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Wind Generators and Turbines used for Wind Power Generation – A Review

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ABSTRACT

Wind energy is a crucial source of renewable energy. Harvesting wind energy in an effective manner will be very crucial. For this purpose, we are utilizing wind turbines and wind generators. There are different types of wind turbines utilized in practice. Various types of wind generators have also been used in recent years in a similar manner. The main aim behind the present work is to detail more about wind energy generation, and the types of wind turbines and generators used in recent times. It also discusses their compatibility and performance for effective wind power generation.

Keywords—Wind Energy, Survey, Squirrel Cage Induction Generator, Wind Generator, Wind Turbine, Review, Doubly-fed Induction Generator

INTRODUCTION

For centuries, people have been harvesting the kinetic energy of the wind and turning it into helpful forms of energy [1]. The Persians and the Chinese are believed to have invented the earliest windmills 3000 years ago, which were used to lift water and grind corn. Throughout the eighteenth century, small wind turbines ranging from 0.23KW were created in rural areas of the United States for power appliances [2-4]. With the introduction of the Rural Electrification Administration in 1936, which provided grid energy to the majority of rural settlements these early accomplishments came to an end. Wind turbines were first used to generate grid electricity in the 1970s in the United States. Its creation was prompted by the necessity to changeover away from fossil fuel-dependent energy sources and toward renewable energy sources [5-7]. Wind and solar have experienced the most rapid expansion of all renewable energy sources (wind, solar, geothermal, and hydropower).

Wind energy is a sort of secondary energy, generated due to the temperature differences in the air, resulting in pressure and density differences. The disproportion of heating is frequently due to the varying heat capacity of the materials being heated by the Sun (e.g., soil, water) [8-10]. Every coastal region's daily land and sea winds reflect this. The diverse reflecting properties of water,

snow, soil, rocks, and vegetation all contribute. The wind's direction is mainly influenced by both the revolution of the earth and the terrain of the location. Taking these considerations into account, the greatest spots to harness onshore wind power are often the summits of mountains and hills, coastal areas, and gaps in mountain ranges [11].

Turbine blades capture wind energy using the same technique that provides lift to aeroplane wings. Low pressure air pocket is created at the bottom of the wind blade. As a result, the blade turns the rotor as it advances toward the low pressure. It is referred to as the lift. This lift has a far greater force than the wind on the front side of the blade. It is known as drag. The rotor of the wind turbine rotates due to a combination of lift and drag [12-13]. This generates electricity by turning the generator. The power output of a wind turbine is expressed in Equations 1 and 2.

$$P=av3 \quad (1)$$

$$P=br2 \quad (2)$$

Where v is the wind velocity, a, and b are constants, P is the power developed, and r is the wind blade's length.

A wind turbine is used in the wind energy conversion system (WECS) to harvest wind energy. The extracted mechanical power is converted into electrical power using a wind generator [14-15]. Figure 1 depicts a schematic of the wind energy conversion system.

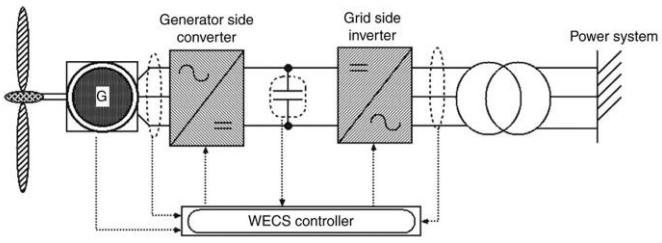

Fig. 1. Wind Energy Conversion System [26]

HISTORICAL BACKGROUND

Windmills have been used for diverse purposes for at least three thousand years. Since the 1300s, horizontal-axis windmills have been a mainstay of the rural economy, falling out of favour only with the introduction of cheaper fossil-fueled engines and, later, the expansion of electrification in rural areas. Wind turbines have been used to generate power since the late 1800s when Brush in the United States created a windmill generator with a capacity of 12 KW. Wind energy was only utilized to charge batteries in faraway households for most of the twentieth century, and these low-power systems were quickly phased out mainly due to the introduction of rural electrification. A significant exemption was the wind turbine with a capacity of 1250 kW invented by Smith–Putnam, which was built in 1941 in the United States of America. This incredible contraption featured a 53-meter steel rotor with flapping blades to reduce load and full-span pitch control for effective control management [16-20].

