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A Comprehensive Review of Wind Energy Conversion Systems: Classification, Working Principles, Advantages, Limitations, and Applications

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Abstract:

With the rising energy demand, environmental issues, and the need for a shift away from fossil fuels, wind energy has become one of the most promising renewable energy resources for sustainable electricity generation. Wind Energy Conversion Systems (WECS) utilize suitable aerodynamics, mechanical and electrical components to transform the kinetic energy of wind into mechanical energy and then into electrical energy. This review provides an extensive discussion of the WECS, their categorization, operation, benefits, drawbacks, and utilization. The classification of wind energy conversion systems is discussed based on the wind turbine axis orientation, aerodynamic operating principle, installation location and power regulation methods. The working principles and main parts of horizontal-axis and vertical-axis wind turbines are discussed, such as rotor blade, gearbox, generator, power electronic converter, control system, and integration to grid. In addition, the benefits of wind power, including the fact that it is a renewable energy source, has low operational emissions, has no fuel requirements, and can generate electricity at a large scale, are emphasized. Some of the drawbacks of wind, site constraints, start-up costs, noise, visual impacts, grid integration and storage issues are also explored. The applications of WECS for utility-scale power generation, offshore wind farms, distributed generation, rural electrification, agricultural pumping, hybrid renewable energy systems and standalone power supplies are discussed. In addition, new advances in turbine design, offshore installation, advanced control methods and energy storage integration are also taken into consideration. The aim of this review is to give a structured understanding of wind energy conversion technology and its place in today's power system. The discussion can be used to assist in the selection, design and delivery of suitable WECS technologies to ensure reliable, efficient and sustainable energy production.

Keywords: Wind Energy Conversion System; Wind Turbine; Horizontal-Axis Wind Turbine; Vertical-Axis Wind Turbine ; Wind Power Generation; Renewable Energy; Wind Turbine Classification; Power Electronic Converters; Offshore Wind Energy; Sustainable Energy Systems.

1. Introduction

1.1 Background and Significance of Renewable Energy

Energy is essential for economic development, industrial growth, technological progress and development of living standards. The population growth, urbanization, industrialization and the growing use of digital infrastructure have led to a huge demand for reliable and sustainable energy resources all over the world. Traditional energy systems have been primarily based on fossil fuels such as coal, petroleum and natural gas to provide electricity and transportation.

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The use of these resources, however, has led to high levels of greenhouse gas emissions, air pollution, environmental damage and issues of long-term energy security. The limited availability of fossil fuels, volatile fuel prices and the requirement to cut carbon emissions have further underscored the significance of shifting to cleaner and more sustainable energy technology[1].

Consequently, renewable energy, such as solar, wind, hydropower, biomass, geothermal and ocean energy, has attracted a lot of interest as an alternative to conventional energy resources. These technologies are based on natural energy flows that can be replenished, and when used appropriately can help decrease reliance on fossil fuels. Wind energy is one of the most promising renewable energy sources due to its technological readiness, scalability, and suitability for various geographic areas. Wind turbines can be used singly to generate electricity at small scale or they can be clustered together into large wind farms that can provide significant electrical power to national and regional distribution networks[2].

Advancements in aerodynamic design, structural engineering, electrical machines, power electronic converters, digital control systems and condition-monitoring techniques have enabled the development of modern wind energy technologies. These advances have led to more efficient turbines, higher energy generation and allowed wind power plants to contribute more efficiently to today's power systems. Additionally, due to the growth of offshore wind and relatively stable wind conditions, there are opportunities for strong and fairly consistent wind resources in the marine environment. Thus, the conversion of wind energy has emerged as a key element of strategies to decarbonise electricity generation and enhance the sustainability of future energy systems.

1.2 Development and Evolution of Wind Energy Technology

The use of wind power is several centuries older than modern electrical engineering. In the past, windmills were used for mechanical work, such as grinding grain, pumping water, and gardens and orchards. The ships were also able to use the wind to move. The first applications were mainly those which utilized the kinetic energy of moving air to generate mechanical power but not electricity. As electrical generators were developed and the turbine technology improved over time, wind energy gradually transformed itself into a technology that generates electrical power[3].

