ISSN: 2710-0588 DOI: 10.29556/FSE.202109_1(6).0014

Wireless Power Transfer System and Its Application

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Abstract

The Wireless power transfer (WPT) technology has been used in a large number of practical applications, such as electric vehicles, implantable medical devices, portable electronics and Internet of Things. In general, the transmission distance is restricted and the power transfer efficiency (PTE) is limited in the WPT system. The main reason is that the coupling efficiency between the resonators drops sharply when the coil-to-coil distance increases. In addition, when the WPT systems deliver energy, the electromagnetic (EM) noise is unavoidably generated and harmful to electrical products, even to the human beings. Therefore, some actions should be taken into account to reduce the EM radiation without affecting system performance in the WPT charging devices.

Keywords

WPT System; Charging Devices; Electric Vehicles.

1. Introduction

The Wireless power transfer (WPT) is a promising charging method [1-3] without physical contact for the electronic products energy supply. However, low transfer efficiency, short transmission distance, as well as the electromagnetic (EM) leakage are commonly main bottlenecks of the WPT technology in the practical applications.

In recent years, the dynamic research of electric vehicle magnetic coupling resonant radio energy transmission [4-6] has attracted the attention of scholars at home and abroad. Improving the transmission efficiency and output power of electric vehicle has always been the research goal of dynamic wireless charging technology. However, due to the lack of physical connection and the offset between the transmitter and receiver of the coupling structure in the charging process, the transmission efficiency of electric vehicle dynamic wireless charging system is not high.

With the rapid development of science and technology and the continuous improvement of people's living standards, cars have become an indispensable means of transportation (as shown in Fig. 1), which has also led to the over exploitation of global oil and caused global environmental pollution such as air, water and soil. Therefore, it is necessary to replace oil with a new environmental energy to reduce environmental pollution. With the research and exploration of radio energy transmission technology by scientists at home and abroad, the charging mode of electric vehicles has changed from wired charging to wireless charging. Wireless charging [7-12] is divided into static wireless charging and dynamic wireless power transfer (DWPT). Wired charging has been widely used in real life. Static wireless charging sets charging piles at specific points and uses the principle of electromagnetic induction coupling to charge electric vehicles.

The principle of dynamic wireless charging is consistent with that of static wireless charging. The difference is that the dynamic wireless charging technology can enable the electric vehicle to charge the on-board battery while driving. Compared with wired charging and static wireless

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charging, it increases the mileage of the electric vehicle and improves the operation efficiency of the electric vehicle. In real life applications, due to the problems of poor offset resistance, insufficient battery capacity and inconvenient charging, electric vehicles have short mileage and low operation efficiency, which makes electric vehicles not widely popularized in life.

