Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 20, Issue 2 Ser. 1 (Mar. – Apr. 2025), PP 07-13
www.iosrjournals.org

Wind energy as new techniques for sustainable life

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Abstract
The rising concerns over global warming, environmental pollution, and energy security have increased interest in developing renewable and environmentally friendly energy sources such as wind, solar, hydropower, geothermal, hydrogen, and biomass as the replacements for fossil fuels. Wind energy can provide suitable solutions to the global climate change and energy crisis. The utilization of wind power essentially eliminates emissions of CO 2 , SO 2 , NO x and other harmful wastes as in traditional coal-fuel power plants or radioactive wastes in nuclear power plants. By further diversifying the energy supply, wind energy dramatically reduces the dependence on fossil fuels that are subject to price and supply instability, thus strengthening global energy security. During the recent three decades, tremendous growth in wind power has been seen all over the world. In 2009, the global annual installed wind generation capacity reached a record-breaking 37 GW, bringing the world total wind capacity to 158 GW. As the most promising renewable, clean, and reliable energy source, wind power is highly expected to take a much higher portion in power generation in the coming decades.

Date of Submission: 08-03-2025 Date of acceptance: 18-03-2025

I. Introduction

Energy is an essential ingredient of socio-economic development and economic growth. Renewable energy sources like wind energy is indigenous and can help in reducing the dependency on fossil fuels. Wind is the indirect form of solar energy and is always being replenished by the sun. Wind is caused by differential heating of the earth's surface by the sun [1]. It has been estimated that roughly 10 million MW of energy are continuously available in the earth's wind. Wind energy provides a variable and environmental friendly option and national energy security at a time when decreasing global reserves of fossil fuels threatens the long-term sustainability of global economy.

The power of the wind has been utilized for at least the past 3000 years. Until the early 20th century wind power was used to provide mechanical power to pump water or to grind grain [21]. At the beginning of modern industrialization, the use of the fluctuating wind energy resource was substituted by fossil fuel fired engines or the electrical grid, which provided a more consistent power source [5]. The first wind turbines for electricity generation had already been developed at the beginning of the 20th century. The technology was improved step by step since the early 1970s [17]. By the end of the 1990s, wind energy has re-emerged as one of the most important sustainable energy resources. During the last decade of the 20th century, worldwide wind capacity has doubled approximately every 3 years [32]. The costs of electricity generated from wind power have fallen to about one-sixth since the early 1980, and the trend seems to continue [7].

The wind turbine technology has a unique technical identity and unique demands in terms of the methods used for design. Remarkable advances in the wind power design have been achieved due to modern technological developments [16]. Since 1980, advances in aerodynamics, structural dynamics, and ''micrometeorology'' have contributed to a 5% annual increase in the energy yield of the turbines [21]. Current research techniques are producing stronger, lighter and more efficient blades for the turbines [1]. The annual energy output for turbine has increased enormously and the weights of the turbine and the noise they emit have been halved over the last few years. We can generate more power from wind energy by establishment of more number of wind monitoring stations, selection of wind farm site with suitable wind electric generator, improved maintenance procedure of wind turbine to increase the machine availability, use of high capacity machine, low wind regime turbine, higher tower height, wider swept area of the rotor blade, better aerodynamic and structural design, faster computer-based machining technique, increasing power factor and better policies from Government [19].

Table (1): development of wind turbine size between 1985 and 2002 [6]

Year	Capacity (kW)	Rotor diameter (m)
1985	50	15
1989	300	30
1992	500	37
1994	600	46
1998	1500	70
2001/2002[a]	4000	88

This fast development of the wind energy market as well as of the technology has large implications on research, education as well as on professionals working for electric utilities or the wind energy industry. It is important to mention that about 80% of the worldwide wind capacity is installed in only five countries: Germany, USA, Denmark, India and Spain [11]. Hence, most of the wind energy knowledge is based in these countries. The use of wind energy technology, however, is fast spreading to other areas in the world. Hence, the available information must also be spread around the world [25]. However, despite the fact that wind energy has already been utilized for 3000 years, it is a very complex technology. The technology involves technical disciplines such as aerodynamics, structural dynamics, mechanical as well as electrical engineering.

