

Technique of Wireless Charging and Its Selected Applications

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Abstract. Wireless charging is a means of transferring power without physical connection to an electrical device for recharging. The fast advancement in wireless charging and the associated applications have presented a new interesting technique for energy replenishment. Traditionally, charging is done through wired ways. This has disadvantages such as the need for a physical connection, leading to restricted movement and the wear and tear on charging cables as frequent plugging and unplugging of cables. different devices requiring various cable types. These limitations have driven the adoption of wireless charging, offering greater convenience and freedom by eliminating the need for physical cables and enhancing charging flexibility. Recently, new advancement has emerged in the area. The article will cover the fundamentals of wireless charging, including its three different working principles and its applications in mobile device and electronic vehicles. This work demonstrates that the wireless charging method is a powerful technology that is beneficial to the human being.

Keywords: Wireless charging; Inductive charging; Mobile device; Electronic vehicles.

1. Introduction

In an era where electronic devices have become everywhere in people's daily lives, the need for efficient and convenient charging has grown. Conventional wired charging methods, although effective, are often inconvenient with the tangled cords and the wear down of charging ports. As a solution, wireless charging technology has emerged, providing a convenient and wire-free way to convey electrical energy [1].

The history of wireless charging is long. Nikola Tesla, known for his work in alternating current electricity, conducted a groundbreaking experiment in 1899 related to wireless power transmission. One significant milestone is to transfer 108 volts of high-frequency electric power to light 200 bulbs and launch an electric motor 25 miles away [2]. In 1901, Tesla went on to construct the Wardenclyffe Tower (see Fig. 1), hoping to transmit electrical energy globally without the need for physical cords and with the help of the ionosphere [3]. However, due to the technological constraints at the time, this concept was dropped. It wasn't until the 1920s and 1930s that magnetrons were introduced, allowing electricity to be converted into microwaves [4]. This breakthrough paved the way for wireless power transmission over long distances. Wireless charging, also called inductive charging or cordless charging, enables the transfer of electrical energy between a transmitter and a receiver without the need for direct physical connections such as wires. The technology comes in three different techniques, which will be discussed in the article later.

This paper has introduced the basics of wireless charging. Then the working principles of wireless charging will be discussed. Next, the paper will present applications of wireless charging in mobile device and electronic vehicles.

2. Wireless Charging Technique

There are three different techniques used for wireless charging. The power in the near field weakens significantly as the distance increases. On the other hand, the technique of microwave radiation covers larger distances, operating in the far field. Additionally, when utilizing the far-field technique, the transmitter remains uninfluenced by the absorption of radiation. In contrast, the near-field techniques are influenced by the load on the transmitter due to radiation absorption.

2.1. Magnetic Inductive Coupling

Magnetic inductive coupling is based on the principle of inducing a magnetic field to transfer electrical energy from one coil to another. This takes place typically within a range smaller than the wavelength. As a result of this near-field power, voltage and current are induced across the secondary coil which receives energy. This induced voltage can then be used to power a compatible appliance. The efficiency of this energy transfer is related to the distance between the two coils and other factors, such as alignment, distance, diameter ratio, and coil shape [5].

Magnetic inductive coupling boasts several advantages, including straightforward implementation, user-friendly operation, high efficiency at short distances (typically within the span of a coil's diameter), and safety considerations. Because of these attributes, it finds practical applications and popularity in a range of mobile devices. Researchers at MIT have recently achieved a remarkable breakthrough with their wireless charging technology known as MagMIMO [6]. This innovation enables wireless charging of devices from distances of up to 30 cm. Furthermore, they said that MagMIMO has the ability to detect and direct a concentrated energy beam towards a device, even if it's tucked away in a pocket.

