An Overview of Renewable Energy Sources: Physics of Solar and Wind Power

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Abstract

The demand for "renewable energy sources" has risen due to worries about climate change and the depletion of fossil resources. Two of the most widely used and innovative renewable energy sources are solar and wind power. This study has provided an in-depth analysis of the current scientific foundations for wind and solar energy, as well as the opportunities and obstacles associated with their use. It has examined solar radiation properties, photovoltaic cells, the photoelectric effect, and wind turbine aerodynamics, blade design, and kinetic energy concepts. Due to its dispersed, clean, and endless ability to create power, solar energy may be able to provide almost all of the world's energy needs. The present development status of grid-connected technology and wind power new energy are adopted in the essay. By using energy storage, we may enhance the dependability of the electrical system and provide a sustainable power supply, since a large portion of renewable energy comes from grid-connected sources.

Keyword: Fossil fuels, Renewable energy, Solar and wind energy, Photovoltaic cells, Wind turbines, Blade design.

I. INTRODUCTION

Economic growth is said to be mostly driven by energy. For the worldwide economy to prosper and for industrialisation to continue, we need sources of energy that will sustain our whole planet. However, every activity involving the transfer and conversion of energy has an effect on the environment. The use of fossil fuels has a detrimental effect on the environment, animals, and the purity of water and air [1]. Renewable energy not only provides a competitive advantage over traditional energy sources but also a sustainable substitute, aiding in the accomplishment of the UN's 2015 Sustainable Development Goals (SDG). Bioenergy counterbalances the negative social and environmental effects of using nuclear power and fossil fuels [2]. Seventh Sustainable Development Goal (SDG): To achieve the goal of providing contemporary, cheap, dependable, and sustainable energy to everyone, a higher percentage of renewable energy must be included in the world's energy mix [3]. To meet the growing concerns of "energy emissions, consumption, energy dependability, and climate change," governments worldwide have set high criteria for the use of renewable energy sources and a reduction in gaseous and particle emissions. The advancement of wind and solar energy installations worldwide is still largely driven by these objectives [4].

In comparison to fossil fuels, the distribution of clean drive is widespread and involves comparatively little trading. It provides chances to improve global energy stability, diversifies the supply, reduces the quantity of oil imported, and diminishes the economy's exposure to demand changes. Utilising energy from renewable sources will also make the energy supply more efficient, particularly in areas where grid access is currently limited. Improved controls, better design, and a variety of driving bases might all lead to more wellbeing [5].

A. Solar energy

All of the different "fuels and energy sources" that humans utilize eventually come from the sun, which has been producing energy for millions of years. People have been using solar radiation, or the sun's rays, to dry fruit, meat, and cereals for thousands of years. Over time, technologies to capture solar radiation for heating and convert it to electrical power have advanced. Often known as a solar cell, a "photovoltaic (PV) cell" is an electrical device that can function entirely on sunlight without the need for a machine. Certain PV cells may generate power from artificial light. Photons, or solar energy particles, make up sunlight. Photons in the sun spectrum have varying energies, which are correlated with distinct wavelengths. Semiconductors make up a PV cell's constituent parts. Photons that strike a photovoltaic cell have three possible outcomes: they may either pass through the cell or bounce back, or they can be captured by the material that contains semiconductors. The sole source of energy required to produce electricity is photon absorption. Electrons in semiconductor materials are freed from their atoms when they absorb sufficient sun radiation. In order to induce liberated or dislodged electrons to spontaneously move to the PV cell's surface, the cell's front interface is carefully treated during manufacture to boost its receptiveness to these electrons. When it comes to turning sunshine into energy, various semiconductor materials and photovoltaic cell technologies perform differently in terms of efficiency. About 15% of commercially available solar panels had an efficiency of below 10 percent in the mid-1980s; by 2015, that number had climbed to above 15%, and for the most sophisticated modules, it was approaching 25%. PV cells for niche applications, such space satellites, and experimental PV cells have both reached around 50% efficiency [6].

