WIND ENERGY

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Annotation: This scientific work discusses the natural source of wind energy, its operating principles, advantages, and disadvantages. The study highlights the technology of generating electricity through wind turbines, their environmental cleanliness, and economic efficiency. It also analyzes the potential and prospects for the development of wind energy in the context of Uzbekistan. Furthermore, the necessity of transitioning to renewable energy sources and the role of wind energy in sustainable development are emphasized.

Keywords: Wind energy, renewable energy, alternative energy sources, wind turbines, electricity, environmentally friendly technology, sustainable development, energy efficiency, wind generator, atmospheric motion, air currents, aerodynamic force, energy conversion, wind speed, wind density, energy production, Uzbekistan's energy potential, green energy, power grids, energy transformation.

Introduction: Wind power plants are typically built-in locations where the average wind speed is high—4.5 m/s or more. Preliminary studies of the area are conducted beforehand. Anemometers are installed at heights ranging from 30 to 100 meters to collect data on wind speed and direction over the course of one to two years. The gathered data can be combined into wind resource maps. These maps (along with specialized software) help potential investors estimate the return on investment of the project. Wind speed increases with altitude. Therefore, wind power plants are usually constructed on hills or mountain ridges, and the generators are mounted on towers 30 to 60 meters high. Obstacles that might affect wind flow—such as trees or tall buildings—are taken into account during planning [1-4].

Wind is a clean and widely available source of energy. The kinetic energy of moving air masses originates from the uneven heating of the atmosphere by the sun and the rotation of the Earth. Historically, wind energy was first harnessed to propel sailing ships and to power windmills for grinding grain. Today, wind energy primarily refers to the generation of electricity using wind as a resource. Wind turbines convert the kinetic energy of the wind into electrical energy [5-7].

Wind power plants are classified based on their location as either onshore or offshore. Onshore wind farms are built on land, while offshore farms are constructed above the surface of water bodies. Although both types operate on the same principle, their construction and operation vary due to differences in environmental conditions.

Onshore wind farms are less expensive and easier to install and maintain; however, they often suffer from lower efficiency due to inconsistent wind patterns on land. On the other hand, offshore wind farms are more efficient due to stronger and more consistent wind flows over water surfaces, but they require more complex infrastructure and higher capital investment due to their challenging locations [8-11].

Onshore Wind Power Station

The first automatically controlled wind turbine was created by American inventor Charles Brush in 1888. It had a rotor diameter of 17 meters. Modern wind energy began its development in the 1980s, with turbines producing as little as 50 kW. In the early 1980s, the Soviet Union developed a plan to build wind power stations in the Far North to supply energy to autonomous facilities, with military engineers designated to construct these stations. Later, an experimental wind farm was established along the Desna River in the Vyshhorod district of Kyiv Oblast in the Ukrainian SSR, equipped with several wind turbines [12-15].

In 1988, the first experimental wind power station of a fundamentally new type was launched near the town of Medemblik in the Netherlands. Unlike traditional bladed wind engines, this facility used a modern wind turbine design. Today, the world's largest operational wind power station is the Gansu Wind Farm located in Jiuquan, Gansu Province, China, with a total installed capacity of 7,965 MW.

Offshore wind farms are typically built at short distances from coastlines, either in seas or oceans. Coastal areas experience frequent and consistent winds due to the differential heating of land and water surfaces. During the day, a sea breeze blows from the water toward the land, while at night, a land breeze flows from the cooled land back to the water. Offshore wind farms are typically constructed 10 to 60 kilometers away from the shoreline.

These offshore installations offer several significant advantages:

They are barely visible from the coast.

They do not occupy land space.

Thanks to steady and strong marine winds, they achieve higher efficiency—particularly in terms of capacity factor (the ratio of actual output to potential output).

Offshore wind turbines are installed in shallow waters, typically on foundations built with piles driven into the seabed at depths of up to 30 meters. Electricity generated offshore is transmitted to land through underwater cables. The construction and maintenance of these stations require self-elevating vessels capable of operating in marine environments [17-19].

However, building offshore wind power stations is considerably more expensive than onshore ones. They require more robust infrastructure, including taller towers, larger foundations, and specially protected generators. Additionally, the saline sea environment can cause corrosion to metallic components.

By the end of 2008, the total installed capacity of offshore wind power worldwide was approximately 1,471 MW, with 357 MW added that year alone. The largest offshore wind station in 2009 was Denmark's Middelgrunden Wind Farm, with a capacity of 40 MW. In 2013, the largest became the London Array in the United Kingdom, with an installed capacity of 630 MW.

The Middelgrunden floating wind power station is located near Copenhagen.

On September 6, 2018, the Walney Extension offshore wind farm was commissioned in the Irish Sea, approximately 19 kilometers off the northwest coast of England. The total installed capacity of its wind turbines is 659 MW. Later, in July 2020, the East Anglia ONE wind farm, with a capacity of 714 MW, was also put into operation. The steel tower of each wind turbine extends 100 meters below sea level, while the visible section rises 65 meters above the water surface. The turbine rotor has a diameter of 82.4 meters.

To ensure the stability of the wind turbine tower and to submerge it to a designated depth, ballast materials (such as gravel and rocks) are added to its base. The tower is secured against floating or drifting by three anchoring cables, each attached to mooring points below. The generated electricity is transmitted to shore via underwater power cables.

Conclusion

The findings of this study indicate that wind energy is currently one of the most promising and sustainable sources of power in the context of global climate change, energy shortages, and environmental concerns. Its renewable nature, ability to reduce emissions of harmful substances into the atmosphere, and its potential to lessen dependence on fossil fuels make it a highly advantageous energy solution.

The technological advancement of wind power plants has led to increased efficiency and economic viability, particularly in regions with high wind potential. In Uzbekistan, natural and climatic assessments reveal favorable conditions for the development of wind energy in specific regions — notably in the Republic of Karakalpakstan, as well as the Navoi, Bukhara, and Jizzakh provinces.

In conclusion, wind energy plays a critical role in ensuring modern and sustainable development and stands out as an environmentally safe and viable alternative energy source, contributing significantly to the progress of society.

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