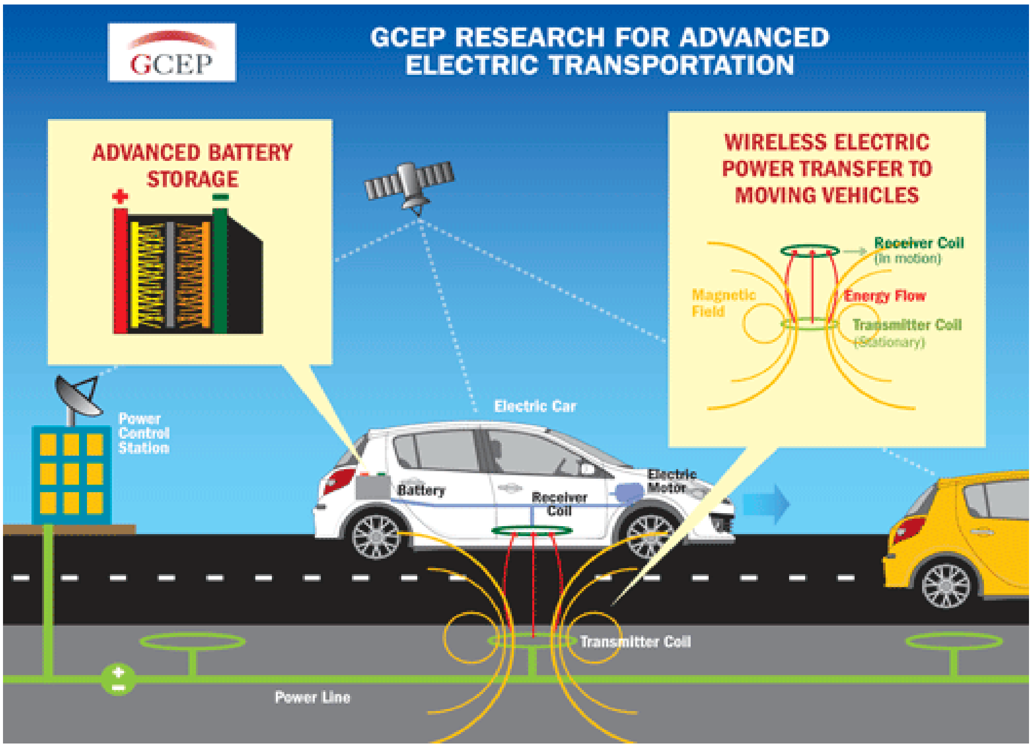

Fig. 1 Illustration of wireless electric power transfer to moving vehicle

2. Wireless power transfer applications

The cost of laying underground coils for dynamic wireless charging of electric vehicles is equivalent to that of charging piles, and the dynamic wireless charging method reduces the capacity of on-board batteries, not only reduces the environmental pollution caused by batteries, but also has lower cost and higher safety than the static wireless charging method.

Although the dynamic wireless charging mode of electric vehicles [13-15] realizes charging while running, there are still many technical problems that limit the popularity of dynamic wireless charging in life. The main problems are as follows:

(1) The transmission efficiency is unstable. Due to the frequent replacement of the transmitter during the charging process, the coupling coefficient changes continuously, resulting in unstable output power, affecting the service life of the on-board battery and wasting resources. In addition, the magnetic field radiation causes a lot of energy loss. Even in the resonant state, it will also cause a lot of energy loss due to the conversion circuits such as inverter circuit, rectifier circuit and high-frequency converter, so that the transmission efficiency is not high.

(2) Electromagnetic environment problem, ensuring the electromagnetic environment safety of WPT technology is a focus of research in recent years. A certain electromagnetic radiation dose will not only cause varying degrees of interference to electronic products, but also cause certain harm to human body.

(3) The cost is high and the anti-offset characteristic is poor. The transmitting coil required for vehicle dynamic wireless charging must be equipped with corresponding detection device, which makes the cost high.

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The working principle of electric field coupled radio energy transmission is that power frequency alternating current provides high-frequency alternating current for the transmitting end through rectification and inversion, forms capacitive coupling between metal plates, and supplies power to the load in a non-contact form. In the process of energy transmission, electric field coupling has low transmission efficiency and short transmission distance. It is mainly suitable for the field of micro electric transmission of low-power electric energy transmission.

The working principle of microwave radio energy transmission is that the RF power amplifier transmits electric energy in the form of microwave, and then the electromagnetic wave collected by the antenna is converted into electric energy for load use. Microwave transmission can realize ultra-long distance transmission, but it is not suitable for high-power transmission because of its low transmission efficiency, unstable output power, low safety factor and high control accuracy. It is generally used in the field of micro electric transmission of space station.

Magnetic coupling resonance radio energy transmission adopts near-field resonance transmission mode. When the self-excited oscillation frequency of transmitting coil and receiving coil is equal to the natural frequency of resonance network, space magnetic field is used for energy efficient transmission. Magnetic coupling resonant radio energy transmission has the advantages of short transmission distance, safe electromagnetic environment, relatively simple design process and strong transmission direction, but it also has high requirements for the quality factor and frequency characteristics of the coil. At present, although magnetic coupling resonance wireless charging has achieved some results, there are still many technical problems to be solved. Therefore, this charging method has not been widely popularized in real life, but it has high transmission efficiency and output power, and short transmission distance, which makes it a research hotspot in recent years, as in Fig. 2.