Golding in the year 1955 and Shepherd in the year 1994 provide an enthralling account of the early development of wind turbines. They exhibit the construction of the Balaclava 100 kilowatts wind farm in the Soviet Union in 1931, as well as the Andrea Enfield 100 kilowatts 24-meter diameter pneumatic design in the United Kingdom in the early 1950s. These turbines drew air up through the tower using hollow blades with open tip, while another turbine powered the generator. The sharp rise in oil prices sparked a flurry of large-scale government-funded research, development, and demonstration projects. This prompted the development of different prototypes of wind turbines in the United States. In the United States, a 3 MW horizontal-axis wind turbine was developed and deployed in 1981. The entire construction was oriented into the wind instead of a yaw drive, and hydraulic transmission was used [21-23].

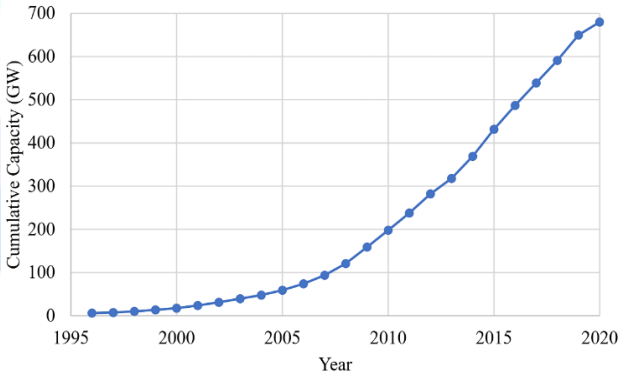

Fig. 2. Wind Power Cumulative Capacity (Globally)

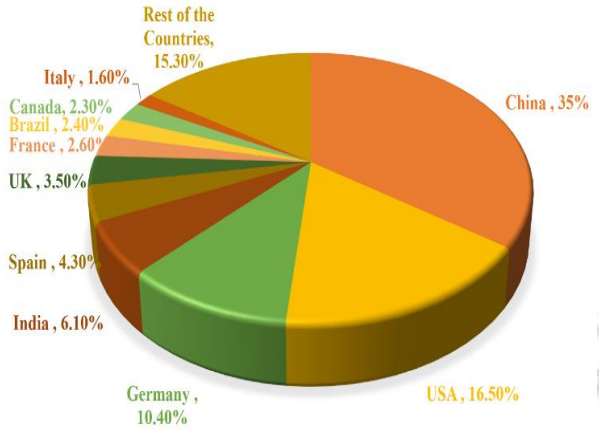

Fig. 3. Installed Wind Power Capacities All Over the World

The world is focusing more on renewable energy in the twenty-first century due to the continual rise in fossil fuels and other sources of energy. In response to growing environmental concerns in the 1990s and 2000s, governments around the world implemented incentives to promote the make use of renewable energy sources. It also gave tax and investment benefits to wind energy projects, as well as money for research and development to help down the cost of wind turbines. Additionally, state governments implemented new renewable energy generation legislation, and electric power marketers and utilities began offering wind and other renewable energy-generated electricity to their customers. The number of wind turbines and the amount of power generated by wind energy have increased as a result of these programs and policies [24-25].

Global wind power cumulative capacity in the present time and its rise from the beginning is shown in Figure 2. Similarly, Figure 3 represents the Installed wind turbine capacity of the different countries all over the world.

WIND TURBINES

Wind turbines exist in a range of shapes and sizes, even though they all operate on the same principles. Vertical axis turbines (VWT) and Horizontal axis turbines (HWT) are a few examples of this. These turbines are frequently used for micro-generation, which means they can be erected to generate electricity in an urban setup [26-27]. Large wind power generation can be achieved similarly by placing wind turbines on or off the coast or in rural areas. Both of these types of wind turbines have their own set of benefits and drawbacks.

A. Horizontal Axis Wind Turbine

The most prevalent turbine configuration is horizontal axis turbines. They are composed of a tall tower with a controller, a generator, a rotor that looks like a fan, and various other components. 2 or 3 blades are common in horizontal axis turbines.