. Working and applications of solar energy

One of the most widely used devices for collecting solar radiation and turning it into thermal energy is a flat-plate collector, which is used in solar heating applications. Due to the limited "solar radiation" at the planet's surface, large collecting regions are necessary. Flat-plate collectors that are most often used are constructed from blackened metal plates that are heated by sunlight. The plate may have one or two sheets of glass covering it. The carrier fluids—air or water—that pass by the rear of the plate then absorb this heat. Either utilise the heat immediately, or transfer it to another medium and store it there. Flat-plate collectors are often used for home heating and solar water heaters. The traditional method for storing heat for use at night or on overcast days is to utilise insulated tanks to hold the warm water from sunny days. A system like this may heat a house by drawing hot water from a storage tank or by heating the water and circulating it via tubes in the ceiling and flooring [7].

Solar radiation may be directly converted into solar energy, or electricity, using solar cells, sometimes referred to as photovoltaic cells. In these kinds of cells, light is created when it strikes the junction of a semiconductor (such as silicon) and a metal, or two semiconductors. Small photovoltaic cells are widely employed in low-power gadgets like watches and calculators. They may be powered by natural or artificial light. Larger units have been used to power water pumps, communications systems in remote locations, and meteorological and communications satellites. Focussing, or concentrating, collectors direct sunlight from a wide region onto a small, blackened receiver in order to produce high temperatures in concentrated solar power facilities. This greatly boosts the intensity of the light [8].

B. Wind energy

The kinetic energy of air is converted by wind energy into mechanical and eventually electrical energy via the use of "wind turbines or other wind energy conversion equipment". The wind drives the turbine blades' rotation, which in turn spins a connected turbine to create energy that varies according to the turbine blades' length and size. Because wind exists everywhere on Earth, wind energy is available worldwide and helps provide energy security. Additionally, since wind energy doesn't produce any pollution or greenhouse gases, it appears to have among "the lowest carbon footprints" in comparison to other energy sources. It is also thought to benefit rural communities since it will encourage economic growth in such areas. There are certain restrictions that must be considered even though wind energy constitutes one of the purest energy sources and has many advantages. The majority of negative impacts are felt by animals, indirectly as well as directly, especially by migratory birds (who are considered an especially animal-friendly energy source). Additional negative impacts include noise, visual unattractiveness, and communications signal interference [9].

1. Primary Components of wind turbine

The three essential components of the most basic wind-energy turbine are as follows:

Rotor blades - Although the blades' most fundamental use is to block wind, more sophisticated blade designs have

other uses. In a sense, the blades are the system's sails. A portion of the energy generated by the wind is transmitted to the rotor when the blades spin.

Shaft - The center of the rotor is attached to the wind-turbine shaft. The shaft and rotor rotate in unison. The rotor provides the shaft with mechanical rotational energy in this manner, which the shaft uses to get to an electrical generator at the other end.

Generator - A "power source" is a very simple device in its simplest state. It creates an electrical charge variation or electrical voltage by using the characteristics of electromagnetic induction. To put it simply, electrical pressure, also referred to as voltage, is the force that transfers "electrical current, or electricity," across one place to another. Consequently, current is produced when voltage is produced. A conductor and magnets make up a basic generator. Usually, the conductor is a coil of wire. A set of permanent magnets around the wire coil is attached to the generator's shaft. When one of the components of an electromagnetic induction system spins in respect to the other and the conductor is surrounded by magnets, voltage is generated in the conductor. As the rotor turns the shaft, the wire coil produces voltage, which causes the magnet assembly to spin. Through power lines, that voltage distributes electrical current, which is usually alternating current, or AC power.

2. Modern wind power technology

Modern wind turbines come in two primary designs: horizontal and vertical axes. Vertical-axis wind turbines, or VAWTs, are not widely used. A VAWT's shaft is orientated vertically and perpendicular to the ground. Because VAWTs are constantly facing the wind, unlike their horizontal axis siblings, they don't need modification when the wind direction changes. But before a VAWT can start moving, its electrical system needs to help. Because guy wires are often used to support it rather than a tower, its rotor elevation is typically shorter [10]. The HAWT shaft is horizontal and oriented parallel to the ground. A yaw-adjustment mechanism is necessary for HAWTs to maintain their alignment with the wind. "The electric gearboxes and motors" comprising the yaw system shift the rotor completely left or right in minuscule increments. The turbine's electronic controller locates any "mechanical or electronic wind vane devices" and adjusts the rotor's position to maximize the collection of wind energy. Almost all of the components of a hawthorn turbine are as high as "260 feet (80 meters) in the air", thus they need extremely little ground space. The turbine's component sections are lifted by a tower so that the turbine's blades may clear the ground and operate at maximum wind speed. The only utility-scale wind turbines built for the commercial sector are called "horizontal-axis wind turbines (HAWTs)". Small-scale turbines and rural water pumping applications may both benefit from the use of VAWTs [11].

