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Optimizing Energy Transfer: A Novel Wireless Bypass Charging System for E-Vehicles with Darrieus Technology

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ABSTRACT

This paper presents a parallel resonant inverter-based solution to power several distributed transmitter coils after giving a summary of the available electric vehicle (EV) charging technologies. Where the receiver coil is attached to the car determines which coils are energized in sequence. By means of this approach, Inductive Power Transfer (IPT) Technology functions. Ingenious magnetic induction bypass charging does away with the need for actual connections between the charger and the charging device. Convenient and easy charging of the smartphone is made possible by the charging station's use of magnetic induction. This method uses electromagnetic fields to help the energy transfer between coils placed in the receiving device and the charging station. Close to the charging station, the device's coils oscillate at the same frequency. An electrical current is therefore generated and sent through the receiver coil, so replenishing the device's battery. Offering consumers an easy and practical way to charge their gadgets without the need for cables or plugs is the aim of wireless bypass charging. By enhancing device portability, convenience, and efficiency in the powering process, this invention has the potential to completely transform a number of industries, including consumer electronics, healthcare, and automotive.

Keywords: Wireless charging; Magnetic induction; Transmitter; Receiver; Coils; Inductive Power Transfer (IPT).

1. Introduction

Electric vehicle (EV) production and sales have increased significantly in recent years in many European nations (the compound annual growth rate in Norway and the Netherlands, for example, is over 100%) [1]. This trend is mostly the result of the EU Air Quality Directive of 2008's strict CO_2 footprint limitations, which internal combustion vehicles are unable to meet. These regulations cover not just light cars but also trucks and buses, which are significant producers of particulate matter (PM) and nitrogen oxide pollution in urban areas. In the near future, the widespread usage of EVs will significantly reduce pollution in large cities, but for the time being, prospective customers are seriously concerned about the limited number of battery charging stations and range anxiety [2]. By resolving major issues and improving the user experience in multiple ways, wireless charging contributes significantly to the electrification of automobiles. Electric car drivers may charge their EVs more conveniently thanks to wireless charging, which does away with the need for physical connections like plugs and cords [3]. All users have to do is park their cars over a wireless charging pad, and the charging process will start on its own without any human input. In addition to being included into the car itself, wireless charging technology can also be found in public charging stations, garages, and parking lots. By facilitating a smooth charging experience for EV owners, this integration encourages the general use of electric vehicles [4]. Range anxiety, a common concern among potential electric vehicle buyers, can be alleviated by the ease and convenience of wireless charging. Wireless charging technology accelerates the transition to eco-friendly transportation by incentivizing a greater number of individuals to transition to electric vehicles through the provision of convenient and effortless charging alternatives [5]. Here are the key findings from the research. To optimize the charging efficiency, assess the energy transfer efficiency of wireless charging systems by considering factors such as alignment, distance, and power loss

Mediterranean Journal of Basic and Applied Sciences (MJBAS)
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[6]. Analyze user perspectives, behaviors, and viewpoints regarding wireless charging technology in the context of vehicle electrification, aiming to identify obstacles to its adoption and strategies to promote its acceptance. Conduct a comprehensive techno-economic evaluation of wireless charging alternatives for electric vehicles, considering the benefits, drawbacks, and financial returns of each option compared to conventional charging infrastructure. Design innovative algorithms and control schemes to enhance the reliability and efficiency of wireless charging systems, resulting in faster charging times and improved user satisfaction.

2. Literature Survey

The discussion regarding wireless charging systems for electric vehicles (EVs) covers a wide range of factors, including user convenience, charging efficiency, and economic feasibility [7]. This paper critically analyzes the existing literature to identify gaps in our understanding of wireless charging technology for electric vehicles (EVs). Due to the growing need for convenient electric vehicle (EV) charging options, wireless charging technology has become a promising solution. Early studies primarily concentrated on improving inductive charging systems, which involve the transfer of energy through electromagnetic fields between a charging pad and the receiver coil of a vehicle. Nevertheless, researchers were motivated to investigate alternative methods due to limitations such as reduced efficiency compared to wired charging, vulnerability to misalignment, and limited charging range [8].