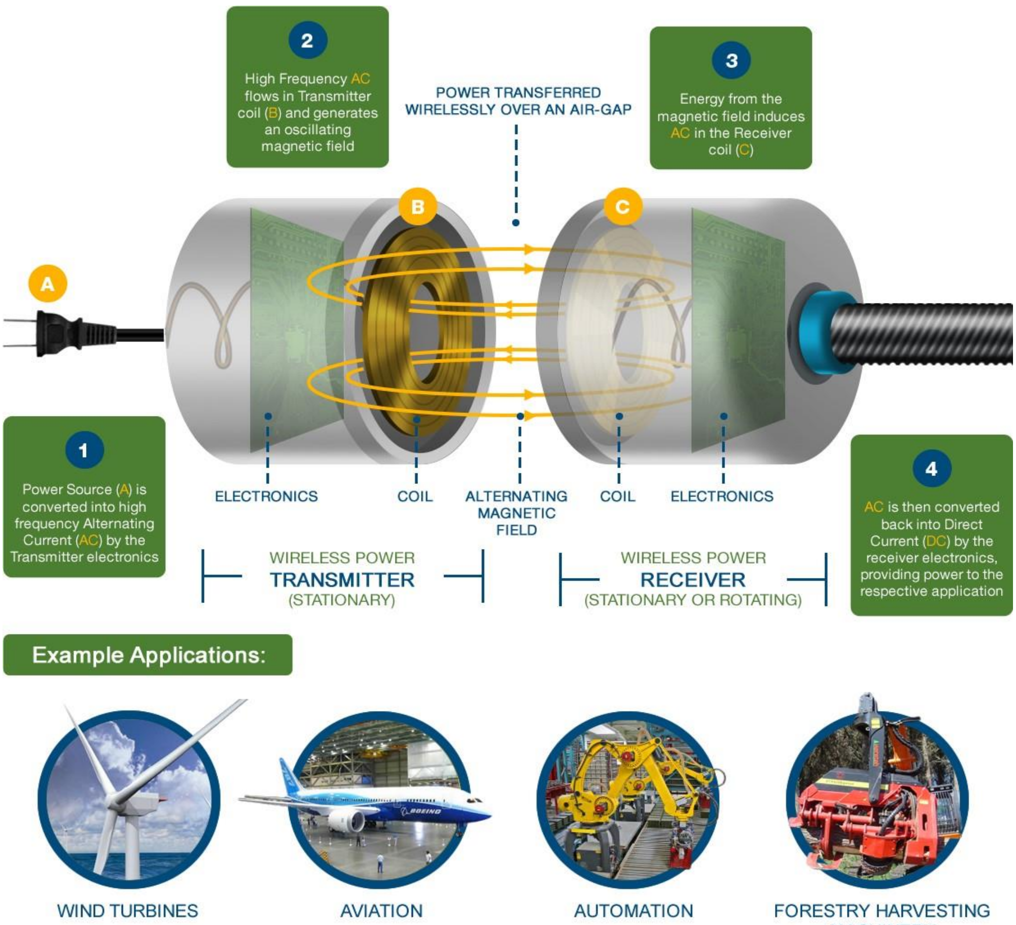

Fig. 2 Illustration for WPT system and its various applications

ISSN: 2710-0588 DOI: 10.29556/FSE.202109_1(6).0014

Several applications of wireless power transfer are apparent and obvious. Firstly, WPT could eliminate traditional charging systems in place today. Instead of plugging in a mobile phone or laptop via power cord to charge the battery, wireless power can be harnessed and implemented in a home such that a laptop and phone charge continuously and wirelessly without the need for plugging anything in. Higher level applications include charging of electric vehicles (EVs). As EVs become more and more prevalent on the roads, the feasibility of driving such a vehicle can be maximized via stationary, and even mobile, WPT systems. Future and theoretical applications include a potential solution to renewable energy for the planet, by means of satellites collecting sunlight and sending power back to earth through MPT.