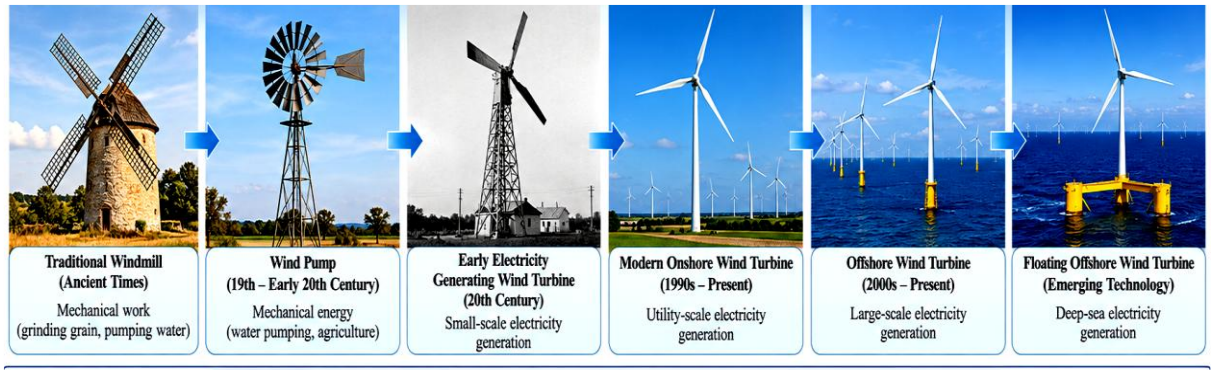


Figure 1: Evolution of Wind Energy Conversion Systems

Modern wind turbines were developed by combining aerodynamic rotors, mechanical power transmission systems, electrical generators, and structures. The wind turbines used to generate electricity in the early days were fairly small and were often installed in remote areas where there was no regular electricity supply or where electricity was disrupted. As the increasing awareness of environmental issues and energy security, research, commercialization, and deployment of wind energy systems increased[4].

Today's wind turbines have advanced control systems designed to maintain a constant rotor speed, maximize energy production and safeguard the components during different wind loads. Variable speed operation enables the turbines to adjust their speed to the wind speed, which increases their capture of energy over a wider operating range. Pitch-control systems are used to control the angle of the blades in order to achieve optimum operating conditions and to reduce power production when wind speeds are high. Furthermore, with the development of power electronic converters, the control of electrical power, reactive power and the characteristics of the electric connection have improved.

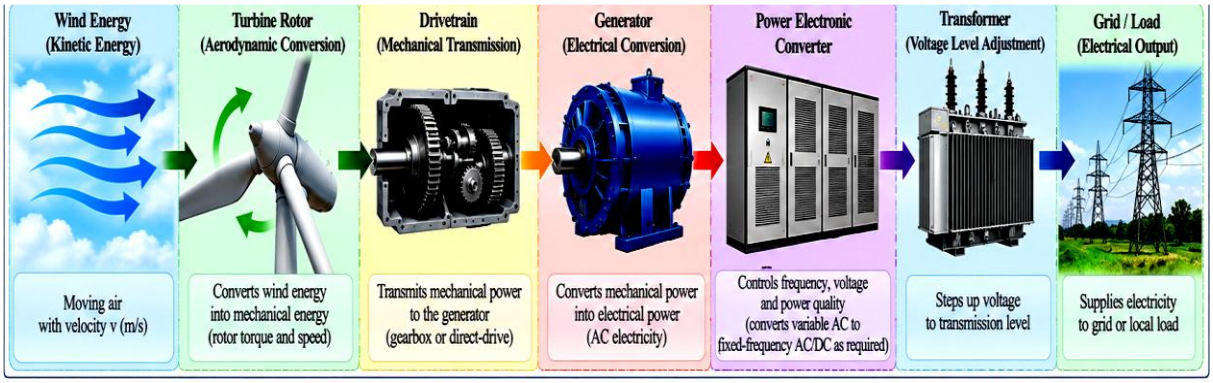


Figure 2: Basic Energy Conversion Process in a WECS

Marine wind resources can be exploited by offshore wind farms, which can incorporate large turbines, but these farms rely on special foundations, subsea electrical systems, corrosion protection, and systems for maintenance. An additional challenge is that floating offshore wind platforms have pushed the potential for wind turbine deployment into deeper waters where fixed-bottom foundations are not technically and economically viable. The developments indicate the ongoing evolution of wind energy conversion systems to higher power ratings, better operational flexibility and greater geographical applicability[5].

