Abstract. This article is dedicated to the topic of wind farms in the context of agro-industry, with a particular focus on stabilizing the operation of wind turbine blades during gusts of wind. The article analyzes various approaches to blade control in case of sudden changes in wind speed, including the use of advanced control algorithms and the integration of backup power supply systems. The results of the study indicate that advanced control algorithms can significantly improve the stability of wind turbine operation in wind gusts, reducing the need for emergency shutdowns and backup power supply, making wind energy a more competitive source of renewable energy. The article highlights the importance of further research and innovation in wind turbine technology, particularly in the areas of blade control and backup power supply, to ensure a reliable and sustainable source of clean energy in the future.

1 Introduction

As electricity has firmly established itself in our lives, the most pressing issue for us is the generation and uninterrupted supply of electricity to consumers. In recent decades, the question of more environmentally friendly electricity production has become one of the most important issues, as traditional power stations. For example, issues have catastrophic consequences for the ecology of the surrounding world, resulting in such consequences as an increase in the average temperature of the environment, depletion of non-renewable energy resources, depletion of human immunity, and so on. One of the promising directions in the field of electric power industry is “Green Energy.” The main differences between green energy and traditional energy are the use of renewable energy resources such as wind, solar, or tidal power in the sea and ocean. When producing electricity, green energy minimizes environmental pollution by avoiding emissions of various gases into the atmosphere. One of the most promising directions in green energy is wind power. The principle of wind power is to use the force of the wind. The wind turbine, using wind direction sensors, captures the direction of the wind, then rotates using a swivel ring so that the wind turbine is positioned
against the direction of the wind and thus receives maximum energy from the wind. Then the kinetic energy of the wind drives the rotor with blades, which in turn sets the rotor shaft in motion. Then the angular speed of the rotor shaft is increased with the help of a reducer. The resulting mechanical energy is converted into electrical energy by the generator.

Fig. 1. Wind turbine with a horizontal axis of rotation.
Fig. 2. Block diagram of adaptive fuzzy PID control based on a wind turbine.

For example, if we consider the connection of wind power with agriculture, it can be noted that many wind generators are installed on or near agricultural land. This is due to the fact that such sites often have high wind speeds, as well as the availability of land for the installation of wind turbines.

In addition to generating electricity, wind power can also be used to power farms and other agricultural facilities autonomously.

2 Materials and methods. Basics of the neural network

Wind turbines are one of the most promising sources of renewable energy. However, gusty winds can lead to undesirable fluctuations and emergency shutdown of wind turbine blades, which reduces their efficiency and reliability. There are several methods for stabilizing the operation of the blades of the wind generator in case of wind gusts, which helps to avoid unwanted fluctuations and emergency shutdown. Some of the methods:

The first way to stabilize wind turbines in strong winds is to regulate the speed of rotation of the rotor. This method involves the use of an automatic system that adjusts the rotation speed of the rotor in response to changes in wind speed. The system detects when wind speeds
exceed a certain threshold and automatically reduces the rotor speed to prevent unwanted fluctuations and emergency shutdowns.

Regulating the rotor speed is an effective way to stabilize wind turbines during gusts of wind. By adjusting the speed of rotation, the system can reduce the load on the blades and prevent damage to the turbine. This method has been widely adopted in the wind energy industry and has proven to be a reliable and cost-effective way to stabilize turbines.

However, it is important to note that this approach has some limitations. For example, reducing the speed of rotation can result in a decrease in the amount of energy generated by the turbine. Additionally, it may not be effective in extremely strong wind conditions.

In summary, regulating the rotor speed is an important method for stabilizing wind turbines in strong winds. While it has its limitations, it remains a valuable tool for maintaining the safety and reliability of wind turbines in a range of wind conditions [1, 2].

