

# Study of Wireless Transfer of Energy from a Higher Source of Energy Machine to a Low Energy Machine

**Bharatbhai Pravinbhai Navadiya**  
Electrical Engineer, Svtronics Inc.  
bharatnavadiya96@gmail.com

## Abstract

The wireless energy transfer (WET), which is a promising technology that enables devices to power themselves without the need for a physical connection, has been identified as a potential game-changing innovation. This paper explores the various aspects of this technology and its origins, tracing its origins back to Nikola Tesla's pioneering work. This article explores the various types of WET transmission methods, such as inductive, RF, beamforming, and magnetic resonance. Through a comprehensive analysis of these techniques, we can identify their limitations and strengths and guide our selection based on the specific requirements of our applications. This concluding research work covers the present and upcoming developments of WET, emphasizing its crucial role in fostering a more sustainable and connected energy sector.

**Keywords:** Wireless, Energy Transfer, Inductive, RF, and Sustainable Energy.

## I. Introduction

The development of wireless energy transfer (WET), which eliminates the need for physical connectors, is poised to transform how devices are powered. It can be used in various sectors, such as industrial machinery and consumer electronics [1]. Nikola Tesla's pioneering work during the 19th and 20th centuries paved the way for wireless transmission of energy. He envisioned a future in which power could be transferred over long distances and utilized without wires. Through his experiments, Tesla was able to demonstrate the feasibility of wireless energy transmission [2].

Despite its promise, the practical implementation of wireless energy transfer has been hampered by various factors. For instance, due to the development of advanced materials, such as insulators and conductors, it has become more efficient. On the other hand, advancements in power electronics have allowed it to convert electrical power at varying distances [3].

Due to the emergence of new communication technologies, the interest in wireless energy transfer has been revived. Some of these include the use of signal processing and modulation techniques, which are designed to improve its safety and reliability. These innovations can help ensure that

the power is delivered securely and efficiently to the intended devices [4].

The practical applications of wireless energy transfer have been widely adopted in various sectors. For instance, in consumer electronics, charging pads for mobile devices have become widely available. These pads eliminate the need for physical connectors and offer a convenient and comfortable alternative to traditional batteries [5]. Medical devices, such as neurostimulators and pacemakers, can also benefit from this technology as it eliminates the need for invasive surgery. In industrial settings, wireless energy transfer is being widely used to improve the efficiency and automation of various processes. For instance, it can be used to power robotic systems and automated vehicles, which are commonly used in warehouses and factories. In addition, the ability to charge electric cars through dynamic wireless charging is expected to revolutionize the transportation industry [6].

The wireless energy transfer market is expected to grow significantly during the next few years due to the technological advancements that will allow it to improve its efficiency and safety. Some of these innovations include the development of new standards and methods for the transmission of power over long distances [7].

The potential of wireless energy transfer to transform the way electrical power is harnessed is immense. Its origin can be traced back to Nikola Tesla's pioneering work, which has led to numerous technological advancements and inspired a new era of energy efficiency and connectivity.

## **II. Principles of Wireless Energy Transfer**

In wireless energy transfer, electrical power is transferred through space using electromagnetic fields. There are various techniques for this [8].

- One of the most common methods is the use of an electromagnetic induction technique, which involves generating a magnetic field in a primary conductor. This leads to a voltage being generated in a secondary conductor. This principle is commonly used in wireless charging pads.
- An alternative method is the use of a resonant inductive coupling. This involves using a pair of resonant circuits in a receiver and transmitter. The improved efficiency of this method can be achieved by tuning the frequencies of the two circuits.
- An electric power transmission using radio frequency waves is known as RF transmission. This method is commonly used in wireless sensors and devices that are powered by RF waves.

## **III. Methods to implement Wireless Energy Transfer**

Wireless energy transfer is a process that involves various techniques and methods tailored to specific needs. This list serves as a sampling of the many common approaches used in this area.

### **1. Inductive Coupling**

An inductive coupling process involves transferring energy between two coils which are connected magnetically.