1.3 Concept and Importance of Wind Energy Conversion Systems

A Wind Energy Conversion System (WECS) is a combination of aerodynamic, mechanical, electrical and control elements that are put together to convert the kinetic energy of the wind into useful electrical energy. The conversion process starts when the moving air comes in contact with the turbine blades and creates aerodynamic forces, which cause the rotor to experience torque. The mechanical power is transmitted to the rotor by mechanical means using a drivetrain that can include a gearbox, or a direct-drive arrangement. The mechanical power is then converted to electrical power by an electrical generator, and the electrical generator is associated with power electronic converters, transformers, protection devices and control systems that regulate and deliver the generated electricity to a load or storage system or an electrical grid[6].

The performance of a WECS is determined by a set of interdependent parameters such as: wind speed, air density, rotor swept area, aerodynamic properties of blades, turbine rotational speed, generator efficiency, electrical conversion losses. The energy that the wind can deliver is given by

$$P = \frac{1}{2}\rho A V^3 \qquad (1)$$

where (P) is the kinetic power available in the wind, (\rho) is air density, (A) is the rotor swept area, and (v) is wind velocity. Actual turbine output is lower than the available wind power because of aerodynamic and electrical losses and the physical limitations of energy extraction

Alternatively, by expressing the rotor swept area (A) in terms of the blade length or rotor diameter (D), the formula can also be written as

$$P = 1/8 * rho * pi * D \wedge 2 * V \wedge 3 \qquad (2)$$

The significance of WECS goes beyond its ability to convert wind energy to electricity. Requirements of modern systems include also operational reliability, electrical power quality, grid stability, mechanical durability and environmental performance. Power electronic converters and control systems are used in a grid-connected installation to control the output of the VFG (where applicable), control reactive power (where applicable), and meet applicable grid-interconnection requirements. For standalone applications, energy storage or hybrid power sources might be needed to ensure power availability during periods of low wind resources. Designing WECS will therefore involve considering the aerodynamic performance, electrical properties, control strategies, economic aspects and application.

1.4 Motivation, Objectives, and Scope of the Review

The ongoing growth of wind energy conversion technologies have created a need for a systematic understanding of the configurations, operating principles, performance characteristics, benefits, limitations and application requirements of wind technologies. The range of turbine types, generator technologies, power electronic converter

technologies, control systems and available installation site conditions necessitates evaluation of WECS in a common technical context. This evaluation can be used to derive the differences between technologies available and elucidate the factors that dictate the suitability of the technologies for different operating conditions.

The main aim of this review is to give a detailed technical description of wind energy conversion system with a special attention on the classification, working principle and working components of the wind energy system, and its various applications. It looks at the horizontal axis and vertical axis wind turbines, onshore and offshore wind installations, fixed speed wind turbines and variable speed wind turbines, and the main generator technologies currently in use for modern wind energy conversion systems (WECS). It also covers aerodynamic principles of energy conversion, the importance of power electronic converters and power electronics control systems, and the importance of grid integration.

2. Fundamentals of Wind Energy Conversion Systems

2.1 Basic Principle of Wind Energy Conversion

Wind Energy Conversion Systems (WECS) are systems that are engineered to harness the kinetic energy of moving air and transform it into a useful mechanical or electrical energy. The uneven heating of the earth's surface by solar radiation gives rise to a pressure gradient in the atmosphere, which is the source of wind. Thermal gradients, pressure differences, the rotation of the Earth, surface roughness and geographical features all modify the resulting motion of air. These factors generate differences in wind speed and direction and hence differences in the energy available for conversion at a specific site[7].

A WECS is based on energy conversion processes. The wind passing over the wind turbine's rotor blades creates the aerodynamic forces based on the pressure of the air around the blade surfaces. In turbines that operate on lift, the shape of the blades produces lift, which helps to spin the rotor. As a result, rotational motion is generated in drag based turbines due to the differences in aerodynamic drag between the moving air and the turbines surfaces. A part of the wind's kinetic energy is transformed to mechanical energy by the rotating rotor, which is then transferred through a drivetrain to an electrical generator[8].