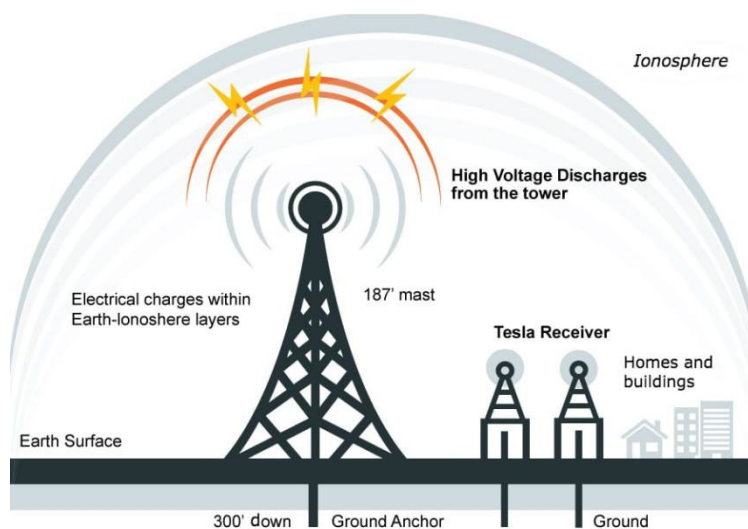


Fig. 1 Graphical representation of Wardenlyffe Tower [3].

2.2. Magnetic Resonance Coupling

Magnetic resonance coupling operates on the idea of evanescent-wave coupling. This method enables the generation and transferring electrical energy from one resonant coil to another by utilizing oscillating or fluctuating magnetic fields. These coils work under the same frequencies, so they are tightly interconnected, ensuring efficient energy transfer with minimal loss to non-resonant external components. This characteristic also confers the benefit of resistance to environmental factors and a lack of line-of-sight constraints. Magnetic resonance charging has the advantage of extending the effective charging distance comparing to magnetic inductive charging [7]. Moreover, magnetic resonance coupling can establish a connection between a single conveying resonator and multiple accepting resonators, enabling simultaneous charging for numerous devices, leading to higher efficiency altogether. Nevertheless, the coupling of coils can come up with interference concerns, necessitating careful tuning to address these issues effectively.

In 2007, MIT researchers introduced a highly efficient mid-range wireless power transmitter called Witricity, which is developed based on the concept of strongly coupled magnetic resonance. It was documented that this method could light a 60W light bulb from distances over 2 meters, achieving an efficiency of about 40%. The efficiency level rises to around 90% when the distance is shortened to 1 meter. However, due to the need for a distributed capacitive coil, it remains a challenge to shrink the size of Witricity, making it difficult to integrate into portable devices [8].

2.3. Microwave Radiation

Microwave radiation uses microwaves as a means of transmitting energy. Microwaves travel through space at the speed of light. The power trans process begins with alternating current to direct current conversion, followed by a direct current to radio frequency conversion using a magnetron on the transmitting side. Once transmitted through the air, the microwaves captured by the receiver's rectenna are transferred back into electric power. Usually, devices with energy-harvesting capabilities can either collect microwave radiation from specific sources or from the nearby surroundings. The average frequency range for microwaves spans from 300 MHz to 300 GHz. While other EM waves such as infrared and X-rays can be used for energy transfer, safety concerns have limited their widespread usage [9].

Microwave energy can be emitted in all directions (isotropically) or focused through beamforming, depending on the application. Isotropic radiation is ideal for broadcast scenarios. For one-on-one communication, beamforming involves directing EM waves in a focused manner, known as power beamforming, this technique enhances the efficiency of power transmission. A focused beam can be created through the utilization of an antenna array. The precision of power beamforming shows a positive correlation with the amounts of transmit antennas, and large antenna arrays can further enhance this precision.

Microwave radiation not only facilitates longer transmission distances but is also fitted together with now-existing communication systems. Microwaves can be used to carry both energy and information. Information is conveyed through the amplitude and phase modulation of microwaves, while the energy is carried by the radiation and vibration of these waves.

3. Applications

3.1. Small Devices

The most common form of wireless charging in mobile devices is inductive charging. This method uses electromagnetic coils in both the charging pad (or dock) and the device to establish a magnetic field in between. When the device is positioned on the charging pad, this magnetic field induces an electrical current within the device's coil, subsequently converted into direct current power to replenish the battery. An important milestone occurred in September 2012, with the release of the Nokia 920, the first commercially available smartphone to feature built-in wireless charging capabilities, with the Qi specification.

