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WIRELESS POWER TRANSFER SYSTEM FOR POULTRY FARM

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Abstract

Poultry farming plays a crucial role in global food security. However, traditional power supply methods for poultry farms pose challenges such as environmental pollution, safety risks, and limitations in remote areas. To address these issues, a wireless power transfer system is proposed for poultry farms. This system eliminates the need for cumbersome and potentially hazardous wired connections, replacing them with wireless technology. By harnessing electromagnetic fields, power can be transmitted from a specific source to various devices and equipment throughout the farm. This enhances safety by reducing the risk of accidents caused by exposed wires and increases efficiency by eliminating the need for manual power distribution. The wireless power transfer system also offers greater flexibility in farm layout and expansion, particularly beneficial in remote or rural areas with limited access to conventional power sources.Adoption of wireless power transfer systems in poultry farms can significantly improve productivity, cost-effectiveness, reduce environmental impact, and enhance overall safety. This technology holds the potential to revolutionize poultry farming practices, allowing farmers to overcome the limitations of traditional power distribution methods and ushering in a more sustainable and efficient future for the poultry industry.

Keywords: Wireless power, Poultry, Safety, Agriculture, Efficiency

Introduction

Wireless power transfer offers a convenient solution for charging devices remotely and without physical contacts. Recent advancements in research and development have significantly expanded the capabilities, variety, and maturity of wireless power transfer solutions. This survey provides a comprehensive overview of the state-of-the-art in various technological concepts, including electromagnetic coupled and uncoupled systems, as well as acoustic technologies [1]. It covers solutions for transferring power ranging from milliwatts to megawatts, over distances ranging from millimeters to kilometers, and utilizing wave concepts from kilohertz to terahertz frequencies. Wireless power transfer presents an attractive charging option for existing applications while also opening up new opportunities. Various technologies are proposed for providing wireless power to devices, with challenges mainly revolving around efficiency and transfer range. Innovative approaches such as beamforming and UV-assisted methods are highlighted [2]. Designers will find valuable insights into implementation and operational aspects, standards, and safety regulations. Additionally, a high-level catalog of potential applications is provided, mapping them to suitable technological options for wireless power transfer.

The Near-Field Transmission

Electric power is traditionally transmitted from a source, such as a generator or a battery, to a load through the application of an electric potential differential over a conductor. The use of cables and wires to establish this connection has long been the preferred method, enabling the flow of electrons [3]. However, as technology advances, electronic devices become increasingly compact and mobile. Relying solely on cables attached to power outlets becomes impractical for these devices. Moreover, wired connections can restrict mobility and pose security risks if damaged [4].

To address these challenges, research has focused on converting electrical energy into other forms that can be transmitted through specific mediums without the need for conductive wires. Wireless transmission of energy, exemplified by the use of radio waves to transmit sound, video, and data, has become increasingly prominent. In a radio station, for instance, a voltage signal representing information is generated and converted into an electromagnetic energy pulse [5]. This pulse is then broadcast into the atmosphere, where it propagates in all directions. An antenna detects the electromagnetic energy signal, which is subsequently converted back into an electrical voltage signal to retrieve the information.

Depending on the distance between the transmitter and receiver, energy can also be converted and transmitted wirelessly. Electromagnetic waves are generated in the surrounding medium by various electromagnetic field sources, such as point particles, dipoles, antennas, or coils. These waves exhibit distinct properties based on the characteristics of the fields and their association with the medium through which they travel [7]. Typically, these fields are categorized into two types: the near-field and far-field, determined by their proximity to the source and the dominant characteristics of the waves in these regions.

Capacitive Power Transfer

The earliest methods of electromagnetic coupling, dating back to Tesla's discoveries in the 1900s[7], involved capacitive coupling, enabling the use of the electric field for power transfer in the near-field. However, a significant drawback was the presence of high voltage between the transmitter and receiver, posing the risk of electric shock. This was primarily due to the experimental setup relying on electric arcs.

In this setup, the transmitter and receiver of the power transfer system were represented by two electrodes on a capacitor, with air serving as the dielectric medium between them. During each voltage pulse, the output voltage would rise to a level where ionization of the air surrounding the high voltage terminal occurred, leading to phenomena such as corona, brush discharges, and streamer arcs emerging from the terminal. This phenomenon arises when the electric field strength exceeds the dielectric strength of air, typically around 30kV per centimeter. Due to the concentration of the electric field at sharp points and edges on the high voltage terminal, air discharges tend to initiate from these locations [8].

An electric arc discharge is characterized by visible light emission, high current density, and high temperature. The voltage on the high voltage terminal is limited by air breakdown voltage, asany excess electric charge injected into the terminal from the secondary winding simply dissipates into the air. While air breakdown limits the output voltage of open-air Tesla coils to a few million volts, coils submerged in pressurized tanks of insulating oil can achieve higher voltages [9, 10].

To address the safety concerns associated with electric arcs, Capacitive Power Transfer (CPT) systems utilize two parallel plates (forming a capacitor) positioned very close to each other. The transmitter is connected to one of the plates on each capacitor, ensuring safe operation and mitigating the risk of electric arcs.

Inductive Power Transfer

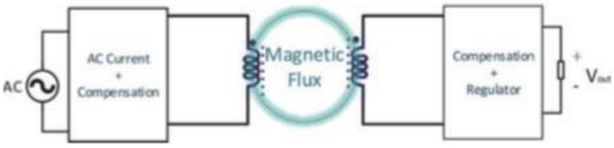
Utilizing a magnetic field for power transfer offers the safety advantage of avoiding high voltages and minimal interaction with most biological materials. Consequently, the magnetic field is widely employed in modern near-field Wireless Power Transfer (WPT) studies and finds applications across various domains [11].

