Hybrid Renewable Power Production on Unfavorable Conditions—A Review

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Abstract Wind energy an unimpeded and simply accessible renewable source. It is a more abundant source regardless of the time factor. Further, the capability of wind in producing energy as a green source makes it a favorite for renewable power generation. Wind energy can be exploited for producing power in a fresh environment. The number of unconventional power generation resources is steadily increasing. In this review, we looked at the efficiency of wind turbines in comparison with solar energy, as well as the possibility of combining the two as a hybrid power source. The literature expressed that the power production using renewable sources are being seasonally successful. So, we analyzed the performance of hybrid renewable power generation as a source for future development.

Keywords Wind energy · Renewable power generation · Solar · Hybrid · Future

1 Introduction

Natural resources have been depleted in recent years as a result of greenhouse gas emissions, resource scarcity, and a lack of energy supplies. The researchers are putting forth effort because they want to use renewable energies to the greatest extent possible. Wind turbines with vertical and horizontal axes were tested for performance [1]. Wind energy, according to Djamal Hissein Diane et al., is a readily available, cost-free, and long-term sustainable source. Even though it is in high demand, the supply will remain constant in the future. It is a source of non-polluting, clean energy. There is no waste or greenhouse gas production. It is a green fuel source that, unlike coal or natural gas-fired power plants, does not pollute the air [2].

This paper is organized as follows. In Sect. 1, wind turbines classification, Sect. 2 unconventional wind turbines, Sect. 3 solar power generation, Sect. 4 effects of hybrid power generation and concluded in Sect. 5.

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2 Wind Turbines Classifications

Horizontally axis wind turbines are distinguished by the fact that their rotating axis is on the same layer as the ground, and they are best suited for large-scale applications. Since they can be mounted on rooftops, vertical-axis wind turbines are ideal for small-scale wind turbines. Horizontal axis setups are typically used for higher power requirements, but they perform poorly in highly turbulent environments [3].

2.1 Horizontal Axis Upwind Turbines

The blade of an upwind turbine is facing the wind. Upwind designs have the major benefit of avoiding the wind shadow behind the tower. This is the most famous wind turbine design. In the vicinity of the tower, there is almost a wind shadow, this implies that the wind bends away from the tower until it hits the tower itself, even though the tower is not in the shade. As a result, each time the rotor approaches the tower, the wind turbine's power decreases slightly. The rotor must be made reasonably rigid and ride at a safe distance from the tower, which is the key flaw. To hold the rotor facing the wind, and the upwind machine needs a yaw mechanism [4].

2.2 Horizontal Axis Downwind Turbines

The rotor of a downwind turbine is mounted on the tower's low side. If the rotor and nacelle are constructed in such a way that the nacelle follows the wind passively, they can be mounted without a yaw mechanism. However, this will not be more efficient for large wind turbines since cables are needed to transport the current away from the generator. Also, the rotor must be made more flexible, which is a major lead. A downwind can be made lighter than an upwind machine is a huge advantage. The key drawback to this method is the fluctuation of wind power generated by the rotor passing through the wind shadow of the tower. It would result in higher fatigue loads upon on turbine than that of an upwind design [5].

2.3 Vertical-Axis Wind Turbines

The vertical-axis wind turbine (VAWT) is a wind turbine with a vertically oriented main rotational axis. They have a rotational axis that is vertical or perpendicular to the ground. The ability to produce well in turbulent wind conditions is a key benefit of using a vertical-axis turbine. Wind turbines with a vertical axis can also rotate in any direction. When the wind blows from top to bottom, it can also be powered. Vertical-axis wind turbines are thought to be ideal for installations where wind patterns are unreliable or where public ordinances prevent the turbine from being mounted high enough to benefit from steady wind [6].

2.4 Darrieus Vertical-Axis Wind Turbines

Darrieus wind turbines are a type of vertical-axis wind turbine (VAWT) that consists of a collection of curved aerofoil blades mounted on a rotating shaft or framework. The curvature of the blade allows it to be strained only at high rotational speeds. Several highly associated wind turbines use straight blade wind turbines. The blades of a Darrieus turbine can be twisted into a helix, such as three blades with a 60° helical twist [6].

