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ADVANCEMENTS IN WIRELESS POWER TRANSMISSION TECHNOLOGY

J. Ganesh Prasad Reddy[*1], B. Anji Babu[*2], A. Srinivasa Rao[*3]

[*1, 2, 3] Assistant Professor, Dept. of Electrical and Electronics Engineering.

A.M Reddy Memorial College of Engineering and Technology, Andhra Pradesh.

Abstract— Wireless power transmission (WPT) has garnered significant attention across various disciplines and emerged as a vibrant area of research, owing to its potential to revolutionize daily life through cutting-edge technology. With its capability to transmit electrical energy from a power source to an electrical load without the need for physical wires, wireless power transmission is poised to become indispensable in the near future. In this study, we conduct an exploratory analysis to elucidate the existing technologies of wireless power transmission, including recent advancements and anticipated future trends. Additionally, we delve into a myriad of applications where wireless transmission can be leveraged.

Keywords— **Wireless power transfer, inductive coupling, Qi standard, A4WP, microwave power transmission.**

I. INTRODUCTION

Electricity energy needs to be transported to the distribution lines through cords. One of the major issue in power transmission is the losses occurs during transmission and distribution process of electrical power due to the energy dissipation in the conductor and equipment used for transmission. As the demand increase day by day, the power generation and power loss are also increased. In addition, the cost of making electricity is harmful to the environment. Therefore, reducing transmission loss is very crucial because the saved power can be used as an alternative to minimize the cost. Despite power loss during the transmission process is inevitable, some alternatives can be interpreted to mitigate this problem. In order to minimize power losses in the power distribution network, wireless power transmission has been known for centuries to clean sources of electricity.

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. Such a transmission is used in cases where interconnecting wires are hazardous or inconvenient.

In the early period different scientist proved different approaches to transfer power without physical connection between the source and appliance. Each type of wireless power transfer has its own characteristics and applications. To make this idea for familiarize for the new researchers we reviewed the background histories, recent technologies and future advances. This paper will briefly survey a variety of potential wireless power technology and compare them in different features. The structure of this paper is organized as follows. After introduction, wireless power transfer is reviewed in Section II. The recent technologies in wireless power transmission are described explicitly in Section III, while in Section IV some applications of power transmission are presented. Finally, conclusions are presented in Section V.

II. WIRELESS POWER TRANSFER (WPT)

Wireless power transmission, also known as inductive power transfer, can be used for short range or even long range without cords. This technology provides efficient, fast, and low maintenance cost as compared to previous technologies. It also allows portable electronics to charge themselves without ever being plugged in ubiquitous power wire. On the other hand, power loss of this technology is very less as compared to wired electricity transmission. The main function of wireless power transfer is to allow electrical devices to be continuously charged and lose the constraint of a power cord. There are three main systems used for WPT such as microwaves, resonance, and solar cells. Microwaves would be used to send electromagnetic radiation from a power source to a receiver in an electrical device.

The founder of AC electricity, Nikola Tesla, was first to conduct experiments dealing with WPT. His idea came from the notion that earth itself is a conductor that can carry a charge throughout the entire surface. While Tesla's experiments were not creating electricity, but just transferring it, his ideas can be applied to solve our energy crisis. Each application has its respective drawbacks but also has the potential to aid this planet in its dying need for an alternative to creating power.

Today, portable technology is a part of everyday life. But from portability emerges another challenge is energy. Almost all portable devices are battery powered, meaning that eventually, they all must be recharged using the wired chargers currently being used. Now instead of plugging in a cell phone, PDA, digital camera, voice recorder, mp3 player or laptop to recharge it, it could receive its power wirelessly. Although wireless power transfer is feasible and helps in human daily lives, but this technology suffers from several drawbacks namely requires a network of hundreds of satellites and interferences with other electronic devices. There are two techniques in wireless power transfer, which are near-field technique and far-field technique. In general, far-field techniques provide lower frequency transmission with simple pattern measurements and near-field technique with higher frequency transmission and complete pattern measurement.

A. Near-field Techniques

The near-field techniques are measuring with appliance near from the power source. It can be broken down into three categories, which are electromagnetic radiation, inductive coupling, and magnetic resonant coupling. These techniques can be used to eliminate problem due to weather and security concerns.

