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Research Paper

Modern Trend in Wireless Battery Charging Technology

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ABSTRACT: *Wireless Battery charging has been attracting a wide range of subjects in various fields and also become a highly active research area because of the potential in providing high technology to our daily lives. The wireless battery charging which is a term associated with Wireless Power Transfer (WPT) will be mandatory to use in the near future because this technology enables the transmission of electrical energy from a power source to an electrical load across an air gap without interconnecting wires. This seminar work presents the existing technologies of wireless battery charging systems, their recent technology as well as its future trends. Furthermore, the work also describes plenty of applications in wireless battery charging.*

KEYWORDS: *Wireless Power transfer (WPT), wireless Battery charging system, Electric Vehicle, Inductance, microwave power transmission*

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I. INTRODUCTION

The use of portable electronic devices and electric vehicles has become more widespread recently, the many electronic devices and electronic vehicles are plugged into wall outlets via power cables for many hours a day, and the use of wired charging apparatuses has become a part of daily life. In this scenario, a large number of wire-chargers are discarded as E-waste due to contact failures such as broken wires or short-circuit problems, etc. Due to the increasing E-waste problem, there has been increasing interest in the study and development of wireless power transfer (WPT) technology that can be utilized to transfer power to batteries without requiring expensive failure-prone connectors.

Battery charging with wireless power transfer is a novel approach. However, the concept of wireless power transfer even for charging batteries is not a new idea. It has been invented by researchers but not widely implemented yet. Wireless power transmission is revolutionizing the mode of electricity transmission to enable the reliable and efficient wireless charging of millions of everyday electronic devices with integrating a power source to an electrical load without the aid of wires [1]. Such a transmission is used in cases where interconnecting wires are hazardous or inconvenient.

WPT technology can provide charging systems with low maintenance costs, high reliability, and the ability to operate even in extreme environments. However, a wireless battery charging system requires more power stages than a wired battery charging system [2]. The wireless battery charging system needs a WPT system that consists of a power transmitter and a power receiver. An exclusive controller is also required to regulate the output of WPT system since the power transferred to the receiver of WPT system is not regulated whenever the load changes. The inverter or converter in power electronics is usually controlled by three methods; pulse width modulation (PWM), frequency modulation (FM), and amplitude modulation (AM). The AM method requires an additional stage for the DC-DC converter in order to control the amplitude of the input voltage. On the other hand, both PWM and FM need no additional stage since the inverter or converter uses power semiconductor switches for the power conversion. For this reason, when PWM or FM is applied to the power transmitter of a WPT system, the power transferred to the receiver can be easily regulated. Nevertheless, high current stress and large power loss are generated since the voltage and current in the power transmitter are not in phase. Due to this problem, regulation circuits such as synchronous rectifiers or impedance tuners [3] are necessary in the receiver of a WPT system. Furthermore, battery-charging circuits such as lowdropout (LDO) regulators or synchronous buck converters are required for the battery charging. Figure 1 shows a conventional wireless battery charging system. As mentioned above, the conventional system consists of the following five key power stages; AC-DC converter, power transmitter of WPT system, power receiver of WPT system, regulation circuit, and battery-charging circuit.

II. FUNDAMENTALS OF WIRELESS BATTERY CHARGING SYSTEM

For the wireless battery charging system, the power receiver, regulation circuit, and battery charging circuit must be embedded inside portable electronic devices or electric vehicles, but there is usually not enough space for these power stages. In addition to this problem, the regulation and battery-charging circuits generate huge heat and raise the problem of thermal stress on the electronic devices while being charged.