As a response, investigations focused on techniques such as resonant inductive coupling and magnetic resonance coupling. Resonant inductive coupling requires the use of resonators in both the transmitter and receiver coils that operate at the same frequencies. This is necessary in order to achieve efficient charging over long distances. Additionally, magnetic resonance coupling enables more accurate alignment of the coil, thereby decreasing the need for precise positioning of the vehicle [9]. Progress in materials science has significantly contributed to the improvement of wireless charging systems, enabling them to have longer distances and higher effectiveness. Using magnetic materials with high permeability in charging pads and receiver coils reduces power losses and maximizes energy transfer [10]. The success of EV wireless charging systems relies on the paramount importance of efficient and rapid energy transfer. A comprehensive investigation has been conducted to analyze the various factors that affect the efficiency of charging, such as environmental conditions, coil alignment, and the distance between the transmitter and receiver coils [11]. Coils must be perfectly aligned to achieve optimal performance. Any misalignment will lead to higher power loss and decreased efficiency. Adaptive charging systems have been developed to address this problem by automatically adjusting the positions of coils to achieve optimal alignment. The close proximity between the transmitter and receiver coils has a significant impact on the efficiency of charging [12]. Magnetic resonance coupling allows for increased versatility in the positioning of coils, thereby streamlining the transmission of energy over long distances. However, achieving optimal effectiveness over long charging distances continues to be a difficult task, requiring additional investigation. The importance of user perceptions regarding wireless charging cannot be overstated, as they are influenced by factors such as simplicity, reliability, and cost-effectiveness. Research suggests that electric vehicle (EV) owners have a strong inclination towards wireless charging because it eliminates the inconvenience of cable connections [13].

Mediterranean Journal of Basic and Applied Sciences (MJBAS)
Volume 8, Issue 2, Pages 80-90, April-June 2024

Strategically positioning wireless charging stations in areas with heavy foot traffic could promote widespread acceptance. Nevertheless, apprehensions regarding dependability and security may impede approval, emphasizing the necessity for thorough testing and certification [14]. Although the initial investment in wireless charging infrastructure may be higher, the convenience it offers surpasses the difference in cost, as indicated by studies [15]. The combination of smart grids and renewable energy sources presents opportunities for generating revenue, but additional research is necessary to evaluate the profitability and scalability of these opportunities. Recent progress in resonant inductive and magnetic resonance coupling has effectively resolved numerous issues associated with wireless charging, rendering it a highly promising substitute for traditional approaches [16]. The level of its adoption will depend on factors such as reliability, user acceptance, and economic feasibility, highlighting the significance of ongoing research and innovation. Wireless charging systems possess the capability to expedite the shift towards environmentally friendly transportation, thereby diminishing dependence on fossil fuels.

3. Proposed System

By putting together a few parts and making a smart block diagram, you can use a Darrieus wind turbine to charge an electric vehicle (EV) without a wired connection. Here is a block diagram that has been cut down. The Darrieus Wind Turbine is the main source of power. It has blades that are arranged vertically and turn when the wind blows, making mechanical energy. The mechanical energy from wind turbines is turned into electricity by a generator. This is alternating current (AC), which is a type of electricity. While the generator's AC output needs to be changed to direct current (DC) for the rectifier to work, the EV battery can be charged. A rectifier is used to make this change. It's possible that the rectifier doesn't give off the right voltage for the EV battery.