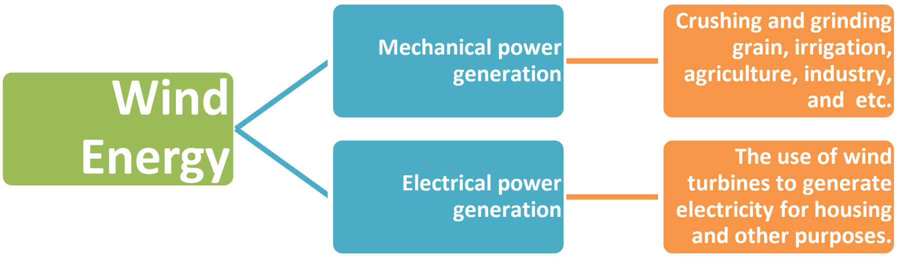

Figure (1): the historical uses of wind energy.

II. The history of wind energy

The earliest recorded windmills are vertical-axis mills. These windmills can be described as simple drag devices. They have been used in the Afghan highlands to grind grain since the seventh century BC [12]. The first details about horizontal-axis windmills are found in historical documents from Persia, Tibet and China at about 1000 AD. This windmill type has a horizontal shaft and blades (or sails) revolving in the vertical plane. From Persia and the Middle-East, the horizontal-axis windmill spread across the Mediterranean countries and central Europe. The first horizontal-axis windmill appeared in England around 1150, in France in 1180, in Flanders in 1190, in Germany in 1222 and in Denmark in 1259 AD. This fast development was most likely influenced by the Crusaders, taking the knowledge about windmills from Persia to many places in Europe [14].

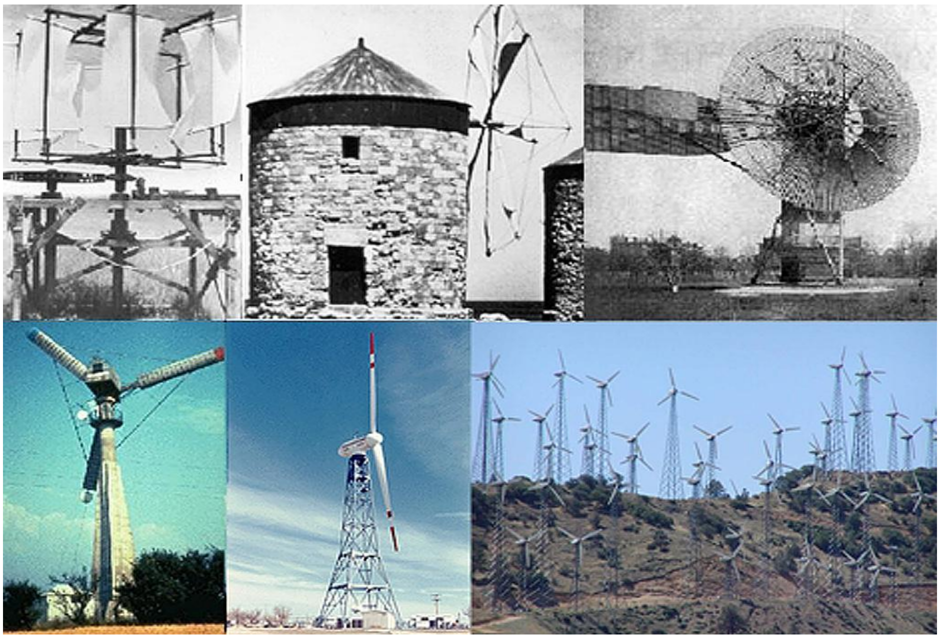

Figure (2): From the early stages of wind energy exploitation to the outbreak of California [7].

By the time the European windmills slowly started to disappear, windmills were introduced by settlers in North America. Small windmills for pumping water for livestock became very popular. These windmills, also known as American Windmills, operated fully self-regulated; hence they could be left unattended. The self-regulating mechanism pointed the rotor windward during high wind speeds [28]. The European style windmills usually had to be turned out of the wind or the sailing blades had to be rolled-up during extreme wind speeds, to avoid damage to the windmill. The popularity of windmills in the US reached its peak between 1920 and 1930 with about 600,000 units installed. Various types of American Windmills are still used for agricultural purposes all over the world [17].