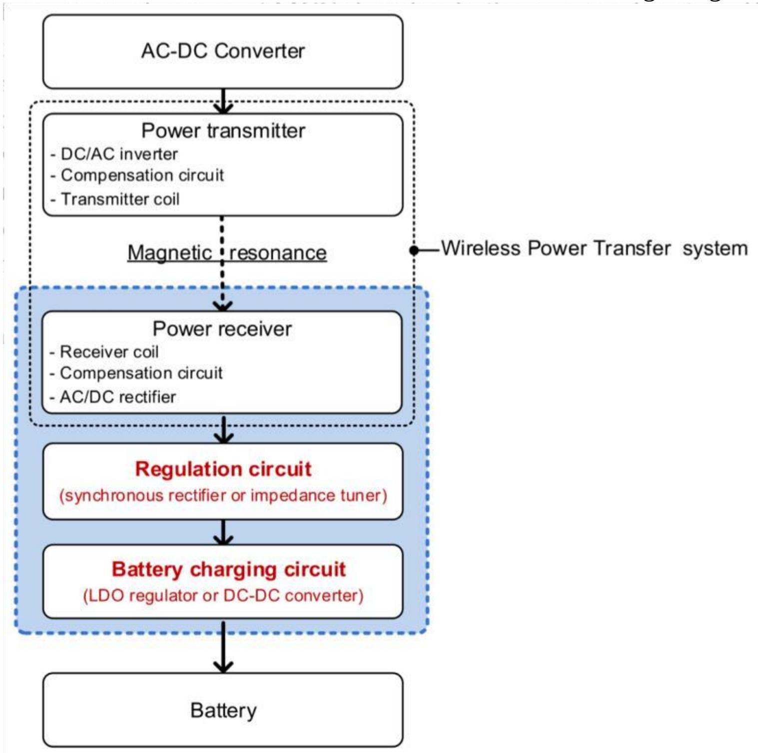

Fig 1: Conventional wireless battery charging system. [3]

Compensated Wireless Power Transfer

In the wireless battery charging system, the SS-WPT system followed by AC-DC converter consists of a half-bridge inverter, resonant tank, full-bridge rectifier, filter, and load as the battery, as shown in Figure 2. The half-bridge inverter applies a square voltage into the resonant tank. The square voltage, V_{square} can be described as:

$$V_{square}(t) = \begin{cases} V_{IN} & (0 < \omega t \leq \pi) \\ 0 & (\pi < \omega t \leq 2\pi) \end{cases} \quad (1)$$

where $\omega = 2\pi f_S$ and f_S is the switching frequency of the half-bridge inverter in Figure 2.

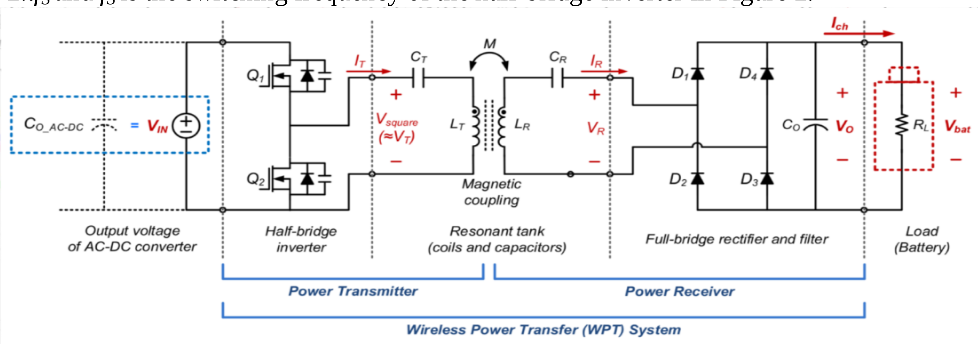

Figure 2. Series-series compensated wireless power transfer circuit

The resonant tank consists of s transmitter coil, receiver coil, transmitter capacitor, and receiver capacitor. The capacitors in the resonant tank resonate with coils and improve the conversion efficiency of the system. Since the capacitors are in series with coils, the structure is called series-series (SS) compensation [4].

Since the series-series compensated resonant tank acts as a band pass filter, the effect of any harmonic components in the input square voltage V_{square} can be neglected, except for its fundamental component. Then, the transmitter and receiver voltages in the resonant tank are sinusoidal and expressed as V_T and V_R, respectively.

III. WIRELESS CHARGING STRATEGY

Topologies are very important for wireless charging systems, for they are the major power transfer carrier and affect the system transfer characteristics. LC series and LC parallel are the basic two topologies, and their combinations derive four topologies, including LC series-LC series, LC series-LC parallel, LC parallel-LC series and LC parallel-LC parallel [5] To ensure the reflected impedance of LC parallel topology is purely resistive, an additional inductor is employed to compensate the imaginary part, which derives the LCL-LCL topology.