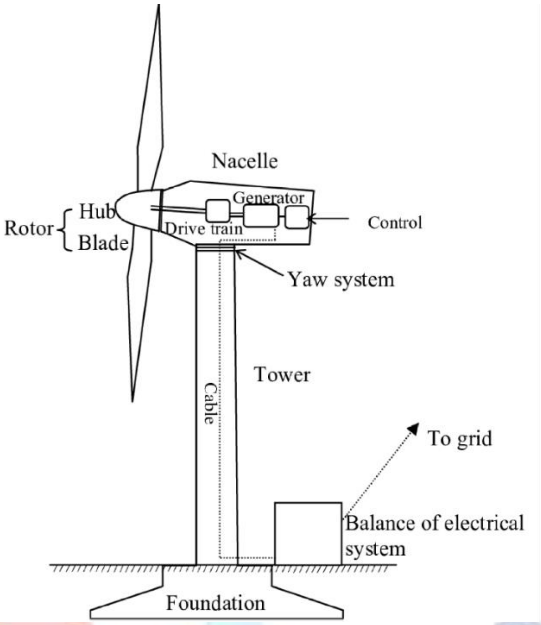

Fig. 4. Horizontal Axis Wind Turbine [28]

HWT is installed atop tower-like structures to reap the benefits of the stronger but also less turbulent wind that exists at 30 metres or more above ground level. The rotor rotates like a propeller as a result of the lift and drag forces, and the spinning shaft powers a generator to generate power [29]. The HWT schematic is shown in Figure 4.

B. Vertical Axis Wind Turbine

Savonius and Darrieus are the two types of vertical-axis turbines. Neither of these turbines is commonly used. In the 1920s, the Darrieus turbine was first developed in France. It captures additional energy from drag forces by utilizing aerodynamic lift. Darrieus turbine versions include the Cycle and Giromill turbine. The Savonius turbine has a S shape when viewed from above. This drag turbine rotates slowly yet produces a lot of torque. It can grind grain, pump water, and perform a variety of other duties, but its modest rotational rates make it unsuitable for power generation. These are still employed for a wide range of applications [30]. Figure 5 represents the schematic of different types of VWT.

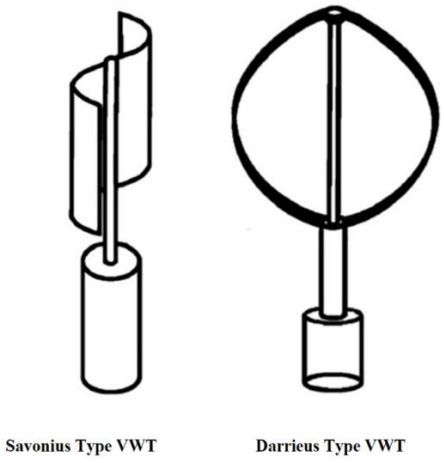

Fig. 5. Vertical Axis Wind Turbine [31]

WIND GENERATORS

In wind turbines, there are several different types of electrical generators are deployed. The control flexibility, load type, turbine position, and installed power are all factors to consider when choosing a wind generator. Squirrel-Cage Induction Generators (SCIG), Synchronous generators (SG), Permanent-Magnet Synchronous Generators (PMSGs), and Brushless DC (BLDC) generators are the most prevalent types of generators used in wind turbines. BLDC or SGIG generators are commonly used to power mini and micro-scale wind turbines mainly used in residential applications. Doubly-fed induction generators (DFIGs) are commonly employed in megawatt-scale turbines. Other machines utilized in wind turbine applications include Switched Reluctance generators (SRGs) and permanent-magnet synchronous generators (PMSGs) [32-39]. Figure 6 depicts the general block diagram of the wind energy system incorporating a wind turbine, wind generator, and other equipment.

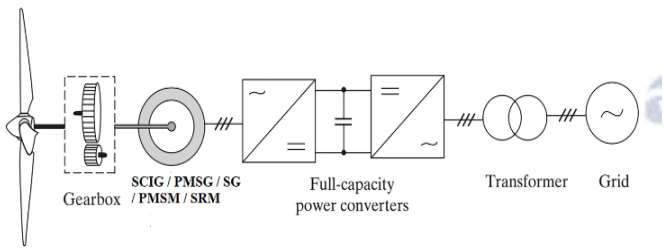

Fig. 6. Overall Wind Energy Systems [26]

A. Squirrel Cage Induction Generator

The squirrel cage induction generator (SCIG) shown in Figure 7 can be used to generate electricity in a variable-speed wind turbine. This generator output is connected to a two-sided pulse width modulated converter. A voltage source rectifier (VSR) converts the SCIG's AC voltage to DC. In the similar way, the DC is again inverted to AC by a voltage source inverter (VSI). The rating of power converters and more number of devices utilized leads to an increment in the cost and efficiency of the entire system [35]. The power flow regulation of the system is adjustable.