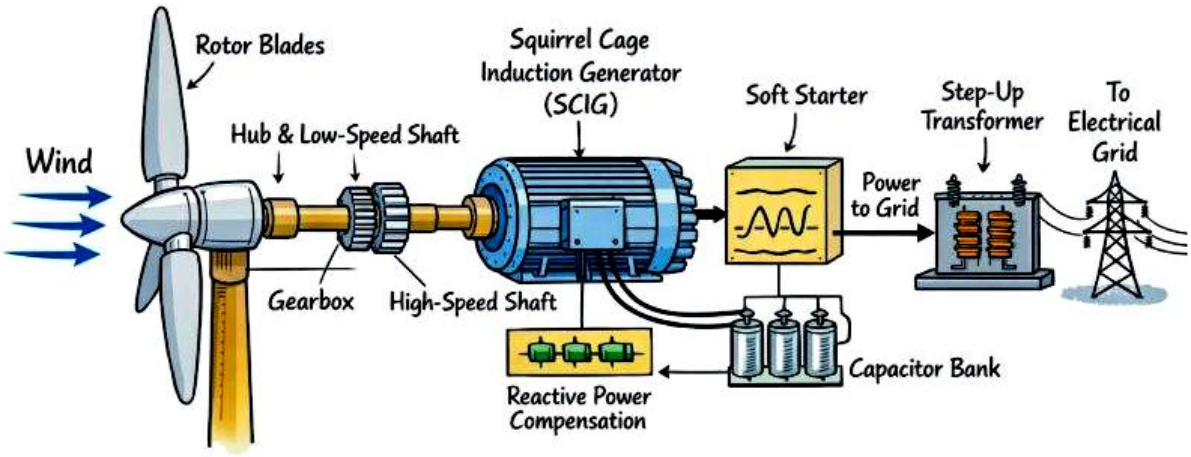


Figure 3. Basic energy conversion process in a Wind Energy Conversion System (WECS).

The main parts of a traditional wind energy conversion system are the rotor blades, hub, drivetrain, generator, power electronic converter, transformer, and wind tower. The energy from the wind is picked up by the rotor, and the mechanical power is transferred to the generator via the drivetrain. Depending on the turbine configuration, the drivetrain can either be made up of a gearbox or a direct drive option. The generator transforms mechanical energy into electrical energy by the process of electromagnetic induction. Variable-speed generators can be connected to the electrical grid or a local load, and the electrical output is controlled by power electronic converters.

The overall energy conversion process can be represented as:

Wind kinetic energy → Aerodynamic rotor → Mechanical rotational energy → Electrical generator → Power conditioning → Electrical load or grid.

The efficiency of a WECS depends on the wind speed, air density, rotor area, blade shape, rotor speed, generator characteristics, and losses due to conversion. Because the wind speed also fluctuates, the turbine needs to run in different aerodynamics and electrical conditions. Modern systems use control methods to achieve maximum energy capture when wind speeds are in a range that is conducive to the system and to prevent damage to the system when the wind speed is outside of the allowable operating range.

The wind power generating system can be grid connected or standalone. Grid connected systems provide power to the transmission and distribution networks, while stand-alone systems provide power to isolated loads and are connected to batteries or other sources of energy. Hybrid systems utilize wind turbines to work with solar PV, storage or back-up generation to enhance supply reliability. In summary, therefore, WECS are a combination of aerodynamic, mechanical, electrical and control technologies for the efficient and reliable generation of energy[9].

2.2 Major Components of WECS

A wind energy conversion system (WECS) is a system of interconnected mechanical, electrical, structural and control components, which together convert the wind energy into useful electrical energy. The arrangement of these components is a function of turbine size, rotor design, generator type, installation site and grid connection needs. A knowledge of the functions of the major components is necessary to assess the performance, reliability and maintenance of a system.