3.2. Qi Charging Standard

The Qi charging standard is a widely adopted wireless charging standard for electronic devices, particularly for smartphones and other portable gadgets. Qi is developed and maintained by the Wireless Power Consortium (WPC), a group of companies that collaborate to establish and promote common wireless charging standards. To use Qi wireless charging, the device must have a Qi-compatible receiver, often integrated into the device or added as an accessory. Qi is designed to be an open standard, which means that devices from various manufacturers that support the Qi standard can charge on Qi-compatible charging pads. This interoperability has contributed to its widespread adoption. Qi supports different power levels for charging, including 5W, 7.5W, 10W, and higher, depending on the capabilities of the charger and the device being charged. Higher power levels allow for faster charging. Qi chargers often include safety features like foreign object detection, which prevents charging if a non-compatible object is placed on the charging pad, reducing the risk of accidents or damage. Qi wireless charging is commonly found in smartphones, smartwatches, wireless earbuds, and other consumer electronics. The technology continues to evolve, with advancements in efficiency, speed, and convenience. Qi is one of the most recognized and widely used wireless charging standards in the market.

3.3. Vehicles

Comparing to gasoline engine vehicles, electronic vehicles (EV) need longer refueling times, demand specific charging connectors, and have fewer available charging stations. There are mainly two wireless charging for EV (see Fig. 2), which are the static and dynamic wireless charging [10]. Static charging offers several advantages, like the removal of the risk of electrical shocks associated with traditional wired charging methods and the flexibility to be built in favorable locations such as residential garages and parking lots. The dynamic wireless charging system consistently charges the EV as it travels along designated charging lanes on the road.

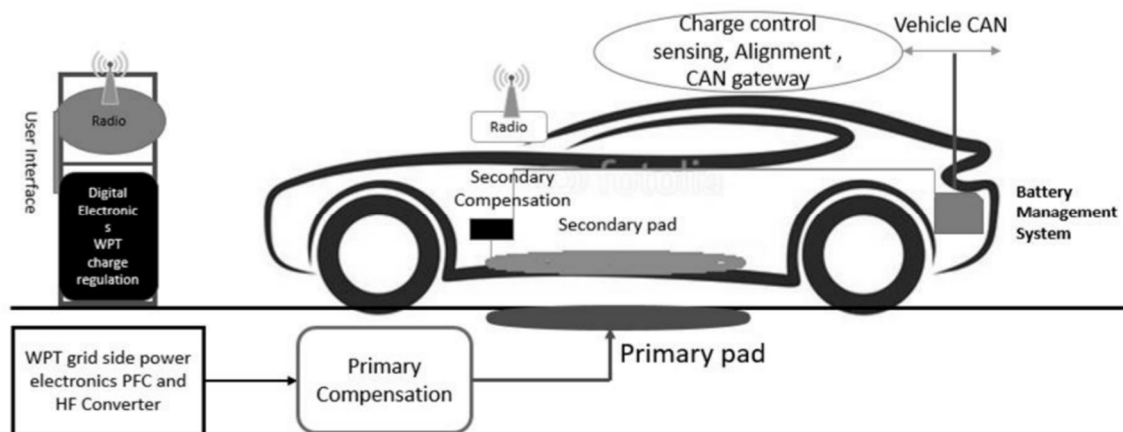


Fig. 2 Static wireless charging deployment with automatic control system [10]

4. Conclusion

In conclusion, wireless charging technology has emerged as a convenient and efficient solution to the growing need for powering electronic devices in people’s daily lives. This article provided an overview of the fundamentals of wireless charging and explored the three primary methods used: magnetic inductive coupling, magnetic resonance coupling, and microwave radiation. Each technique presents different benefits and obstacles, rendering them well-suited to diverse applications. Magnetic inductive coupling, with its simplicity and user-friendliness, has found widespread use in mobile devices. Recent innovations have pushed the boundaries of this technology, enabling wireless charging from greater distances. Magnetic resonance coupling, on the other hand, extends the effective charging distance and allows for simultaneous charging of multiple devices. Witricity technology demonstrated remarkable efficiency at mid-range distances, although challenges remain in integrating it into portable devices. Microwave radiation, while offering the advantage of compatibility with existing communication systems, faces regulatory constraints due to health concerns. Nevertheless, it holds promise for certain applications, particularly in delivering energy and transferring information simultaneously. Furthermore, the article discussed the applications of wireless charging, including its usage in mobile devices and its potential to revolutionize the charging experience for electric vehicles. Wireless charging offers efficiency and convenience comparable to traditional plug-based charging methods. As wireless charging technology continues to involve, it plays a crucial role in reducing the reliance on conventional wired charging methods, contributing to a more convenient and environmentally sustainable future. With ongoing research and development, people can expect further innovations and improvements in wireless charging efficiency, safety, and usability across various sectors of daily lives.

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