2.5 Savonius Vertical Wind Turbine

The Savonius vertical-axis wind turbine (VAWT) transforms the wind's power into torque on a spinning shaft. On the ground or in air-borne designs, the turbine is made up of several airfoil sections straddling vertically on a revolving shaft. It is a two- or three-scoop drag scheme [7]. When moving toward the wind, the turbine experiences less drag than when moving with the wind due to the curvature. The Savonius turbine spins due to the differential drag. Savonius turbines are known for their drag-type turbines. Since wind speeds are lower at lower altitudes, much of the swept area of a Savonius rotor may be close to the ground if it has a small mount without an extended post, lowering overall energy extraction efficiency [8].

3 Unconventional Wind Turbines

3.1 Savonius Wind Turbine

The shrouded wind turbine is a novel design that encloses the turbine in a venturi-shaped shroud or duct (vent-duct), creating a low-pressure sub-atmosphere behind it. The Betz limit is bypassed by the variable area shrouded turbine, which represents the volume of air over the turbine and helps it to run at higher efficiencies than if it were just a turbine. According to the claims, a shrouded turbine generates 1.15–4 times the energy of a non-shrouded turbine [9]. In an open flow, the 59.3% Betz conversion efficiency cap for a turbine still applies, although it can be increased further in veiled applications. A shrouded turbine's output is determined by the shroud design; not all shrouded turbines are created equal [10].

Shrouded turbines cannot operate at optimum efficiency unless the shroud intercepts the current flow at the correct angle, which may happen as currents eddy and swirl. As a result, operational efficiency suffers. At lower turbine efficiencies, the increased cost of the shroud can be balanced, while at higher efficiencies, the cost of the shroud has less of an effect on commercial returns. The cost of the shroud's supporting structure must also be balanced against its increased performance. Although yawing (pivoting) the shroud and turbine at the proper angle, so that it always faces upstream like a windsock, could boost turbine output [11].

3.2 Wind-Lens Turbine

The hybrid approach, in which the flow and acoustic fields are solved separately, was found to be an efficient technique for such a study's computational. Since the possibility of using a wind-lens turbine was discovered, a need to examine this hypothesis has grown steadily. Wind-lens design, fringe size, and average velocity are some of the effective parameters investigated to improve the turbine's performance [12]. When a bare wind turbine's noise is compared with the noise produced by various types of wind-lens turbines, it is clear that the wind lens generate more noise. The human ear perceives loudness in the 20 Hz–20 kHz natural hearing range [13]. The noise generated by wind lens is the focus. In comparison with existing wind turbine designs, the wind lens needs considerably more materials. The fabrics for the shrouds, as well as the mesh, take a lot of time and money to make. The wind pressure on the wind lens is higher, and the wind lens may be too difficult to sustain due to structural issues [14]. This may indicate that it has a lot of power it's not using or that the wind lens is more prone to breaking. The wind lens is being considered as a way to boost clean energy generation and other clean energy sources[15].

The wind lens can be used to replace current manufacturing energy from fossil fuels, which is detrimental to the environment, as well as the less efficient wind turbine since it is adaptable to more conditions and produces more energy [16].

3.3 INVELOX Turbine

INVELOX is a novel approach for increasing the velocity of the wind. It works by the speed of the wind. The wind is collected by a large intake, funneled down to a venturi section by tapered tubing, and finally released by a diffuser. The INVELOX venturi portion houses the turbines [17]. The turbine converts kinetic energy into mechanical rotation, and we use a generator to generate electricity. The INVELOX system's venturi impact component concentrates and accelerates wind. The pressure is raised, causing a significant amount of kinetic energy to be transmitted to the turbine. It separates the turbine from the intake, just like a hydropower plant [18]. It is based on the hydropower principle. The duct in the shape of a diffuser is the primary contributor to the accelerated flow of air toward the turbine. The following components make up the INVELOX system: Wind is carried into the pipe and is accelerated. System of intake When a fluid flowing through a pipe is forced through a narrow segment, the venturi effect occurs, resulting in a decrease in pressure and a rise in velocity [19]. The accelerated wind is sent to the turbines/generators, which convert it to electricity. Wind is funneled into the system. Because of the omnidirectional intake area, wind can be collected from any direction. The wind is captured at the top of the funnel-shaped INVELOX structure[20].