Magnetic coupling can be improved by designing coils with the appropriate materials and geometries. The selection of the operating frequency is also important to improve the efficiency of the energy transfer process. The distance between the receiver and transmitter coils is also controlled to maintain a successful connection.

Devices such as electric toothbrushes and smartphones are commonly used with wireless charging pads.

### **2. Resonant Inductive Coupling**

The principle of resonant inductive coupling is to improve the efficiency of energy transfer by utilizing the resonance between the receiver and transmitter coils.

To maximize the energy transfer, a resonant circuit design is used. It involves designing the receiver and transmitter circuits at the same frequency. The process of frequency matching involves ensuring that the tuning of the receiver and transmitter components is precise. The alignment tolerance helps maintain the efficiency of the energy transfer while allowing for spatial variations between the coils.

This type of design is commonly used in applications such as medical implants and wireless charging electric cars.

### **3. Radio Frequency (RF) Transmission**

Wireless power is transferred using radio waves. This principle is referred to as RF transmission.

A good antenna design can help transmit and receive energy efficiently. Various modulation techniques can be used to encode and decode the energy transfer signals sent by wireless power. For long distances, power amplifiers can be used to boost the transmission power.

These power amplifiers are ideal for applications that require high power transfer distances, such as industrial automation equipment and sensors.

### **4. Magnetic Resonance Coupling**

A magnetic resonance coupling is a type of energy transfer that uses magnetic fields to move the energy between two coils [9].

A resonant coil design is used to create a magnetic resonance coupling that's optimized for energy transfer. Precise alignment of the coils and the use of magnetic materials can enhance the efficiency of the magnetic resonance coupling. Besides shielding the components, safety features such as the use of protective equipment can also help prevent electromagnetic interference.

Applications of magnetic resonance coupling include those that require high efficiency, such as in wireless power transfer.

5. Beamforming and Directed Energy

The beamforming technique concentrates energy in a specific direction using phased array antennas and other directional methods [10].

The phased array antenna is used to direct energy beams toward receivers. Advanced signal processing techniques are utilized to optimize the energy delivery and beamforming process [11]. Dynamic beam steering allows the control of the energy beams' direction to track the movement of the receiver [12].

The technology can be used in various applications such as wireless power delivery and precise energy transfers.

Implementation Considerations

- The process of efficiency optimization involves selecting the appropriate materials, designing circuits, and optimizing operational frequencies and energy transfer rates.
- Follow safety regulations and standards when it comes to the exposure of people and electromagnetic emissions.
- The ability to design systems that can handle various power levels is a crucial aspect of scalability.
- Interoperability involves ensuring that devices and standards are compatible with one another.

Researchers and engineers can make use of these techniques and methods to develop wireless energy transfer systems that can be tailored to specific applications. This will allow them to improve the efficiency of energy distribution networks. The table below compares the disadvantages and advantages of different WET methods [13]-[15].

Table 1. Comparison of the disadvantages and advantages of different WET methods.

| Method                          | Principle                                        | Efficiency        | Range                           | Power Capacity   | Safety                                 | Applications                                                 |
|---------------------------------|--------------------------------------------------|-------------------|---------------------------------|------------------|----------------------------------------|--------------------------------------------------------------|
| Inductive Coupling              | Magnetic field between two closely coupled coils | Moderate (60-80%) | Short (up to a few cm)          | Low to moderate  | Safe with controlled proximity         | Consumer electronics (smartphones, toothbrushes)             |
| RF Transmission                 | Electromagnetic waves in the RF spectrum         | Low (10-40%)      | Long (meters to kilometers)     | Low              | Safety concerns with high power        | RF-powered sensors, low-power devices, industrial automation |
| Magnetic Resonance Coupling     | Magnetic fields with resonant coils              | High (80-90%)     | Medium (up to several meters)   | Moderate to high | Generally safe with shielding          | Home/office power transfer, larger devices                   |
| Beamforming and Directed Energy | Focused energy transmission using phased arrays  | Moderate (40-70%) | Long (meters to tens of meters) | High             | Safety concerns with high energy beams | Industrial automation, telecommunications, moving objects    |

The efficiency of a device that transmits energy is measured to determine how much of it is used and received. Magnetic resonance and inductive coupling are more efficient than RF when it comes to energy transmission.