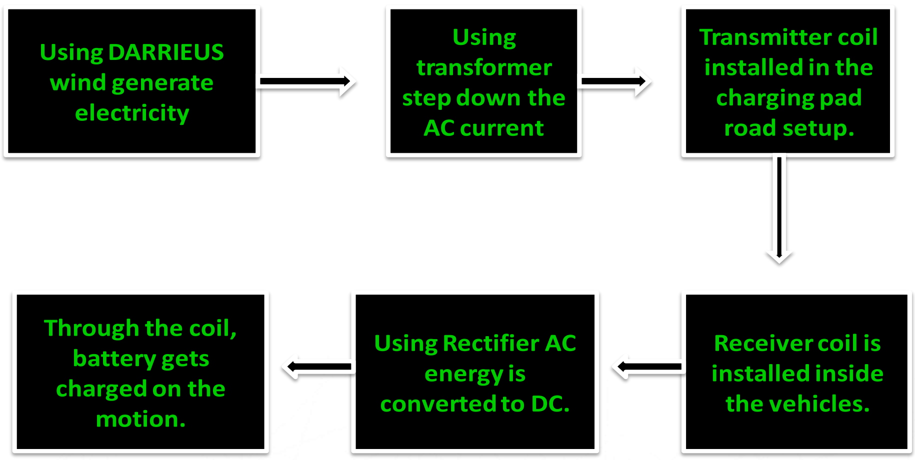

Figure 1. Block diagram

The voltage is regulated to the appropriate level for battery charging by means of a DC/DC converter. In turn, the DC output of the DC/DC converter is utilized to power the wireless charging system. This system is comprised of a transmitter coil positioned on the charging station and a receiver coil situated on the electric vehicle. When the coils are appropriately aligned, electromagnetic induction is employed to transmit energy wirelessly from the charging station to the electric vehicle. The charging process is monitored and regulated by the Battery Management System (BMS) to ensure that the battery is charged securely and efficiently. It regulates current, voltage, and temperature, among other variables. The battery pack of the electric vehicle is responsible for storing the necessary energy to drive the vehicle. After receiving the wireless energy transmitted from the charging station, it retains it for subsequent use. The responsibility for overseeing the entire charging process lies with a control system. It regulates the electric vehicle's communication with the charging station, verifies that the coils are properly oriented for efficient charging, and monitors the charge status. User interface-based information is provided regarding the charging status, including battery level, charging rate, and estimated time to full charge. It may include screens, smartphone applications, or indicators.

3.1. Darrieus Wind Turbine

The Darrieus wind turbine is one type of vertical axis wind turbine (VAWT) that generates electricity using wind energy. The turbine consists of numerous curved aerofoil blades mounted on a rotating shaft or framework. The straining effect of a blade's curvature is limited to extremely high rotation speeds while in tension. There are several models of straight blade wind turbines that are essentially identical. Typically, a Darrieus turbine comprises a vertical axis onto which are affixed a number of airfoil blades. A helical or eggbeater-like arrangement of these blades encircles the central axis. The Darrieus turbine harvests wind energy through the utilization of lift generated by revolving airfoil blades. In contrast to Darrieus turbines, which function along a vertical axis, horizontal-axis wind turbines (HAWTs) rotate along a horizontal axis. They can now capture wind from any direction by transforming into the wind without requiring a yaw device. At the turbine's central vertical axis, a minimum of two airfoil blades are positioned [2]. Typically, these blades are curved in order to generate lift as the wind passes over them. The turbine rotates due to the lift force. Frequently, the blades are organized in the shape of an eggbeater or an elongated helix, arranged helical around the central axis. This design enhances the rotational balance and efficiency of the turbine.

In order to ensure the secure installation of the vertical axis and blades of Darrieus turbines, a sturdy support structure is necessary. Design and dimensions of the turbine may have an effect on the support structure. Transmission and Generator System: Darrieus turbines, akin to alternative wind turbines, employ a generator to transform the rotational energy into electrical energy. A transmission system is also present to facilitate the transfer of power produced by the turbine to either the grid or a storage system. Safety Functions: Frequently, overspeed prevention devices are installed on Darrieus turbines to safeguard against damage in the event of high wind conditions.

3.1.1. Efficiency of Darrieus

Vertical-axis wind turbines include the Darrieus wind turbine. It was invented by French engineer Georges Darrieus. However, horizontal-axis wind turbines (HAWTs) have propeller-like blades. However, Darrieus turbines have vertically spinning blades. Cons and pros affect how well this unique design works and does its job. A major benefit of Darrieus wind turbines is their ability to use wind from any direction. Because of this, they work well in cities and other rough places with multidirectional wind. Vertical turbines allow for easier maintenance and installation because they can be placed closer to the ground.

Mediterranean Journal of Basic and Applied Sciences (MJBAS)
Volume 8, Issue 2, Pages 80-90, April-June 2024

Several factors affect the Darrieus turbine's efficiency, which is crucial to wind turbine design. Aerodynamic blade design is crucial. Like airplane wings, Darrieus turbines have airfoil blades to maximize lift and minimize drag. This design makes wind kinetic energy easier to convert to rotational energy. Aspect ratio, or blade length to chord, also affects efficiency. Most blades with a higher aspect ratio generate more lift and less drag, improving efficiency. To get the best aspect ratio, you must choose between performance and structural integrity. Turbine performance also depends on speed. Due to their faster tips and smaller size, Darrieus turbines usually spin faster than HAWTs. Faster speeds allow the turbine to harness more wind power, improving efficiency. However, noise and vibration are difficult to control. The turbine's location and surroundings affect efficiency. Darrieus turbines thrive in open spaces with consistent wind flow. Turbulence from buildings, trees, and other obstructions reduces turbine efficiency. Wind speed and direction can also affect Darrieus turbine performance. They catch wind from all directions because they are omnidirectional. They may not work as well as HAWTs in light or rough conditions.