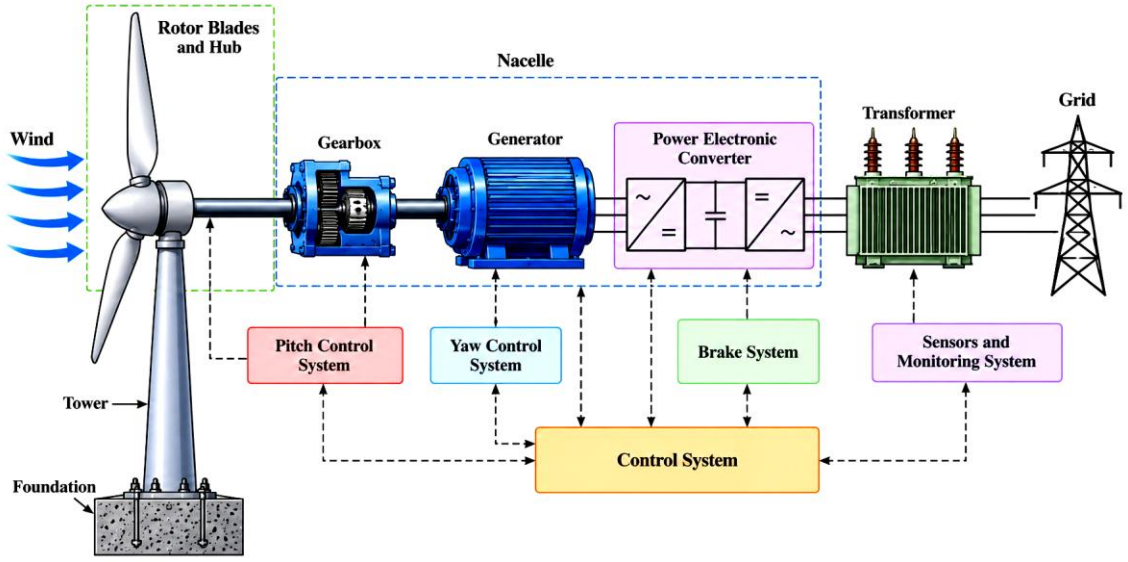


Figure 4. Major Components of a Wind Energy Conversion System (WECS)

- **Energy collecting components:** Rotor Blades and Hub – The rotor blades extract the energy from the flowing air through aerodynamic forces. They affect the amount of energy they can get from the wind by changing their shape, length, material and pitch angle. Usually, modern utility-scale turbines use three blades, although there are units with two blades. The hub is the part that attaches the blades to the main shaft, and also distributes the torque generated by the blades through the drivetrain.
- **Nacelle:** The housing attached to a standard horizontal axis wind turbine tower. Contains large parts of the power transmission mechanism (gearbox if fitted), generator, brakes and related control equipment. It is designed to offer structural support and protection from environmental factors..
- **Drivetrain and Gearbox:** The drivetrain converts the mechanical power generated by the rotor to the generator. Turbines with a gearbox have a relatively low rotor speed that is raised by the gearbox to the speed required by the generator. Direct-drive turbines do not have a gearbox and instead use a generator that is geared to run at a reduced speed. Selection is based on efficiency, mass, reliability, maintenance and economics.
- **Electrical Generator:** It is a machine used to transform mechanical rotational energy into electrical energy by electromagnetic induction. Squirrel-cage induction generators, doubly fed induction generators, permanent magnet synchronous generators and electrically excited synchronous generators are all common generator technologies. These technologies require diverse excitation, speed control and power conversion and grid integration requirements.

- **Power Electronic Converter:** Power electronic converters control the electrical output of turbines with variable speed, and enable the connection of the turbines to the electrical grid. They can be used for AC–DC–AC conversion, active power/active/reactive power control and grid requirements support based on generator configuration.
- **Pitch and Yaw Control Systems:** Pitch control system adjusts the pitch angle of blades to control aerodynamic power and safeguard the turbine from high wind. Yaw Control moves the nacelle in order to keep the horizontal axis turbine aligned with the wind direction. Such mechanisms enhance energy capture, and also contribute to maintain safe operating conditions.
- **Tower and Foundation:** Tower stands at an appropriate height, supporting the rotor and nacelle system, to gain access to the wind resource. The foundation is a structural component that carries forces to ground or sea bed. The foundations for offshore turbines must be custom-built and either a fixed-bottom foundation or floating support structure must be used depending on water depth and site conditions.
- **Transformer & Grid-Connection Equipment:** These adjust the voltage to the level needed for collection or transmission. Switchgear, protection relays, cables and monitoring devices aid safe operation and integration with the electrical network.

2.3 Wind Turbine Power Curve and Operating Regions

The wind power curve of a wind turbine is the graph that depicts how the electrical power generated by the wind turbine varies depending on the wind speed at which it is operating, under a set of given operating conditions. It is an important property that is important in the selection of turbines, the estimation of turbine energy output, assessment of turbine performance and in windfarm planning. The power curve shape is influenced by turbine design, rated power, rotor diameter, control strategy, air density and environment[10].

The four operating zones of a typical wind turbine are below cut-in speed, below rated operation, rated-power operation and above cut-out speed.

