the proposed control methods are adaptive to changing environmental conditions and operate efficiently even under unstable wind conditions or external disturbances. This makes them more stable and reliable compared to traditional control methods;

– increased wind turbine efficiency, reduced maintenance and operating costs, and reduced greenhouse gas emissions and environmental impact have a direct impact on the economy and the environment. This contributes to sustainable development and reduction of negative environmental impacts, and allows achieving an optimal balance between performance, reliability and environmental sustainability of energy systems;

– the results of this work open prospects for further development of technologies in the field of control and diagnostics of wind power plants. Their

successful realization can become the basis for the creation of more efficient and sustainable wind power generation systems in the future.

The novelty and importance of the results obtained lies not only in the development of specific methods and technologies, but also in their potential impact on industry, economy and ecology in general.

Relevance to science development directions or state programs

The strategies of the Republic of Kazakhstan with regard to the development of renewable energy and environmentally sustainable technologies are:

– work on the development of intelligent control systems for wind power plants directly corresponds to the direction of renewable energy development. It helps to increase the efficiency of wind energy utilization, increase the share of wind power in the total energy mix and reduce dependence on fossil fuels;

– the work contributes to the Sustainable Development Goals by reducing environmental impacts and facilitating the transition to clean and green energy. This is in line with the principles of environmental sustainability and environmental protection;

– the developed methods of control and diagnostics of wind power plants represent innovative technologies that contribute to the development of modern scientific and technological base and intellectual potential of the country;

– the development of innovative technologies in the field of energy strengthens the scientific and technical potential of the country, making it more competitive in the world market and contributing to its economic development. Implementation of the developed methods of control and diagnostics of wind power plants contributes to increase energy security and promotes sustainable development of the energy sector. This corresponds to the priorities of the state programs in the field of ecology and sustainable development;

– the results of the work are important for the development of scientific research and innovations in the field of energy systems management. They can become the basis for further research and development in this field, contributing to the progress of science and technology.

The results of the work correspond to the current scientific and technological trends and directions of development, as well as government programs aimed at sustainable development and modernization of the energy sector. Their implementation and utilization can contribute to the achievement of key goals in the field of energy, environment and economy.

Description of the doctoral student's contribution to each publication

Personal contribution consists in setting the goal and objectives of the work, conducting research, processing and analyzing the results, forming conclusions, writing scientific publications and theses of reports.

By results of the executed scientific researches of the dissertation work 15 scientific works are published, from them, 1 article is published in the scientific edition recommended by the Committee on the control in the sphere of education and science of Ministry of Science and Higher Education of the Republic of Kazakhstan, 4 articles are published in foreign editions, included in the international citation base Scopus (Q3/26) and (Q4/22), 6 articles published in the

proceedings of foreign conferences, 3 of which are indexed in the international citation base Scopus (percentile 29%), 3 foreign joint monographs and 1 article published in a foreign edition.

The main results of the study were presented at international scientific-practical conferences:

- 18th Conference on Optical Fibers and Their Applications, 2018, Naleczow, Poland. Proceedings of SPIE 11045, Optical Fibers and Their Applications 2018, 110450L (15 March 2019);
- Collection of first International scientific-practical conference «Global science and innovations 2018», Astana, 2018;
- The 17th International Scientific Conference «Information Technologies and Management». April 26, 2019, ISMA University, Riga, Latvia.

Industrial tests of intellectual algorithms (models) were carried out at the production site of TELMZ LLP jointly with Future Power Solutions LLP.