C. Comparison over Solar and wind energy

Solar panels work best in suburban or urban environments since they may be mounted on the roofs of homes, buildings, schools, and commercial establishments. Soon, windows and rooftops will be combined with transparent solar panels. Solar energy requires less maintenance and oversight. Urban settings are not appropriate for wind turbines. It works well in rural areas that are remote from cities and have little power availability. The equivalent power output per kWh of a wind turbine is about 48,704 solar panels.

Solar and wind turbine efficiency is based on how well they convert solar radiation into electrical energy that can be used. Not even the most effective solar panels can really convert all of the energy into electrical energy—only around 22%. Wind turbines have the potential to convert up to 60% of their captured energy into electrical energy that is usable. While solar energy is more effective than wind power, wind power is harder to make money from than solar electricity [12].

It will produce 8,000–12,000 kWh annually, or a mean expenditure of 20.3 cents per kWh, for the whole year. For this reason, solar energy is less costly than wind energy. The ideal choice is to use a variety of renewable energy sources, such as wind and solar electricity, to power a home. It only makes sense, however, in rural places with plenty of open space. The ideal choice for homes searching for a "sustainable energy source" is solar panels since they are inexpensive to install and need no maintenance. Utility scaling will include wind. Renewable energy sources benefit the environment and assist in lowering energy expenses. Wind and solar power have the potential to become formidable competitors to fossil fuel companies if they maintain their startling growth rates [13].

Depending on their demands and the location they live in, people may pick between wind and solar energy. Choosing the wrong course of action might cost you a lot of money. Professionals with experience in using sustainable energy may assess the circumstances and provide guidance on the best kind of sustainable energy. Unreliable energy

sources like wind and solar power provide electricity. One will perform superior to the other in certain situations. which, given your position, is more beneficial. Places with more sunshine will see far higher energy generation from solar panels than from a single wind turbine. If wind turbines are situated in a location with plenty of wind, they will produce more electricity. For wind systems to work, large windbreaks and buildings need to be almost nonexistent in the surrounding area. That clarifies the purpose of the wind turbines that are positioned in lakes and oceans to produce power [14].

II. LITERATURE REVIEW

(Babaremu et al., 2022) [15] The technical and commercial potential of solar-wind hybrid plants was examined in this research. The excessive production in Germany and the instance investigation into enabling policies in India are two of the important case studies used in this research to illustrate the pressing issues that "solar-wind hybrids" must solve. This evaluation focusses on particular, workable solutions that have been suggested for these issues. It was discovered that most academic research on this subject dealt with "the theoretical and techno-economic aspects" of these hybrid systems, as was previously noted in the literature. Yet, more thorough papers and research with real-world applications are available from "original equipment manufacturers (OEM) and engineering, procurement, and construction (EPC)".

(Gan, 2021) [16] The earth's capacity to store resources is steadily declining due to the ongoing growth of the social economy and population, and non-renewable resources are progressively running out. The survival of people will be gravely endangered. Therefore, the main strategy used by our nation to overcome the resource scarcity is the development and utilization of "clean energy and renewable resources". The dilemma of human life brought on by the depletion of coal resources may be successfully mitigated by the development and use of new wind power generation. The article aims to promote the sustainable development of our country by examining the current level of grid-connected technologies and embracing wind power as a new source of energy.