2.1. Electronic devices

Cell phones, laptops, tablets, even smart watches are found all over the globe and are owned and used by billions of people. What these devices all have in common is the need to recharge their internal battery so that the device can be used while mobile, shown in Fig. 3. Such is the paradox of portable devices: they provide convenience by running off internal power so they can be used anywhere, but always must return to be tethered to a power cord in order to charge.

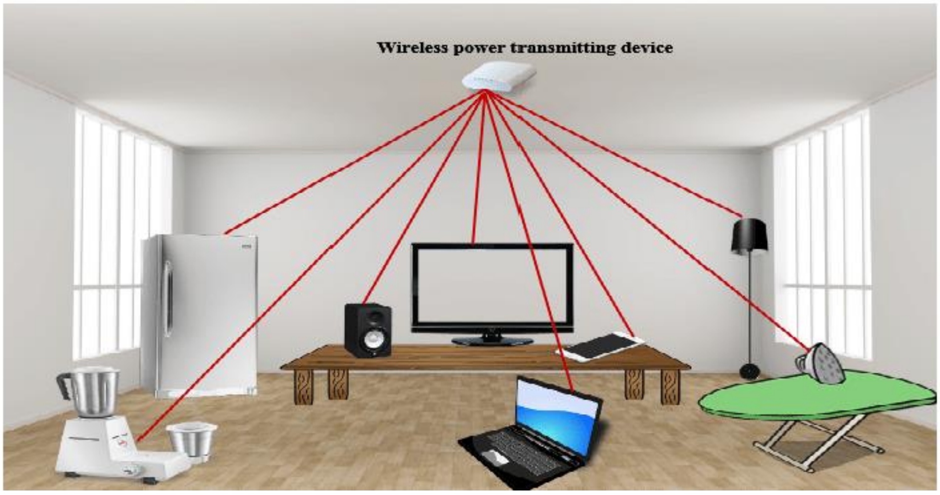

Fig. 3 Wireless power transmitting devices within WPT system

WPT has the potential to disrupt and revolutionize the traditional portable device, not only by making mobile devices more convenient by eliminating the need for a physical power supply, but also safer (power cords carry risk of shock and can cause fires), as well as a reduced cost for consumers. Research has even been done into multi-hop WPT systems, wherein a generator transmits power wirelessly to targets, which can then in turn become sources for other targets, and transfer power wirelessly to those targets. Thus, a network of WPT can be created to support several devices.

2.2. Electric Vehicles

As concern over global warming and greenhouse gas emissions grows across the globe, the prevalence of electric vehicles has also increased. One of the drawbacks of electric vehicles is their battery. Electric vehicles currently need to be plugged in to recharge their internal batteries, and take many hours to do so. However, many envision that in the near future, one need only park her car in a pre-determined spot in her driveway and the car will charge wirelessly and automatically. Thus a great deal of research has been done into WPT, specifically through the MPT mechanism, and how it can be used for the charging of electric vehicles.

The transmitter emits 10kW power through microwaves at 2.45 GHz, and the rectenna converts those microwaves with an efficiency of greater than 80%, yielding more than 7kW to the electric

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vehicle. Accounting for other losses through the charging of the system, the battery is able to receive more than 5kW power. The figure depicts a practical application of MPT. Importantly, the MPT system depicted has a high density with respect to the forming of the beam, and since the beam is highly focused, thus it does not create a large area of microwave radiation which could potentially be unsafe for human exposure.

2.3. Aerial Vehicles and Solar Power Satellites

While portable device and vehicle charging are applications that could be implemented in the near future, some other theoretical applications have been posited for further research and development.

One such application is the Stationary High Altitude Relay Platform (SHARP). The SHARP system consists of an unmanned airplane that flies at an altitude of approximately 13 miles above the earth, constantly circling the earth in a 2 kilometer diameter. The SHARP airplane would then be used as a communications relay. Here, the SHARP airplane has a large rectenna behind the wings, allowing for power to be transmitted to it from the earth, and thus is able to stay in the air for long periods of time, potentially months.

Another exciting and future application of MPT is that of the Solar Power Satellites (SPS) system. Carbon dioxide (CO2) emissions from burning fossil fuels have become a point of great concern with respect to global warming. Additionally, fossil fuels are a nonrenewable energy source, and by some estimates fossil fuels could be completely consumed in 100 to 150 years.