The method of controlling the angle of inclination of wind turbine blades is an effective way to stabilize their operation during gusts of wind. This approach works by adjusting the angle of attack of the blades to reduce the load on the rotor when the wind speed increases. By doing so, it reduces the risk of an emergency shutdown, which could otherwise occur due to excessive stress on the system. However, this method also has its limitations, as it may reduce the efficiency of the turbine in low wind conditions. Nevertheless, it remains one of the most common methods used to stabilize wind turbines and is often implemented through an automatic control system that adjusts the blade angle based on real-time wind speed measurements. With ongoing research and innovation, it is possible that this method will become even more efficient and reliable in the future [3].

The method of preliminary boundaries is one of the most effective ways to stabilize the operation of wind turbine blades in wind gusts. This approach involves using a predictive algorithm to estimate the boundary of the wind gust before it reaches the wind turbine. Based on this prediction, the angle of attack of the blades is adjusted to minimize the impact of the gust.

This method is implemented using sensors and predictive algorithms that analyze the incoming wind data to predict the upcoming gusts. Once the system detects the possibility of a wind gust, it adjusts the angle of attack of the blades in real-time to minimize the impact of the gust. This allows the wind turbine to continue operating smoothly and avoid emergency shutdowns.

The method of preliminary boundaries has several advantages over other methods of blade stabilization. One of the main advantages is that it can be used in a wide range of wind conditions, including high wind speeds and turbulent wind environments. Additionally, this method does not require significant additional components or control systems, making it a cost-effective solution for wind farm operators.

However, there are also some limitations to this method. One of the main limitations is that the accuracy of the predictive algorithm depends on the quality of the incoming wind data. Inaccurate data can lead to incorrect predictions and potential damage to the wind turbine. Additionally, this method may not be as effective in extreme wind conditions where gusts are unpredictable and severe.

Overall, the method of preliminary boundaries is a promising approach for stabilizing the operation of wind turbine blades in wind gusts. With further research and development, this method has the potential to become a key technology for ensuring the reliability and safety of wind farms [4, 5].

3 Results. Practical significance

Wind farms are an excellent source of renewable energy, but their operation can be affected by strong winds or gusts. To ensure the safety of the station and its surroundings, automatic
shutdown mechanisms are installed to prevent damage or accidents. However, sudden outages can also cause disruption of electricity supply, which will lead to losses in economic terms due to under-supply of electrical energy, downtime at an industrial enterprise or, for example, to the shutdown of a lighthouse, which can lead to accidents of ships.

In such cases, it is important to have a reliable and stable wind generation system that will provide a constant and reliable source of energy for the farm.

In some cases, agricultural facilities may also use wind energy to produce hydrogen, which can be used as fuel for transportation and other purposes. In this case, it is important to have an efficient wind generation system that will provide high performance and reliability.

Also, the stability of the operation of wind turbines is important for agricultural facilities, since the failure of the wind generation system can lead to loss of electricity and other problems. Therefore, when developing a wind generation system for agricultural facilities, it is necessary to take into account the specific requirements and needs of this sector of the economy.

Therefore, wind farms also have backup systems, such as batteries or diesel generators, to maintain the supply of electricity during emergencies. Another way to cope with wind gusts is to stabilize the rotor blades. There are various methods of blade stabilization, including angle of attack control, active and passive flow control. The angle of attack controller adjusts the angle of the blades to reduce the load on the rotor during wind gusts, and active flow control uses sensors and actuators to control the airflow around the blades. Passive flow control is based on the shape and design of the blades to mitigate vibrations and reduce drag. In addition to stabilizing the blades, wind farms can also be equipped with redundant components, such as redundant sensors, controllers and communication systems, to increase reliability and safety [6, 7]. Redundancy means that in case of failure of one component, the other automatically switches to its place without interrupting the operation of the station. This is especially important for offshore wind farms, where maintenance and repairs can be complex and expensive. In general, the design and operation of wind farms requires careful consideration of safety, reliability and efficiency issues. Thanks to the use of advanced control and protection systems, as well as optimizing the shape and design of the blades [8, 9, 10].