III. Indispensability of wind energy

Wind energy, the world's fastest growing energy source, is a clean and renewable source of energy that has been in use for centuries in Europe and more recently in the United States and other nations [31]. Wind turbines, both large and small, produce electricity for utilities and home owners and remote villages. A new approach to wind energy offers a clear path to a more secure and prosperous future and more livable world for the human being as well as for the entire living creature. Renewable energy sources are easily accessible to mankind around the world [26]. It is not only available in a wide range but is also abundant in nature. Increased use of wind energy and other renewable energy sources will spur economic growth, create job opportunity, enhance national security, protect consumers from price spikes or supply shortages associated with global fuel markets and dramatically reduce the pollutant that is warming the planet which causes greenhouse effect [24].

According to the assessment of the Intergovernmental Panel on Climate Change concerning wind energy potential, intermittent wind power on a large grid can contribute an estimated 15–20% of annual electricity production without special arrangements for storage, backup, or load management [14]. Wind energy was the fastest growing energy technology in the 90s, in terms of percentage of yearly growth of installed capacity per technology source. As Paul [10] noticed wind has advanced more quickly to commercialization than other technologies such as solar power, fuel cells and wave power with relatively little Research and Development expenditure [2].

The mechanisms of the wind turbines

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity [22].

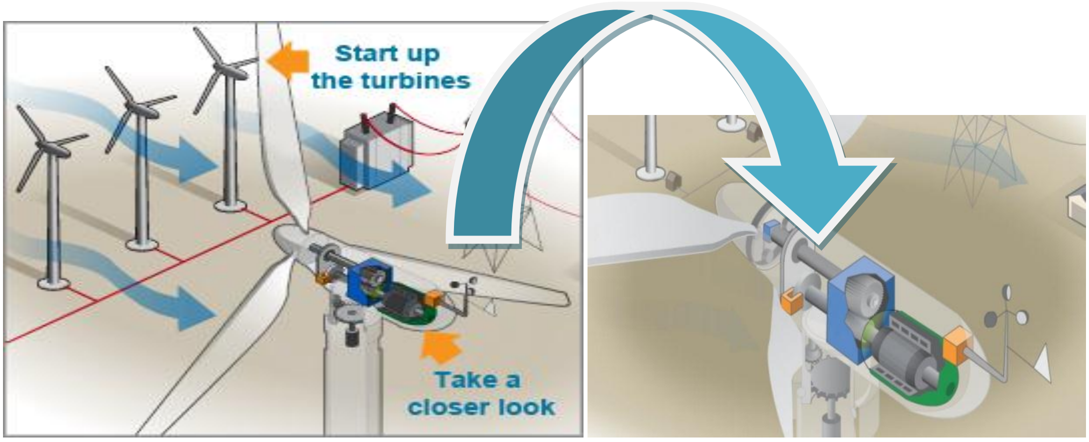

Figure (3): wind turbines structure.

A wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity [27]. The terms wind energy or wind power describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity [29]. Types of wind turbines:

Modern wind turbines fall into two basic groups: the horizontal-axis variety, as shown in the photo to the far right, and the vertical-axis design, like the eggbeater-style Darrieus model pictured to the immediate right, named after its French inventor. Horizontal-axis wind turbines typically either have two or three blades [24].


Figure (4): Two main kinds of wind turbines.

These three-bladed wind turbines are operated "upwind," with the blades facing into the wind. Wind turbines can be built on land or offshore in large bodies of water like oceans and lakes [15]. Single small turbines, below 100 kilowatts, are used for homes, telecommunications dishes, or water pumping. Small turbines are sometimes used in connection with diesel generators, batteries, and photovoltaic systems. These systems are called hybrid wind systems and are typically used in remote, off-grid locations, where a connection to the utility grid is not available [23].