Thus the need for clean, safe, and abundant renewable energy has been a topic of much debate and recent study. Current renewable energy systems have many drawbacks; solar cells are constrained by the weather, most significantly by cloud cover and lack of sunlight during the night. Wind turbines are contingent upon weather as well, and do not function when no wind is present. Nuclear power plants produce toxic waste and have the potential to cause great disasters in the event of a nuclear meltdown.

The SPS, on the other hand is a different system entirely, with the collection of solar power unconstrained by environmental factors. In the SPS system, a satellite is fixed in a geostationary orbit above the earth. This satellite collects solar energy and, using the MPT mechanism, beams the energy back down to the earth via microwaves where it is received and converted to power at a rectenna of a size of approximately 2 km2 and then transfers that energy to existing power grids.

A satellite above the earth is superior to ground based solar power harvesting because it is unaffected by the weather and is unconstrained by lack of sunlight during night hours, and thus can collect solar energy continuously. Even after accounting for loss during conversion of power to and from microwaves, the SPS system is still able to deliver more power than ground based solar panels. For example, solar radiation has been measured on the ground in Tokyo, Japan as approximately 140 W/m2, whereas a satellite in space can collect solar energy that is measured as 1400 W/m2.

The SHARP and SPS systems are both practical implementations of WPT via the MPT mechanism. Indeed, both systems are simply MPT systems, just scaled to a larger size. They consist of a microwave generator that converts power to microwaves and sends those microwaves to a target rectenna that converts the microwaves back to DC power to be used by the target system.

3. Limitations, safety concerns and recent progress

MPT is defined as the transfer of power through space by means of microwaves. In particular, a MPT system converts direct current (DC) power to microwaves, transmits that microwave radiation to a target, and the target converts the microwave radiation back to DC power.

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First the microwaves are generated by the microwave generator. This radiation then passes through the Coax-Waveguide Adapted, which in turn passes through the waveguide circulator, a device that reduces the radiation to exposure from outside power. Finally the radiation passes through the tuner and directional coupler device, which separates the signal according to signal propagation direction. The radiation is then transmitted over the air through antennae, where it is received by the antenna at the rectenna, at which the microwave radiation passes through a low pass filter, then a matching network, then a rectifier as it is converted to DC power.

As exciting and potentially beneficial as MPT can be, there are many potential drawbacks that need to be mentioned and considered. Indeed, the aim has been to demonstrate the numerous benefits of applications of MPT systems. However, MPT has some drawbacks and limitations and even potential risks associated with it. Thus, alternate methods for WPT have been proposed and researched. While the central focus of this study has been on WPT by means of MPT, these alternate methods are discussed briefly for completeness as part of the overview of WPT.

3.1. Limitations and drawbacks of MPT

MPT hinges upon microwaves being transmitted through the media of open space from source to target. While efficiency of conversion of power to and from microwaves has been discussed above, one of the variables of transfer through the use of microwaves is the media through which it travels. Thus, the ability to efficiently transfer microwaves through open space is dependent on whether or not a clear line of sight exists between source and target. Factors such as weather and physical objects can obstruct the line of sight between source and target and can inhibit the transfer of power via microwave. Additionally, as discussed in the case study of the charging of the electric vehicle above, beamforming and focusing the microwave radiation is vitally important for an efficient WPT system. It follows, therefore, that the transfer of power from a source to a moving object, especially at longer distances, would be extremely difficult to do so with a highly directional antenna, and would be inefficient to the point of impracticality with an omnidirectional antenna.

3.2. Safety Concerns

One of the major limitations of MPT, and WPT in general, is the concern of its safety, especially with respect to human exposure to microwave radiation. Indeed, the transference of microwave radiation through free space is a major design consideration in MPT systems. In the charging of the EV example given above, a great deal of effort was made to ensure that the magnetic beam formed by the system was concentrated on the antenna, thus creating a guard area outside of which the power level was low enough for human exposure. The precision with which an MPT system must be implemented, therefore, is extremely important. This limits the use of an MPT system of high energy to very controlled environments, making difficult its use in the power transfer to moving vehicles.