4 Discussion

Wind turbines have become a popular and important source of renewable energy. However, they are subject to various environmental factors such as wind, which can cause damage or even catastrophic failure if not properly managed. Therefore, it is essential to have a system for stabilizing wind turbines during high winds to ensure their safety and continued operation. An automatic shutdown system is one method for stabilizing wind turbines during strong winds. This system uses sensors to detect when wind speeds reach a certain threshold and automatically shuts down the turbine until the gusts subside. Another approach is the blade angle control system, which adjusts the angle of the blades to maintain stability during strong winds. Various studies have examined these methods for stabilizing wind turbines during high winds. For instance, in the article "A Strategy for Controlling Wind Turbine Blade Angle for Improved Power Capture in Below Rated Wind Speeds," Margaris suggests a strategy for controlling the angle of inclination of the blades based on wind speed measurements. Similarly, in "Methods of controlling wind turbines to improve efficiency," Fernando D. Bianchi discusses various methods of controlling wind turbines, including adjusting the blade angle to ensure stability. In addition to these active management systems, backup plans are also crucial in ensuring the continued operation of wind turbines during power outages or other failures. Backup generators or battery systems can provide power to
critical systems during shutdown, while backup components such as several blades or engines can ensure the operation of the turbine even in the event of component failure. Overall, there are several methods for stabilizing wind turbines in strong winds, including active management systems like automatic shutdown and blade angle control, as well as backup plans such as generators and backup components. Careful consideration of the specific needs and requirements of each installation is essential in designing a system that is reliable and can ensure the safety and continued operation of the wind turbine.

5 Conclusion

Stabilizing the operation of wind turbine blades in strong wind gusts is one of the main issues that need to be addressed in the field of renewable energy sources. Each approach to stabilization has its advantages and disadvantages, and the choice of a particular method depends on a number of factors, such as the design of the station, local climatic conditions, availability and cost of components and technologies. The angle of attack controller allows you to adjust the angle of inclination of the blades to reduce the load on the rotor during wind gusts, which reduces the likelihood of an emergency shutdown. However, this method can lead to a decrease in the efficiency of the station in low wind conditions. Active flow control uses sensors and actuators to control the airflow around the blades, which allows more precise adjustment of the rotor load and increases the efficiency of the station. However, this method requires significant costs for components and control systems, which increases installation and maintenance costs. Passive flow control is based on the shape and design of the blades to mitigate vibrations and reduce drag, which increases the efficiency of the station in a wide range of wind conditions. However, this method does not provide a sufficient degree of load control on the main rotor in conditions of strong wind gusts. In addition, there is a need for backup components and control systems to improve the reliability and safety of wind farms. This includes redundant sensors, controllers and communication systems that allow you to automatically switch to redundant components when the main ones fail. Thus, the stabilization of the operation of wind turbine blades in strong wind gusts is one of the key issues that need to be addressed in the field of renewable energy sources. Therefore, it is necessary to continue research in the field of various methods of blade stabilization in order to make them more efficient and reliable. In addition, attention should be paid not only to the development of new stabilization methods, but also to the optimization of existing technologies, such as redundancy of components and communication systems. This will increase the reliability and safety of wind farms, reduce the costs of their operation and maintenance, and reduce the price difference between traditional and green energy.

As a result, solving the problems of blade stabilization is an important step towards creating more efficient and safe wind farms. Despite the fact that this area of research is still under development, it has already demonstrated significant progress in recent years. It is assumed that further research and innovation in the field of stabilization of wind turbine blades will help to achieve even greater success in creating sustainable and environmentally friendly energy.

The study was supported by the Russian Science Foundation grant No. 23-11-20016, https://rscf.ru/en/project/23-11-20016/

References

1. I. Al-Bahadly, Proceedings of Int. Conf. on Circuits, Systems, Signal and Telecommunications (Gold Coast, Australia, 2007)