A non-radiative magnetic field is generated by passing alternating current (AC) through a coil, known as the transmitter, as depicted in the figure. When a load circuit is positioned within the reactive area, an electromotive force (EMF) is induced in a second coil, referred to as the receiver [12]. This allows electrical power to be transferred from the transmitter's coil to the receiver's coil.

The interaction between the transmitting and receiving coils is characterized by mutual inductance. Mutual inductance (M) between two coils, Tx and Rx, is illustrated in the figure, where alternating current flows through the transmitter coil, Tx, inducing current in the coupled receiver coil, Rx. The current flowing in the transmitter coil generates a magnetic field, which passes through the receiver coil, resulting in mutual inductance. When the inductances of the two coils are equal (LT = LR), the mutual inductance equals the value of one single coil, considering both coils have the same value.

The coupling coefficient (k) quantifies the degree of inductive coupling, ranging from 0 to 1, where 0 denotes zero or no inductive coupling, and 1 signifies full or maximum inductive coupling. As one coil induces a voltage in an adjacent coil, the transmitter coil (LT) induces a voltage (vin) in the receiver, and vice versa [13].

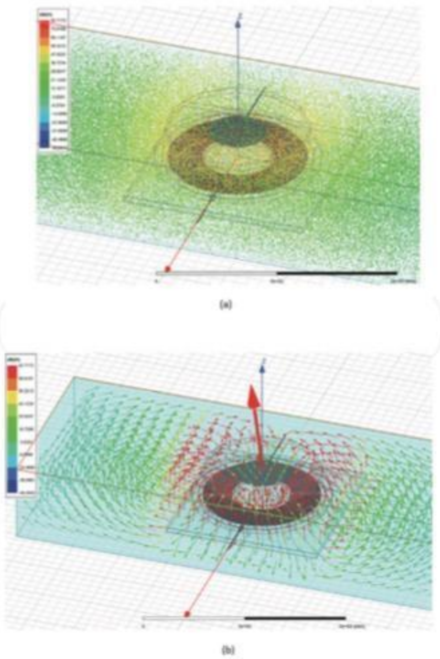
The power transmitted through magnetic fields is determined by the efficiency of the system, with power loss in the components being typically neglected.



Resonance Technique

Resonance is a widely adopted technique in near-field magnetic coupling, significantly extending the potential of near-field Wireless Power Transfer (WPT). By connecting a capacitor to the coils, an LC resonant tank is formed. This creates an impedance transformation network at the oscillation frequency (f0), minimizing the source impedance (VA) and maximizing power transfer to the load. Both the transmitter and receiver circuitry are tuned to resonate at the same frequency, with LT and LR representing the coils, and CT and CR denoting the capacitors of the transmitter and receiver, respectively. Achieving high device efficiency involves designing detailed transmitter and receiver coils, although efficiency decreases as the distance between the transmitter and receiver increases [14].

Overall, the throughput power of Wireless Power Transfer (both Inductive Power Transfer and Capacitive Power Transfer) exhibits a linear decrease (for a logarithmic scale) with increasing frequency. This limitation is primarily determined by power electronics constraints rather than coupling characteristics, affecting both IPT and CPT equally. As frequency increases, power output becomes limited by losses, a phenomenon observed in both IPT and CPT applications. Over the past decade, average power has increased by tenfold alongside a tenfold increase in frequency. This is attributed partly to the development of wide bandgap devices and the optimization of coupling structures to minimize losses. It is anticipated that the empirical limitation of power-frequency will continue to rise over time, akin to a "Moore’s Law" trend or variant for WPT. Additionally, there are typical differences in development between Capacitive Power Transfer and Inductive Power Transfer.



MOSFET Rectifiers

The limitations of diodes can be surpassed by employing MOSFET technology. One of the primary advantages of MOSFETs is their rapid switching speed. MOSFETs are utilized in Dickson charge pumps to integrate them into integrated circuits, as depicted in the figure. This design boasts relatively low threshold voltages and high Power Conversion Efficiencies (PCEs) [15].

Additionally, the differential drive voltage multiplier, as illustrated in the figure, is widely favored due to its low leakage current and potential for customization in specific applications. The sensitivity and efficiency of a voltage multiplier are closely tied to the number of stages it comprises. Increasing the number of stages leads to higher losses per stage, yet facilitates greater voltage multiplication and a smaller threshold voltage at the first stage. Conversely, a voltage multiplier with fewer stages experiences less voltage drop between stages but requires higher threshold voltages for all stages to function concurrently [16]. Thus, the optimal number of stages should be carefully determined based on implementation objectives.

However, MOSFET-based circuits suffer from voltage losses across the devices, resulting in reduced efficiency. This issue is exacerbated by reverse leakage current. Furthermore, as frequency rises, efficiency diminishes due to increased power losses from reverse leakage current in MOSFETs.

Conclusion:

In conclusion, wireless power transfer techniques have garnered significant research attentionand are increasingly prevalent in consumer electronics and electric vehicles. While near-field and far-field transmission methods offer alternatives, this paper provides an overview of various wireless power transfer concepts. The investigation of receiver blocks is further explored by examining the characteristics of rectifier technologies.

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