4. Conclusions

The transfer of power from source to receiver is a technology that has existed for over a century. Wireless power transfer (WPT) has been made feasible in recent years due to advances in technology and better implementations of transfer techniques, such as Microwave Power Transfer (MPT). The MPT system works by converting power to microwaves through a microwave generator and then transmitting that power through free space where it is received, and converted back to power at a special device called a rectenna. The applications of MPT are numerous, not only to change the way existing technologies work, but also as theoretical constructs for future constructs. While the benefits are great, there are many limitations and drawbacks of MPT, necessitating the discussion of possible alternative methods for WPT. The

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transfer of power wirelessly has the potential to completely disrupt and revolutionize existing and future technologies. WPT is an extremely useful technology that has numerous applications and benefits. Cell phones, laptops and other mobile devices could function without ever having to be plugged in, cars could drive on highways burning no fossil fuels; wireless power even has the potential to solve much of the renewable energy issues we face.

References

[1] El-Shahat, A., et al., Electric Vehicles Wireless Power Transfer State-of-The-Art. Energy Procedia, 2019. 162: p. 24-37.

[2] Guo, Z.-H. and S.-E. Dong, Receiver power allocation and transmitter power control analysis for multiple-receiver wireless power transfer systems. Journal of Electronic Science and Technology, 2019. 17(4): p. 100009.

[3] Zhang, B., et al., Challenges of future high power wireless power transfer for light-duty electric vehicles----technology and risk management. eTransportation, 2019. 2: p. 100012.

[4] Jawad, A.M., et al., Wireless Power Transfer With Magnetic Resonator Coupling and Sleep/Active Strategy for a Drone Charging Station in Smart Agriculture. Ieee Access, 2019. 7: p. 139839-139851.

[5] Li, J., et al., Optimization Method of Magnetic Coupling Resonant Wireless Power Transfer System with Single Relay Coil. Progress in Electromagnetics Research M, 2019. 80: p. 57-70.

[6] Zhang, Q., et al., Optimal Resonant Beam Charging for Electronic Vehicles in Internet of Intelligent Vehicles. Ieee Internet of Things Journal, 2019. 6(1): p. 6-14.

[7] Alwesabi, Y., et al., Electric bus scheduling under single depot dynamic wireless charging infrastructure planning. Energy, 2020. 213.

[8] Hu, Q., et al., Space-correlation-based joint data transmission and on-demand charging for rechargeable wireless sensor networks. Iet Communications, 2021. 15(4): p. 546-557.

[9] Liu, L., et al., Charging equaliser based on wireless power transfer for electric scooters. Iet Renewable Power Generation, 2020. 14(18): p. 3662-3667.

[10] Manshadi, S.D. and M.E. Khodayar, Strategic Behavior of In-Motion Wireless Charging Aggregators in the Electricity and Transportation Networks. Ieee Transactions on Vehicular Technology, 2020. 69(12): p. 14780-14792.

[11] Tang, X., et al., Method for metal foreign object detection in wireless charging system of electric vehicle. Sensor Review, 2021. 41(1): p. 57-64.

[12] Zhu, T., et al., Wireless portable light-weight self-charging power packs by perovskite-organic tandem solar cells integrated with solid-state asymmetric supercapacitors. Nano Energy, 2020. 78.

[13] Amiri, S.S., S. Jadid, and H. Saboori, Multi-objective optimum charging management of electric vehicles through battery swapping stations. Energy, 2018. 165: p. 549-562.

[14] Li, Y., et al., Optimal scheduling of isolated microgrid with an electric vehicle battery swapping station in multi-stakeholder scenarios: A bi-level programming approach via real-time pricing. Applied Energy, 2018. 232: p. 54-68.

[15] Lipu, M.S.H., et al., A review of state of health and remaining useful life estimation methods for lithium-ion battery in electric vehicles: Challenges and recommendations. Journal of Cleaner Production, 2018. 205: p. 115-133.