The wind energy policies worldwide

A variety of policies like pricing laws, quota requirements, production incentives, tax credits, trading systems, etc. have been developed and implemented to promote the use of renewable energy (RE) [17]. The main objective of these strategies are reducing reliance on fossil fuels, reducing the environmental impacts of the energy sector and encouraging new industrial development [20]. Yet the feed-in tariff (FIT) and the renewable portfolio standard Renewable Portfolio Standard are the most popular. Though there existing a lot of debates surround their effectiveness, with some expectation that a choice has to be made between them [18] [12]. For this the countries can decide which RE policy can be applicable in their own particular circumstances and objectives. According to Ekins [8], ‘‘No optimal model has emerged, and probably none will do so in the contexts that is shaped by different histories and cultures.

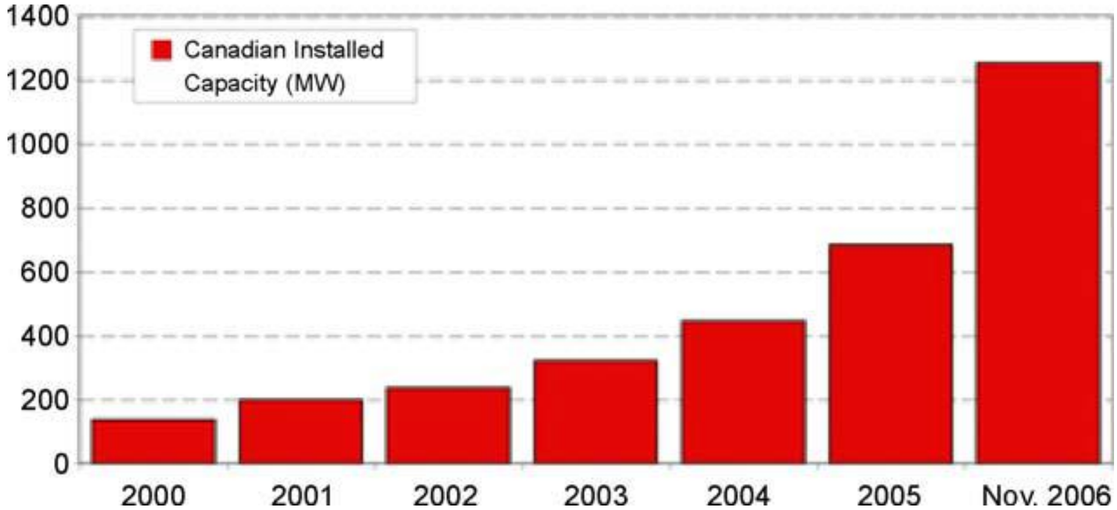

Figure (5): Canadian installed capacity (MW) 2000–2006 [26]

Wind energy storage technologies
The electrical energy can be stored in different energy forms: mechanical, electro-chemical, chemical, electromagnetic, thermal, etc [21]. The classification of energy storage technologies according to the stored energy form is illustrated in figure (6):