According to the Norton’s law, we can easily deduce that the LC parallel topology and LCL topology have the CC characteristic [6]). Additionally, LC series-LC series topology also has a CC characteristic when the load is a strong voltage source, like the battery. So, we can use these topologies to charge the battery directly, which can remove the cascade DC/DC part in the receiver, and thus improve the efficiency. CC/CV strategy is widely used due to the requirements of many commercial power batteries [7]. The battery is at first charged by a constant current. Once its terminal voltage arrives at a predesigned value, the CV stage begins. At this time, the charging instrument works as a voltage source to clamp the terminal voltage of the battery. Then, the internal resistance and OCV (open circuit voltage) of the battery increase continually until the charging current reduces to a threshold, which indicates that the charging process is over. Obviously, we can find that the CC stage is realized easily in wireless charging systems, but for the CV stage, it needs an additional control algorithm as well as some other sensors at high speed [8]. Initially, CV stage is used to charge the lead acid battery, which aims to avoid the electrolysis of the water at the end of the charge, and hence, to prevent excessive gaseous emissions [9].

IV. RECENT TRENDS

Creating a Utilization of resonance has rapidly grown in recent years to enhance the efficiency of wireless energy transfer in a wide variety of applications. In addition, the necessary core components of electronic product are being developed by electronic companies to help speed the introduction of the technology into niche applications. This will boost our creative capacities to bring much more substantial changes in technology so that can be implemented in particular tasks. Some of these revolutionary applications have been launched into market, while others are not ready yet for the commercial market. For instance, automotive charging is a novel innovation but not available into market because of needing standardization in its charging infrastructure. On the contrary, a breakthrough innovation for traditional inductive charging in mobile electronic has already developed by a consortium company. To ensure that multi-vendor products can charge anywhere in a common wireless ecosystem, the Standards Development Organizations (SDOs) is working to construct the interoperability standards in mobile devices for highly resonant wireless power transfer. All these efforts are paving the way toward new trend of wireless power technology, in which can be deployed in many applications.

I. A. Qi Technology

This technology uses the small inductors to transmit power over higher frequencies and also support a charging distance of a few centimetres at most. As a result, portable devices have to be placed quite specifically on the dock for avoiding the shortage of a large magnetic field. Owing to its limitation on charging area, Qi components can use multiple resonator arrays to create a larger charging area. However, it still does not mitigate the problem and even wasting a lot of power to have individual coils switched on. In order to keep a strong enough connection, users therefore need to align their devices precisely with the magnetic fields [10].

Currently, the wireless charger can get warm during charging and it will heat up the back of a device due to the operating frequency heating conductive materials. The Qi standard also incorporates a limited communication protocol to limit the power consumed by multiple coils. With this, the receiving device can tell the charger how much power it requires and when it is fully charged. Additionally, the charger can modify its power output to suit any receiving devices and can switch to standby mode once the device is fully charged or if no device is attached. Despite a wireless charger has not been as efficient as a regular charger, but Qi standard will able to be used in wireless charging in the near future [11].

II. B. Alliance for Wireless Power (A4WP) Technology

A4WP is a next-generation of wireless power transfer enabling the efficient transfer of power to electronic devices. This is based on reference power transmitting and receiving resonators without the use of interconnecting wires. This technology allows multiple devices to be charged with differing power requirements from a single transmitter at any one time. Because this technology uses a larger electromagnetic field rather than the small inductor coils, therefore it enables devices to be charged without having to line-up precisely with the coil. Although A4WP has not released to the market yet the existence of this technology enables the electronic devices to be charged in any positions including Z-axis. A further advantage of A4WP is allowing charger to be embedded in the objects where the magnetic fields can still emit the energy from the objects [12].

III. C. PMA Technology

Another most recent technology is Power Matters Alliance (PMA). This is the organization with the aim of forward thinking in a global, not-for-profit, industry where better power paradigm for battery equipped devices using wireless charging technology has been working with a bunch of research group leaders. PMA has grown rapidly since being founded in 2012. Recently more than 100 members across a diverse set of industries including telecommunication, consumer devices, automotive, retail, furniture, surfaces and more are working with this new standard of technology. PMA growth and success is attributed to a unique approach of making wireless charging ubiquitous in the places that consumers need it most as well as the hard work and dedication for members [13].

V. APPLICATION OF WIRELESS BATTERY CHARGING SYSTEMS

In this section, In the field of wireless power transmission the distance between transmitter and receiver, which is going to be large in the focus of recent research, can make the dream come true in different uses in human life. Applications depend on the uses of low power devices that can be wireless sensor or different electronic mobile devices, power range (less than 1W) and high-powered devices in the field of industrial area, power range (not more than 3KW). Devices like led lights where supplying energy is directly connected with load can be defined direct wireless powering and different charging devices need to be battery or capacitor charge defined wireless charging could be two types of implemented system [14].