Despite these issues, Darrieus wind turbines are becoming more efficient through research and technology. Blade design, materials, and control system innovators want to improve performance and reduce costs. Axial ratio, rotational speed, weather, new technologies, and blade design can affect Darrieus wind turbine performance. Their pros include less maintenance and the ability to catch wind from any direction, but their cons include aerodynamic, structural, and environmental issues. If more research and ideas are developed, Darrieus turbines could help switch to renewable energy and make the future more sustainable. If more research and ideas are developed, Darrieus turbines could help switch to renewable energy and make the future more sustainable.

3.2. Methods of Operation

Darrieus wind turbines operate on several principles. Airfoil blades of the Darrieus turbine initially receive wind. These blades lift in wind due to their shape. The turbine spins from lift. Airfoil blades spin around the turbine's vertical axis due to lift. Blades turn even when wind direction changes due to their helical shape. Energy conversion, Turbine spins generator via shaft. Generators generate electricity from turbine rotation. This electricity powers homes, businesses, and other electrical systems. Control Systems: Darrieus turbines have safety and efficiency controls. Devices may start the turbine in low wind, systems may change blade pitch to maximize energy output, and brakes may slow the turbine in high wind. Putting Grids Together, a power grid receives Darrieus turbine electricity via power lines or other transmission systems. Therefore, electricity can be sent and used anywhere.

3.3. Usage of Transformer

Transformer simulations with identical primary and secondary windings produce similar voltage and current levels. Transformer primary and secondary sides vary in voltage and current. Voltage and current are easily multiplied or divided in AC circuits. Through wire resistance, the transformer reduces power loss along power lines connecting power plants to loads, enabling long-distance electricity transmission. This is done by "stepping up" AC voltage and "stepping down" current. Transformers lower generator and load voltage. This operation is safer and cheaper. Step-up transformers have more secondary than primary turns. P2S voltage is increased. Step-down transformers reverse.

3.4. Transmitter coil setup

Wireless charging sometimes fails without cables. A permanent wall outlet is needed for the charging station. However, your phone charges wirelessly. Start with the charging pad. An alternating current through the charging pad coil creates an electromagnetic field. Phones charge the receiver coil via electromagnetic fields. As mentioned, inductive charging occurs when a metal object nearby changes its electromagnetic field, creating an electric current. Smartphone analog circuitry stabilizes fast-changing currents. Phone batteries are charged by this electricity. Most people use medical, industrial, and automotive wireless charging coils. The tech increases portability and lets small IoT devices charge a few feet away. 5G wireless, consumer electronics, data centers, and phones use wireless charging. Wireless phone charging is convenient because you don't need an outlet or cable. Charging at home or on the go is easier. Wireless charging requires a receiver coil. Power transfer and device compatibility depend on its design and construction. Copper wire is tightly wound around a ferrite core to make it. When AC is applied, this design helps the coil create an electromagnetic field. Coil alternating current creates a magnetic field that oscillates. This initiates electromagnetic induction.

Base stations and charging pads have transmitter coils. It emits a magnetic field the receiver coil must detect. The receiver coil receives an alternating current from electromagnetic induction when the magnetic field changes. After managing this alternating current, the device's battery charges wirelessly. There are many factors that affect receiver coil performance and design. First, the coil is made to fit inside the device and pick up as much magnetic field as possible. Power efficiency and impedance matching can change with wind gauge and number. Receiver coil cores are ferrite or magnetic. This makes the coil magnetic and concentrates magnetic flux. Concentrating magnetic flux improves electromagnetic induction and energy loss, improving power transfer. Rectifiers and capacitors can improve receiver coils and meet charging standards. These parts filter induced current, stabilize voltage, and convert alternating current to direct current to charge the battery. Smartphones, tablets, smart watches, and wireless ear buds have receivers. Because they're small and flexible, they can fit into the device's architecture without altering its function or appearance. Wireless charging is being improved to connect more devices, send power more efficiently, and charge farther. Receivers coils are crucial to these improvements because they connect the device to the charging pad and move power without cables. Wireless charging systems use receiver coils to charge electronics quickly. These coils use electromagnetic induction to charge the device's battery from the charging pad's magnetic field.