(Shakirov, 2019) [17] The article addresses how power fluctuations impact power stability and quality as well as the problem of solar and wind farms running concurrently with the power system. A succinct evaluation of Russia's chances for wind and solar power plant commissioning is provided, along with an explanation of the detrimental effects these projects will have on the electrical grid. A methodological research of the cloudiness and wind speed fluctuations in several Russian localities is carried out. The curves for wind power duration are shown. An examination of potential variations in solar power due to cloud cover is conducted. It is shown how geographically aggregating solar or wind power production may boost assured power generation and lessen adverse effects on the energy system's stability.

(Li et al., 2019) [18] The power characteristics play a critical role in assessing the wind turbine's working status. In order to correctly assess the performance of the real 2.0 MW wind turbine, the recorded "wind speed, power, and other operational data" demonstrating the wind turbine's performance are first compiled, and the data is then analyzed in accordance with the standard specification. To acquire the wind turbine's real power curve and compare it with the planned power curve, this study employs data analysis. Finally, the study analyzes and assesses wind turbine operating performance and, on the basis of its results, offers suggestions for ways to enhance wind turbine performance.

(Guerra et al., 2018) [19] Future human energy demands can be met by solar irradiance because of its energy capacity and endurance. Solar energy is the primary "renewable energy source on Earth". The photovoltaic industry needs to enhance "solar cells" in this domain by lowering the associated loss mechanism, emphasizing process design enhancement, and simplifying and cutting manufacturing costs in anticipation of the forthcoming implementation of more sophisticated designs. This effort is a component of a research project on cutting-edge technical methods meant to raise “silicon solar cells” conversion efficiency. Specifically, a comprehensive examination of the basic ideas related to the physical mechanisms—such as the "generation and recombination process, charge carrier collection, mobility, and the basic analytical 1D p-n junction model"—that are necessary to comprehend the behavior of solar cell structures. The primary loss causes and theoretical efficiency constraints that impact silicon solar cell performance are also described.

(Zahedi, 2014) [4] Energy storage might help the electrical system in addition to sporadic energy sources like wind and solar power. The major advantage of energy storage is that it can keep the system running during times of high peak demand. The second advantage would be that energy storage would assist in adjusting the grid load from periods of high demand to periods of low demand. The third advantage is that the use of energy storage would aid in mitigating the fluctuations in power production that

intermittent and variable renewable resources provide into the system. The third benefit is particularly important as the world's electrical grid will ultimately include more renewable energy sources. This article presents the findings of an investigation into the possible advantages and applications of energy storage incorporated into intermittent sources. With so many renewable energy sources connected to the grid, using energy storage will enable the development of a reliable power supply and improve system reliability.

(Tripanagnostopoulos et al., 2010) [11] We provide a novel idea for integrated solar and wind energy systems intended for building applications in this study. Photovoltaic (PV) systems may be hybridised with thermal collectors via PV integration. The WT and PV subsystems may work in tandem to cover the electrical load of a structure. Thermal storage tank temperature in solar thermal units may increase when "PV/T collectors" are utilized and surplus electricity is not consumed or stored in batteries. The recommended PV/T/WT system's experimental setup is described, and the experimental findings are shown. The solar component's output in PV/T/WT systems is dependent on the amount of sunlight, whereas the wind turbine component's output is determined by wind speed and may be achieved day or night. By using the three subsystems, a significant portion of the building's energy demand may be covered, helping to save conventional energy and safeguard the environment. In rural and isolated locations with power supplied by standalone units or a mini-grid link, PV/T/WT systems are thought to be appropriate. PV/T/WT systems are applicable to standard grid-connected applications as well.

III.CONCLUSION

The need for energy is rising globally. Rapid growth in solar and wind energy might assist several nations in reaching their carbon reduction targets. The environmental effect of solar and wind power projects must be carefully considered before development begins. Adaptive control solutions, for example, are intelligent technologies that may reduce output power volatility, intermittent power fluctuations, and disturbances in wind power systems. In the smart grid, intelligent control system solutions enhance system self-healing and emergency response while guaranteeing clean and multiple power generation. To increase install capacity globally, solar applications must improve performance and market competitiveness. Novel solar cell layouts and enhanced manufacturing techniques are critical for PV system optimisation. An investigation on the benefits and functionality of energy storage in intermittent sources. Energy storage may be able to sustainably deliver electricity, improve power balance, and boost system stability in situations when many renewable energy sources are connected to the electrical grid.

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