- **Below Cut-in Wind Speed:** The cut-in wind speed is the lowest speed required for a turbine to generate electricity that can be harnessed. If this limit is exceeded, the power available from the aerodynamics is not enough to compensate for mechanical and electrical losses or to achieve the turbine's operating conditions. As a result, the turbine is usually left off or does not actually generate any electricity.
- Cut-in, When wind speed is above the cut-in value the turbine starts to produce electricity. The more wind power is available, the more the wind speed increases, and the power available goes up about the cube of the wind speed. In optimal operating conditions, the turbine's control system optimizes speed and other operating parameters of the turbine to ensure maximum energy extraction. The use of maximum power point tracking strategies is common with variable speed turbines in order to keep the tip speed ratio at an optimum level and increase aerodynamic efficiency.
- **Rated-power Operating Region:** The rated wind speed is the wind speed at which the turbine reaches its rated electrical power under the specified reference conditions. At higher speeds, the control system operates the turbine to keep the mechanical loading and the electrical output within limits. Other turbine designs may use a different way of regulating the power output, such as changing the blade pitch which reduces the aerodynamic power produced.Pitch controlled turbines adjust blade pitch to reduce aerodynamic power; other turbine designs may use other ways to regulate power output.This means that the turbine delivers its rated power within a range of windspeed, under certain conditions, which is set by the manufacturer.
- **Above Cut-out Wind Speed:** Above this wind speed, the turbine will shut down or go into a protective operating mode to prevent excessive structural loading or damage. If other operating conditions are met and the wind speed drops below the applicable restart wind speed, the turbine may restart again. The cut on and cut off strategy depends on the type of turbine.

3. Classification of Wind Energy Conversion Systems

Table 1 Classification of Wind Energy Conversion Systems

S. No.	Classification basis	Types
1	Based on rotor axis	Horizontal-Axis Wind Turbines (HAWTs); Vertical-Axis Wind Turbines (VAWTs)

2	Based on aerodynamic principle	Lift-based turbines; Drag-based turbines; Lift-and-drag-based turbines
3	Based on installation location	Onshore wind systems; Offshore wind systems
4	Based on rotor speed	Fixed-speed systems; Variable-speed systems
5	Based on generator technology	Squirrel-Cage Induction Generator (SCIG); Wound-Rotor Induction Generator (WRIG); Doubly-Fed Induction Generator (DFIG); Synchronous Generator (SG); Permanent-Magnet Synchronous Generator (PMSG)
6	Based on drivetrain configuration	Geared systems; Direct-drive systems; Hybrid drivetrain systems
7	Based on electrical connection	Grid-connected systems; Standalone systems; Hybrid systems
8	Based on rated power or application	Micro/small wind turbines; Medium-scale wind turbines; Large-scale wind turbines
9	Based on rotor orientation and design	Upwind turbines; Downwind turbines; Single-rotor systems; Multi-rotor systems
10	Based on foundation or support structure	Fixed-bottom offshore systems; Floating offshore systems