4 Solar Power Generation

Dry-sensitized solar cells could be used instead of P–n junction photovoltaic systems. In p–v applications, the semiconductor often achieves light absorption and charge carrier, but the light in these cells is absorbed by a sensitizer. To separate charges at the interface, photo-induced electron injection is used. More light can be captured by a sensitizer with a large absorption band. Electric energy is converted from photons of wavelengths ranging from ultraviolet to near infrared. An efficiency of about 10% can be achieved using dry-sensitized solar cells. Traditional silicon cells have a lower efficiency, whereas DSC is temperature tolerant [21].

Photovoltaic modules have a lower electric yield since the sun's irradiance is mirrored. With a refractive index of 1.3, water serves as a good medium between glass and air. Coatings and structured surfaces have been proposed as ways to reduce reflection, but they are neither cost effective nor long lasting. It also reduces reflection by 2–3%, reduces cell temperature by up to 220 °C, and increases electrical yield by 10.3% [22].

Quantum dot solar cells produce higher photovoltage or photocurrent by using hot photo-generated carriers, increasing the overall thermodynamic conversion of the solar photon. The accumulation of a hot carrier in a QD array photoelectrode until it relaxes to the band edges due to phonon emission causes the photovoltage to increase. The use of a hot carrier in QD solar cells increases photocurrent by producing and collecting extra electron–hole pairs through the ionization process. Solar cells are quickly gaining traction as a viable source of energy. To reduce solar irradiance reflection, an anti-reflection technique was suggested. This involves using nano-imprint lithography to create a nanometer-scale dot pattern array on the surface of GaInP/Ga(In)As/Ge solar cells [23].

As visible light has a longer wavelength than this nano-pattern, the effective refractive index near the surface gradually increases. As a result, the refraction of light at the surface in the total spectral area is reduced. The refraction was reduced to around 5.3% at a wavelength of 400 nm. GaAs' overall conversion efficiency improved from 27.77 to 28.69% as a result. To make polycrystalline thin films of tin sulfide, spray pyrolysis is used. The film's resistivity was 30 Ω, and its optical energy bandgap was 1.38 eV. Indium-doped cadmium sulfide was used as a window coating and as an absorber in heterojunction solar cells. Finally, their systems were characterized to look into the performance of solar cells. The machine had a solar conversion efficiency of 1.3% and a quantum efficiency of 70%. The efficiency was lower due to the very thin thickness of SnS used in solar cells. As the thickness is increased to 1.5 μm or more, VOC levels rise [15].

The counter electrode for dry-sensitized solar cells was made of graphene and polystyrene sulfonate composite films deposited on indium tin oxide [24]. With a high transmittance and an indium tin oxide coating, this thick composite film can be used as an electrocatalyst. This form of cell's energy consumption performance was comparable to that of cells with platinum as a counter electrode. At a 100 mW AM 1.5 white light irradiance, they had a thermal efficiency of 4.3%. Because of their high transmittance, they were also used in power-generating windows. The use of a hard carbon spherule as a counter electrode for dye-sensitized solar cells has been proposed [24].

The cell's overall conversion efficiency is about 5.7%, which is comparable to Gratzel-type solar cells with a platinum-sputtered fluorine-doped tin oxide counter electrode, which has a conversion efficiency of 6.5%. The surface areas of the carbon material had a major impact on photovoltaic efficiency. The disordered microporous hard carbon spherules showed high electrocatalytic activity in the iodide/triiodide redox reaction, making them suitable for counter electrode fabrication on dye-sensitized solar cells [25].

5 Effects of Wind and Solar Using Together as the Hybrid Source for Power Generation

Jenkins et al. evaluated the possibility of using solar and wind as together for generating the power. They validated the design using the hybrid optimization model for the production of renewable electricity. They performed simulation for capable of producing 250 kW as 100 kW using ten wind turbines and 150 kW of solar PV [26]. Bob Burkett et al. patented the solar-driven fan to push the wind inside the vent for power production. They modeled the system for heating or cooling the room with this setup also they can utilize the setup for the power production [27]. Ehsan et al. described that hybrid power development using both wind and solar as a source of power generation. They tried a new approach of storing both powers in the battery, whereas wind can be utilized as a major contributor and solar as a supporter [15].

6 Conclusion

Power generation using renewable energy sources has been developing a lot on day to day basis. But still, the focus is mainly on individual resources. As we have reviewed the performance and efforts taken for hybrid development only works are limited and mostly not came in real-time applications. The identified issues are mainly the storage and power transmission. We are looking to overcome these shortcomings and will develop more in the future.

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