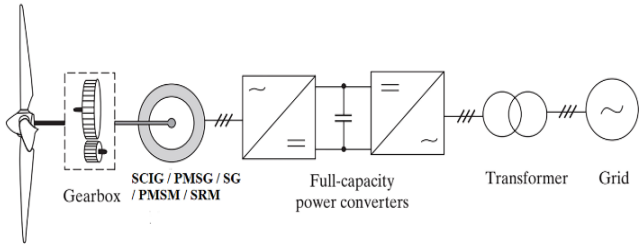

Fig. 7. Wind Turbine with SCIG [26]

B. Synchronous Generator

The Synchronous Generator (SG) as shown in Figure 8 can be utilized in a variable-speed wind turbine for power generation. The terminal voltage of a synchronous generator can be regulated using a separate exciting circuit. Large-scale wind turbines can use this generator. The grid-side inverter allows for control of the power and regulation. The torque is controlled by the generator-side rectifier. The full-scale power converter connected to the grid allows the system to quickly change active and reactive power. As an outcome, the grid connection has advantageous characteristics [40-44]. However, when compared to the DFIG wind turbine, it raises the total cost of the wind turbine system.

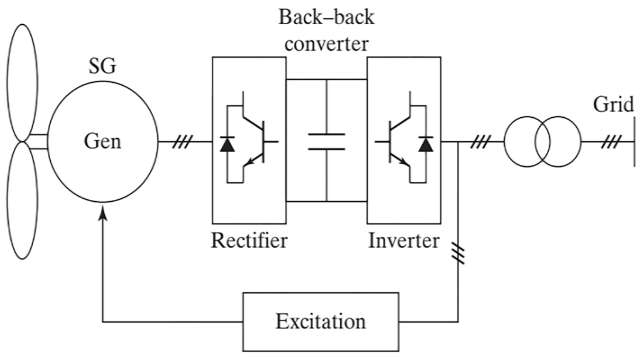

Fig. 8. Wind Turbine with SG [26]

C. Doubly fed Induction Generator

The block diagram in Figure 9 illustrates a variable-speed wind turbine combined with a

doubly-fed induction generator (DFIG). An isolating transformer connects the generator stator to the electric grid directly. The rotor of the wind generator is connected to a back-to-back converter. The rotor-side converter controls the generator's rotor current, while the grid-side converter controls the grid-side power factor and the DC-link voltage. The RSC synchronizes the rotor current and controls the slip power. As an outcome of the narrow range of slip speeds, the power electronics converter sizes are reduced, lowering the capital cost of wind turbines [45-48].

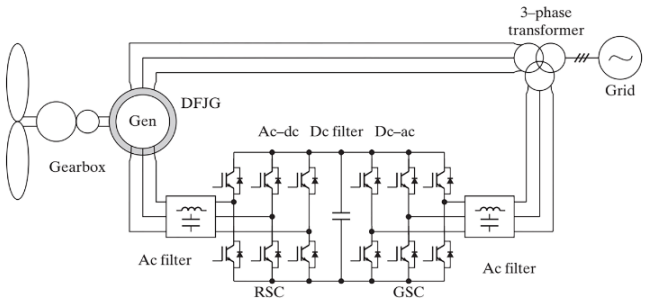

Fig. 9. Wind Turbine with DFIG [26]

CONCLUSION

The present manuscript discusses the importance of wind energy systems for the current global scenario. It comes out with a detailed historical background. The wind power capacity (Cumulatively) increased from 1995 and the total installed wind turbine capacity are shown in a graphical representation for easy understanding. Different types of wind turbines like Horizontal axis wind turbines and vertical axis wind turbines are also briefed in a separate section. The main part of the wind turbine is its wind generator. Different types of wind generators are also discussed in detail with clear pictorial representation. We hope the survey presented in the current manuscript gives a detailed insight into wind energy harvesting and different types of turbines and generators in a brief manner.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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