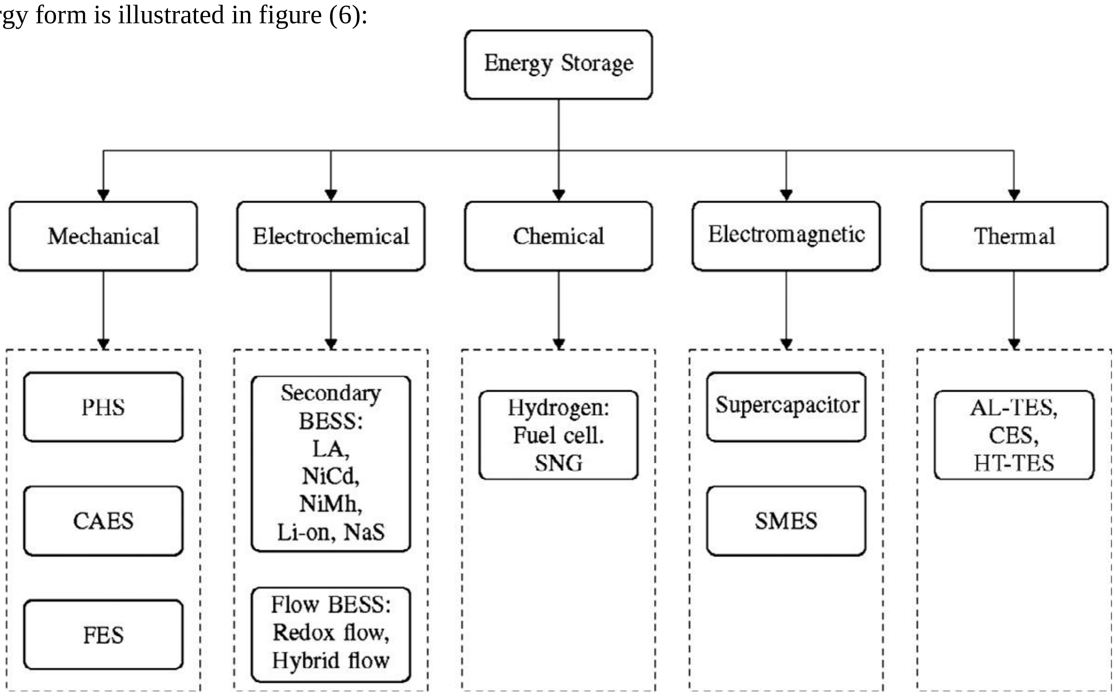

Figure (6): Energy storage classification [21].

The technical details of the energy storage system (ESS) have been described in many literatures [3] [9] [13] [27] [29]. A short description of the principles and potential capability of several commonly used energy storage system (ESSs) for wind power integration support is presented in this section. Wind energy storage systems can be divides in to:

Pumped Hydro Storage (PHS)
The pumped hydro storage has the largest power and energy rating, long lifetime, high efficiency and very small discharge losses. The main applications of the pumped hydro storage for wind power integration are energy management via time-shifting, frequency control and non-spinning reserve supply. Due to the slow response, the pumped hydro storage is not suitable for suppressing wind fluctuations. The installation of the

pumped hydro storage is dependent on geographical conditions and has an impact on the nature environment. Therefore, the flexibility of its application is low.
The economic benefits of the pumped hydro storage (PHS) combined with Wind Farms (WFs) are described and analyzed in [2] and [5] shows that the hybrid PHS-WF system can meet the hourly energy demand.

1.1Compressed Air Energy Storage (CAES)
Many studies improved that the high power and energy capacity rating makes the compressed air energy storage (CAES) another choice for wind farms for the energy management purposes, similarly to the pumped hydro storage (PHS). The storage period can be over a year due to very small self-charge losses [3]. However, the compressed air energy storage (CAES) installation is also limited by topographical conditions.

1.2 Flywheel Energy Storage (FES)
The main advantages of flywheels are the excellent cycle stability, a long life of providing full charge–discharge cycles, little maintenance cost, high power density and high efficiency. The flywheel energy storage (FES) is mainly applied as a power quality device to suppress fast wind power fluctuation, provide ride-through of interruptions of several seconds or bridge the shift between two sources [3]. Besides, it is also designed to provide damping enhancement [5]. The main drawbacks are the short operation duration and high self-discharge losses. They are considered as a support for wind turbines in combination with other energy storage systems (ESSs) rather than standing alone [16].

1.3 Battery Energy Storage System (BESS)
Flow batteries have been built in MW class and can play a more important role for future large scale application. In [19], the Zinc Bromine (ZnBr) battery is used to dispatch the wind power based on the optimal control method. In [31], a washout filter-based scheme is adopted to smooth out short-term power fluctuations of a wind farm with Vanadium Redox Batteries (VRBs).

IV. Conclusion

Wind energy has the potential to play an important role in the future energy supply in many areas of the world [15]. Within the last 30 years, wind turbine technology has reached a very reliable and sophisticated level. The growing international market will lead to further improvements, such as large wind turbines or new system applications, e.g. offshore wind farms. These improvements will lead to further cost reductions, and for the medium term, wind energy will be able to compete with conventional fossil fuel power generation technology. Further research, however, will be required in many areas, for example, regarding the network integration of a high penetration of wind energy [1].

Moreover, under the international agreements on Environment commitments scenario, the penetration is expected to be faster and the 10% level is achieved by this year 2016. The expected saturation level capacity is 1.9-10^9 kW occurring at 2030.

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