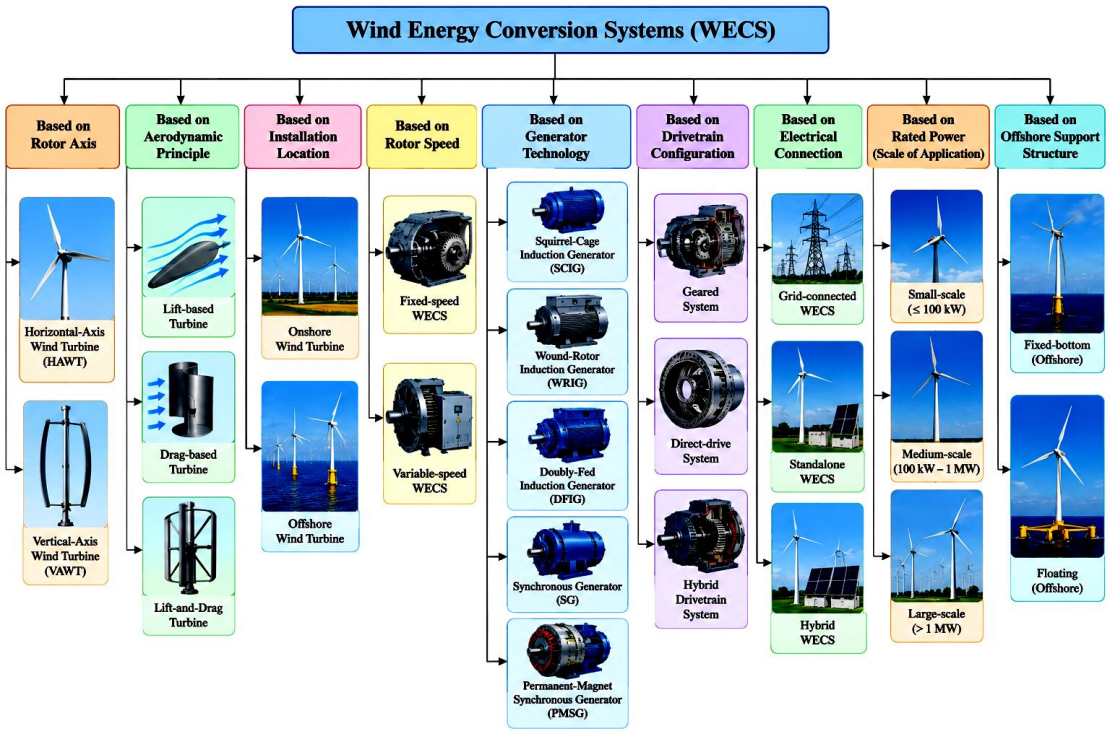


Figure 5 Classification of Wind Energy Conversion Systems Based on Design, Operating Characteristics, and Application.

4. Advantages of Wind Energy Conversion Systems

Table 2. Advantages of Wind Energy Conversion Systems and Their Benefits

S. No.	Advantage	Description	Key Benefit
1	Renewable Energy Source	Wind is naturally replenished through atmospheric processes.	Supports long-term energy sustainability.
2	Low Greenhouse Gas Emissions	Wind turbines generate electricity without direct fuel combustion during operation.	Helps mitigate climate change.
3	No Fuel Cost	Wind energy does not require continuous fuel procurement.	Reduces exposure to fuel-price fluctuations.
4	Low Water Consumption	Wind power generation generally requires very little water during operation.	Conserves water resources compared with conventional thermal generation.
5	Reduced Fossil-Fuel Dependence	Wind power can replace a portion of electricity generated using coal, oil, and natural gas.	Improves energy security.
6	Scalable Technology	Systems are available for small-scale installations and large utility-scale wind farms.	Supports diverse electricity requirements.
7	Land-Use Compatibility	Agricultural activities and livestock grazing can often continue around onshore turbines.	Enables multiple uses of suitable land.
8	Employment Generation	Wind projects create jobs in manufacturing, construction, installation, and maintenance.	Supports economic development.
9	Hybrid System Compatibility	Wind turbines can operate alongside solar PV, batteries, and other generation technologies.	Improves energy-system flexibility.
10	Technological Advancement	Improvements in turbine design, materials, power electronics, and monitoring increase performance.	Supports better efficiency and reliability.
11	Distributed Generation Potential	Small and medium-sized turbines can supply electricity near the point of use.	Can reduce dependence on long-distance electricity supply.
12	Offshore Resource Potential	Offshore installations can access strong and relatively consistent wind resources at suitable sites.	Offers opportunities for large-scale renewable generation.

5. Limitations and Challenges of Wind Energy Conversion Systems

Table 3: Major Limitations of WECS, Their Causes, Impacts, and Potential Mitigation Strategies

Limitation	Main impact	Potential mitigation
Wind variability	Fluctuating power output	Forecasting, storage, and hybrid systems

High capital cost	Longer project payback	Improved turbine design and project financing
Grid integration challenges	Voltage and frequency variations	Advanced converters and grid-support controls
Mechanical failures	Downtime and maintenance costs	Condition monitoring and predictive maintenance
Wildlife impacts	Ecological disturbance	Careful siting and wildlife monitoring
Blade disposal	Waste-management challenges	Recycling and alternative blade materials
Offshore corrosion	Increased maintenance requirements	Corrosion-resistant materials and protective coatings

6. Applications of Wind Energy Conversion Systems

Table 4: Applications of WECS, Typical System Configurations, and Major Benefits

Application	**Typical configuration**	**Main benefit**
Utility-scale generation	Large, grid-connected HAWTs	Bulk electricity production
Rural electrification	Standalone or mini-grid systems	Access to electricity in remote areas
Agriculture	Small turbines or hybrid systems	Water pumping and farm power
Industrial facilities	Grid-connected wind farms or power-purchase arrangements	Reduced dependence on conventional electricity
Offshore generation	Fixed-bottom or floating turbines	Access to strong offshore wind resources
Remote installations	Wind–battery hybrid systems	Reliable local power supply
Green hydrogen	Wind-powered electrolyzer	Production of low-emission hydrogen
Island microgrids	Wind–solar–battery systems	Reduced fuel transportation and diesel consumption