3.5. Working of Rectifier on Wireless Charging

Wireless charging systems require rectifiers to convert alternating current (AC) induced in the receiver coil to direct current (DC) to charge the device's battery. Wireless charging relies on rectifiers to transfer power and comply with many charging protocols. Wireless chargers use rectifiers to convert the receiver coil's alternating current into a unidirectional current to charge the battery. This AC-to-DC conversion is needed because most electronics need DC power to charge their batteries. Wireless charging systems typically use diode-based rectifiers, though they can be configured in many ways. Diodes allow current to flow in one direction but block it in the other. Wireless charging uses full-wave rectifiers or bridge rectifiers with diodes. This configuration uses the

AC waveform in both directions, improving conversion. AC current causes positive and negative cycle alternation in the receiver coil. The rectifier circuit blocks AC waveform negative cycles and allows positive cycles. Thus, the rectifier's output is a unidirectional pulsing DC waveform that capacitors smooth to stabilize DC voltage. The rectifier circuit's efficiency directly affects power transfer efficiency in wireless charging systems. High-efficiency rectifiers reduce energy losses during conversion, sending more power to the device's battery with less heat. Wireless charging system rectifiers must be efficient, have low forward voltage drop, quick response times, and high reverse voltage ratings to survive AC power transmission voltage spikes. Rectifiers ensure wireless charging protocol interoperability. PMA and Air Fuel Alliance define communication protocols, device compatibility, and power transmission. Wireless charging receiver rectifiers follow these specifications, so devices from different manufacturers can charge smoothly on compatible charging pads. Rectifiers may include temperature detection, reverse polarity protection, and overvoltage protection to improve charging safety and reliability. These protections prevent overheating, polarity reversal, and voltage spikes from damaging the device and charging system. As wireless charging technology advances, rectifiers will enable faster charging rates, longer transmission distances, and more device compatibility. Manufacturers are constantly developing more reliable and efficient rectifiers for wireless charging applications.

To charge the device's battery, wireless charging systems use rectifiers to convert AC sent through the receiver coil to DC. To efficiently transfer power and follow many charging protocols, wireless charging uses rectifiers. Wireless charging requires a rectifier to convert the receiver coil's alternating current into one-way current for battery charging. This switch from AC to DC is needed because most electronics charge batteries quickly with DC power. Most wireless chargers use diode rectifiers. Semiconductor diodes allow current in one direction only. Wireless charging uses diode bridge or full-wave rectifiers. AC waveform is used both ways. This boosts conversion. Receiver coil charge cycles are positive and negative with AC current [6]. Since the rectifier circuit blocks AC waveform negative cycles, only positive cycles pass. Thus, the rectifier produces a one-way pulsing DC waveform. Further capacitor smoothing stabilizes DC voltage. Wireless charging power transfer depends on rectifier circuit efficiency. High-efficiency rectifiers send more power to the battery without heat. Low forward voltage drop, fast response, and high reverse voltage are needed for wireless charging rectifiers. They handle AC power's frequent voltage spikes. Rectifiers support multiple wireless charging protocols. PMA and Air Fuel Alliance oversee power, communication, and device compatibility. Wireless charging receiver rectifiers follow these rules to charge devices from different brands on compatible pads. Rectifiers with temperature detection, reverse polarity protection, and overvoltage protection make charging safer and more reliable. These safety features prevent device and charging system overheating, polarity reversal, and voltage spikes. Rectifiers will be essential as wireless charging technology adds chargers and speeds up. To extend rectifiers, especially wireless charging ones, companies are constantly improving them.

4. Methodology

Inductive Power Transfer (IPT) technology fundamentally transforms wireless charging by allowing devices to be powered without the need for physical connections, resulting in a seamless and efficient charging experience.

Through the application of magnetic induction, Inductive Power Transfer (IPT) enables the wireless transmission of electrical power from a charging station to a receiving device. This cutting-edge technology has the capacity to improve charging experiences in terms of portability, convenience, and efficiency. These advancements will have substantial ramifications for various sectors, including healthcare, automotive, and consumer electronics. The IPT technology consists of two crucial elements: transmitter coils located in the charging station and a receiver coil integrated into the charging device. When the device is placed near the charging station, the electromagnetic fields generated by the transmitter coils cause current to flow in the receiver coil. Consequently, the battery is now fully charged. Users can now enjoy a streamlined charging experience, without the hassle of dealing with cords and plugs.