I. A. Field of Electronics

Electronics that is the largest application field of using Wireless charging system is being implemented in electronic products such as laptop by using a wireless power source deployed behind the corkboard. This device enables to deliver over 20 watts of power. It can also charge at a distance over a 40 cm from the wireless charging source. The source and device resonators are oriented perpendicular to each other.

Figure 3: Recent applications of wireless power charging system in our daily life

Analysts expect that the benefits of charging over distance and with spatial freedom will result in highly resonant wireless power transfer capturing over 80% market share of all wireless charging systems by 2020. Mobile devices or smart phone that is capable to take charge from wireless charger is also a great use of this technology. In the same way other devices like iPad or for camera charging in any time any moment even in the public places (shown in figure) this wireless charging technology can be the greatest use for the human being [15].

II. B. Medical Devices

Wireless power transmission has been widely used for implanted medical devices including LVAD heart assist pumps, pacemakers, and infusion pumps. With using this technology, the power can be efficiently supplied to medical devices deeply implanted within the human body. In addition, it can help to eliminate the need for drivelines that penetrate the human body and for surgical replacement of primary batteries [16].

III. C. Electric Vehicles

Rechargeable hybrid and battery electric vehicles can be directly powered with wireless charging systems. These systems deliver 3.3 kW at high efficiency over a distance of 20 cm. With using this technology, it enables the reliable and efficient of power transmission to electric vehicles without the aid of wires. Moreover, it is expected that wireless charging will vastly improve the charging experience for EV owners, making such vehicles even more attractive to consumers.

IV. D. LED Lighting

With using wireless power transmission in LED (light emitting diode) lights, we can directly charge our devices using wireless electricity so it can eliminate the need for batteries in under-cabinet task lighting. Moreover, it can also help architectural lighting designers to create products that seemingly float in mid-air with no power cord.

V. E. Defense Systems

To improve the reliability, ergonomics, and safety of electronic devices by wireless charging in the defense systems designers are creating new design for the future defense technology. As an example, Talon tele-operated robot is being equipped with wireless charging so that it can be recharged while it is being transported by truck from site to site. Another use of defense system is Helmet mounted electronics where night vision is included and radio devices that can be powered wirelessly from a battery pack carried in the soldier's vest, eliminating the need for disposable batteries or a power cord connecting the helmet to the vest mounted battery pack. Last few years a number of standards development organizations and industrial consortia have taken initial activities for the development of specifications and standards relating to the application and commercialization of wireless power.

The Society of Automotive Engineers (SAE) has a committee developing recommendations and ultimately a standard for wireless charging of electric and hybrid electric vehicles such as cars and buses. Moreover, outside of North America, other international (International Electro technical Commission, or IEC) and national organizations (DKE German Commission for Electrical, Electronic and Information Technologies and the Japanese Automobile Research Institute, among others) are doing the same work for the development of more wireless charging applications. From [17], the Consumer Electronics Association (CEA) is active in developing a standard for the deployment of wireless power technologies in consumer applications. Additionally, several industry consortia have been established for the development of specifications about components and systems (as an example the recent three standards Wireless Power Consortium (WPC), Power Matters Alliance (PMA) and Alliance for Wireless Power (A4WP)). These kinds of efforts must be helpful for the fastest adoption of wireless power technology for the different wireless space application field.

VI. F. Solar Power Satellites (SPS)

It is the largest application of WPT by using satellites with giant solar arrays and placing them in Geosynchronous Earth Orbit. These satellites play a pivotal role to generate and transmit the power as microwaves to the earth. Another application of WPT is Ubiquitous Power Source or Wireless Power Source, Wireless sensors and RF Power Adaptive Rectifying Circuits (PARC) [18].

VI. CONCLUSION

The concept of wireless battery charging technology is presented in this research work. There recent technological applications that make the human life more beneficial in the present world have been discussed. New standards of wireless battery charging technology that are already in competition with each other will also be one of the talks of the topic in near future when other more standards are coming soon. More applications that are in under research with wireless power charging and in the field of robotics will be in our daily uses only if wireless power keeps improving.

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