7. Conclusion

Wind Energy Conversion Systems (WECS) have been identified as one of the important technologies to achieve sustainable electricity generation and shift to a low carbon energy system. The basic concepts, classification, key components, working of WECS, pros and cons and the applications of WECS have been studied in this review. The categorization of wind turbines by rotor axis, aerodynamic principle, installation type, operating speed, generator type, drivetrain configuration and electrical connection emphasizes the variety of wind turbine technologies and their viability for various operating conditions. The development of aerodynamic design, lightweight materials, power electronic converters, generator technologies, and control strategies have all helped to enhance energy capture, flexibility, and system reliability. Yet, wind power remains to have various technical barriers such as wind variability, high initial investment, integration with the grid, maintenance costs, environmental impacts, and end-of-life management of turbine components. Solutions to these challenges need to be achieved through advancements in wind forecast, energy storage, predictive maintenance, grid support and sustainable blade recycling. Hybrid renewable energy systems integration of wind and solar photovoltaic (PV) generation and battery storage can enhance power availability and decrease the reliance on conventional energy sources. Moreover, the applications of WECS are increasing with offshore wind power, floating platforms for wind turbines, digital monitoring, and intelligent control

systems. The potential for harnessing renewable energy resources, including onshore and offshore wind, can play a key role in India's future energy landscape, helping to reduce dependence on fossil fuels and improve the country's energy security. The future development of the turbine design should focus on cost-efficient designs, re-usable materials, grid integration and the optimization of the turbine integration with emerging energy technologies. Overall, ongoing technological advancements, policy support and proper infrastructure development will be critical to unlocking the technical, economic and environmental advantages of wind energy and to enhance its contribution to a more sustainable, reliable, and clean global energy transition.

References

[1] T.-Z. Ang, M. Salem, M. Kamarol, H. S. Das, M. A. Nazari, and N. Prabaharan, "A comprehensive study of renewable energy sources: Classifications, challenges and suggestions," Energy Strategy Rev., vol. 43, p. 100939, 2022.

[2] Erdiwansyah, Mahidin, H. Husin, Nasaruddin, M. Zaki, and Muhibbuddin, "A critical review of the integration of renewable energy sources with various technologies," Prot. Control Mod. Power Syst., vol. 6, no. 1, p. 3, Dec. 2021, doi: 10.1186/s41601-021-00181-3.

[3] H. Husin and M. Zaki, "A critical review of the integration of renewable energy sources with various technologies," Prot. Control Mod. Power Syst., vol. 6, no. 1, pp. 1–18, 2021.

[4] N. Nireekshana, R. Ramachandran, and G. V. Narayana, "A Peer Survey on Load Frequency Contol in Isolated Power System with Novel Topologies," Int J Eng Adv Technol IJEAT, vol. 11, no. 1, pp. 82–88, 2021.

[5] P. A. Owusu and S. Asumadu-Sarkodie, "A review of renewable energy sources, sustainability issues and climate change mitigation," Cogent Eng., vol. 3, no. 1, p. 1167990, Dec. 2016, doi: 10.1080/23311916.2016.1167990.

[6] N. Nireekshana, R. Ramachandran, and G. V. Narayana, "An innovative fuzzy logic frequency regulation strategy for two-area power systems," Int J Power Electron Drive Syst IJPEDS, vol. 15, no. 1, p. 603, 2024.

[7] P. A. Østergaard, N. Duic, Y. Noorollahi, and S. Kalogirou, "Renewable energy for sustainable development," Renew. Energy, vol. 199, pp. 1145–1152, 2022.

[8] M. K. G. Deshmukh, M. Sameeroddin, D. Abdul, and M. A. Sattar, "Renewable energy in the 21st century: A review," Mater. Today Proc., vol. 80, pp. 1756–1759, 2023.

[9] Neha and R. Joon, "Renewable energy sources: A review," in Journal of Physics: Conference Series, IOP Publishing, 2021, p. 012023. Accessed: Oct. 30, 2026. [Online]. Available: https://iopscience.iop.org/article/10.1088/1742-6596/1979/1/012023/meta

[10] N. Nireekshana, S. Unissa, B. R. Jaleja, C. M. Tejaswi, P. M. Mahitha, and P. Vaishnavi, "FACTS: Present and future," Int J Innov Sci Res Technol, vol. 9, no. 9, pp. 2350–2358, 2024.