IPT technology offers significant advantages in terms of adaptability and scalability. Charging stations can be installed in residential buildings, commercial establishments, public spaces, and even infrastructure elements like parking lots and roads. Wireless charging has been widely adopted in various devices, including smartphones, electric vehicles (EVs), laptops, and medical equipment, due to its versatile nature. The automotive industry holds substantial potential for the implementation of IPT technology specifically in the domain of electric vehicle charging. Inductive Power Transfer (IPT) allows for convenient and efficient charging of electric vehicles without the use of traditional charging cables or connectors. This is achieved by integrating charging pads or lanes, which contain transmitter coils and receiver coils, into the vehicles. Implementing this approach leads to decreased costs on infrastructure, improved aesthetics of charging stations, and a more efficient charging process for electric vehicle drivers. The utilization of IPT technology facilitates the adoption of sustainable energy sources for the purpose of wireless charging, thereby providing an additional advantage in terms of environmental conservation. By integrating IPT systems with sustainable energy sources like solar or wind power, charging stations can function independently or help stabilize the power grid. This environmentally sustainable approach supports efforts to address climate change and decrease carbon emissions.

5. Results and Discussion

The charging control system of an electric vehicle handles various parts that allow for the smooth wireless bypass charging process. It connects easily to the charging infrastructure, the car's built-in systems, and clean energy sources like wind turbines to make charging smooth and good for the environment. Communication protocols are used by the control system to connect the electric vehicle (EV) to the charging station. This system's job is to make it easier to send data so that charging parameters can be tracked, compatibility can be checked, and charging activities can be coordinated. For charging to work well, the transmitter coil in the charging station needs to be lined up perfectly with the receiver coil in the electric vehicle (EV).

The control system uses algorithms to improve coil alignment, which increases the efficiency of energy transfer and shortens the time needed for charging. Controlling the flow of power correctly while wireless charging is important for safety and efficiency. The charging infrastructure's power output is controlled by the control system, which makes changes based on the battery's level of charge, charging rate limits, and grid conditions. When the control system talks to the EV's Battery Management System (BMS), it can check on the battery's health, temperature, and charging status. It makes sure that the charging parameters stay within safe limits, which keeps the battery from being overcharged, overheated, or damaged. Charging scheduling algorithms are used by the control system to decide which charges to make first based on user preferences, energy prices, and grid conditions. It makes charging times more efficient so that costs related to electricity use are kept to a minimum, the highest level of energy demand is lowered, and the power grid is kept stable.

Electric vehicle owners can get up-to-date information on the status of their charging, as well as scheduling options and information on how much energy they are using, through an easy-to-use interface. It makes remote monitoring and control easier, so users can easily keep an eye on and manage charging sessions through mobile apps or dashboards in their cars.

6. Conclusion

Wireless power transfer technology could be made better by using Darrieus wind turbines for wireless bypass charging. The Darrieus wind turbines and magnetic induction is used in this new way to make clean energy. It has a longer range for wireless charging. In this final section, we'll look at the main pros, cons, and future possibilities of the technology. It is great that devices can be charged wirelessly with Darrieus turbines that use clean, renewable energy.

Darrieus wind turbines work well in areas with lots of people because their axis is vertical. Because of this, they work well for adding wireless charging infrastructure to systems that are already in place. By using wind energy, this technology makes us less dependent on fossil fuels and lessens the damage that charging methods do to the environment. The Darrieus wind turbines are more durable and use less energy because they have wireless power transfer systems. Because these turbines can make electricity even when there isn't much wind, charging stations always have power. Because they are modular, they can be expanded to add more charging stations to meet the growing demand for wireless charging.

A lot of research has shown that Darrieus wind turbines can send power wirelessly. Researchers came up with, built, and improved Darrieus turbine wireless charging systems. Some people have tried to make Darrieus turbines better by changing how they are built and how they work. This is done to make wireless power transfer systems better. Many things, like blade geometry, rotational speed, and system configuration, have been looked into to find the best ways to transfer power.

Declarations

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Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

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