The range refers to the distance that energy can be transferred. Compared to inductive methods, beamforming and RF techniques transmit energy at longer distances.

The power capacity of a device that can be transferred is referred to as its maximum power. With the use of inductive coupling, it can be used for low power levels, while beamforming handles higher capacities.

The safety of a device and its surroundings is a major concern when it comes to energy transmission. Most commonly, the use of inductive methods is safer than those using RF and beamforming.

### **Technologies and Implementations**

In the medical field, WET is commonly used to power wearable devices and implants. For instance, it can be used to power insulin pumps and pacemakers, which can be operated wirelessly. This type of technology usually utilizes resonant inductive coupling [16].

In industrial settings, wireless energy transfer is becoming more prevalent. For instance, it can be used to power robots and automated vehicles, which eliminates the need for a manual connection. It can also be used in hazardous locations due to the safety hazards associated with traditional wires [17].

One of the most common applications of WET is wireless power for consumer electronics [18]. Most of the time, devices, such as smartphones and tablets, use either resonant or inductive charging. Different standards have been developed to make sure that these products work seamlessly with each other and manufacturers [19], [20].

### **IV. Challenges and Future Directions**

Despite the advantages of WET, there are still many challenges that need to be overcome to make it more practical.

- High efficiency over long distances can be challenging, especially for applications that require a lot of power transfer.
- It is important to ensure that the safety of wireless devices, especially those used in consumer and medical applications, is maintained. This includes handling electromagnetic interference and thermal effects.
- The lack of a universal standard for WET technologies can prevent the widespread use of such innovations. Adopting and developing industry-standards is crucial for fostering consumer trust and interoperability.
- Advancements in power electronics and materials are needed to enable scaling up WET systems to support large-scale electric vehicle charging.

### **Future Directions**

The WET is on track to realize a promising future, with ongoing efforts aimed at overcoming challenges that currently exist.

- New developments in materials science could result in better compact and efficient WET systems, which can transfer more power.
- Integrating the WET with storage and energy harvesting could lead to the development of devices that require only a minimal amount of power.
- The development of smart grids could involve the use of WET for wireless transmission of energy between consumers and various sources.
- In addition to space applications, wireless energy transfer can also be used to power various devices, such as satellites and space stations. This eliminates the need for traditional power sources, such as solar panels.

### **V. Conclusion**

The use of wireless energy transfer (WET) is a revolutionary technology that enables us to power and charge our devices without the need for a physical connection. This paper explores the various techniques and methods that are used in this process, such as beamforming, RF transmission, and inductive coupling. The limitations and advantages of each technique make them ideal for different applications.

While it is limited in both power and range, an inductive coupling solution is an ideal choice for low-power electronic devices. Its resonant nature can extend the operational range and improve efficiency, making it an ideal choice for medical implants and electric vehicle charging. Although RF transmission is widely used for industrial automation and sensors, it faces issues related to safety and efficiency. Magnetic resonance coupling, on the other hand, has a moderate range and high efficiency. This type of solution is ideal for transferring power at home. Direct and beamforming energy methods offer promising prospects for high-power applications, though they require careful consideration of safety precautions. An analysis of the different energy transfer techniques revealed that none of them is superior. The solutions depend on certain requirements, such as efficiency, power capacity, safety, and range. The advancements in communication, electronics, and materials science have contributed to the growth of this technology.

Research and development in the field of wireless energy transfer is expected to lead to innovations in the system's safety, scalability, and efficiency. Widespread adoption will also be supported by the need for interoperability and standardization. This technology can help improve the efficiency and distribution of energy in various sectors.

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