1) *Electromagnetic (EM) Radiation*: Energy from the transmission antenna of a power source to the receiver antenna through radioactive EM waves is the process of emission by EM radiation. Omnidirectional radiation and unidirectional radiation, this two-section classified in the sense of the direction of emitting energy. Through omnidirectional radiation process, broadcasting EM waves via transmitter in an assigned ISM band for example 850–950 MHz or 902–928 MHz in the U.S. which can be varies with the different region both with 915 MHz centre frequency, and a receiver for example RFID tags tunes to the same frequency band to harvest radio power. In omnidirectional radiation though information transfer is easier and more suitable but also suffers from a serious efficiency problem in energy transfer because when the distance is going large there is quick decay of EM waves. By the experiment it was found that when a receiver is 30 cm away from the RF transmitter, power transfer efficiency is only 1.5%.

In addition, to protect potential health hazards of humans from EM radiation, only appropriate process is omnidirectional radiation for ultra-low-power sensor nodes for example up to 10 mW with very low sensing activities like temperature, moisture and light. If there is a clear line-of-sight (LOS) path exists in the process of unidirectional radiation, it can gain high power transmission over a much longer distance for example by using a microwave or laser beam the range can be in kilometre. In the microwave-based system mostly, wireless power is transmitted on microwave frequencies of either 2.45 or 5.8 GHz, both in the ISM frequency band. In the Laser-based system, it is still considered less mature than microwave-based system, transmit power under the visible or near infrared frequency spectrum as an example from several THz to several hundred THz.

2) *Inductive Coupling:* Inductive coupling generally defined as coupling between to LC circuits where resonant frequency is same. It works by using magnetic field induction that is the natural part of current's movement through wire, as an example alternating current in a primary coil that is connected to a source can produce a varying magnetic field that induces a voltage across the terminals of a secondary coil at the receiver. Primary and secondary coils are two distinct coils in inductive coupling. Each of these connected wirelessly and the reason of its simplicity, convenience, and safety, inductive coupling has been an important and popular technology to transfer power without wires. With this technological application various kinds of electronic devices
has been already made. Therefore, it has been successfully commercialized to a number of products, including electric toothbrush, charging pad for cell phone or laptop, and medical implants. In inductive coupling, power transfer gradually decreases when the two coils are being separate slowly from each other or when the alignment of two coils is not perfect. These kinds of problems are generally occurred when it's not carefully used. It works best when the charging node of the device and power receiving node are close in contact usually less than a coil diameter, for example the range can be in centimetre and the direction of the charging must have to be aligned.

3) *Magnetic Resonant Coupling:* The last and most important category of WPT technology under the section of near field techniques is magnetic resonant coupling. This technology was developed by Kurs et al., which enable to make the interactions between two different objects very strongly because of the combination of inductive coupling and resonance. In addition, energy will be shifting back and forth between magnetic field surrounding the coil and electric field around the capacitor. To the classical mechanical resonance, the effect of magnetic resonance is analogous, under which a string when tuned to a certain tone it can be excited to vibration by a faraway sound generator if there is a match between their resonance frequencies. In this technology, energy can be transferred efficiently from a source coil to a receiver coil with little loss of energy to alternating current in a primary coil (connected to a source) generates a varying magnetic field that induces a voltage across the terminals of a secondary coil at the receiver. An electrical transformer is a good extraneous off-resonant object. There are several advantages of this technology namely highly efficient, radiation loss will be negligible, provides much greater range and directional as compared to inductive coupling.

B. Far-field Techniques

The far-field techniques are measuring the electrical load far from the power source. These techniques aim at high power transfer and need line of sight. It can be separated into two categories, which are microwave power transmission and laser power transmission.

1) *Microwave Power Transmission (MPT)*: This technology transfers high power from the base station to the receiving station or mobile devices with two places being in line of sight.

With the help of geosynchronous receiving and transmitting satellites, this technology enables the objects to acquire power from the base station with using the magnetron. MPT provides the efficiency in energy conversion but it is slightly difficult to focus the beam in a small region. Besides, this technology could pass through the atmosphere easily. The first step of power transmission is initiated with converting electrical energy to be microwaves energy and then microwaves energy will be captured with using rectenna. In this technology, Alternating Current (AC) cannot be directly converted to microwaves energy. Therefore, AC needs to be converted to Direct Current (DC) first and then DC is converted to microwaves by using magnetron. Transmitted waves are received at rectenna and then rectify microwaves into electricity with more efficiently. It will give DC as the output. In the final step, DC will be converted back to AC.

2) *Laser Power Transmission:* This technology is slightly different with MPT where it enables the power concentrated in a small area by utilizing the mirror. This technology also produces high powers that are coherent and not dispersed. However, laser technology gets attenuated when it propagates through atmosphere. In addition, this technology has been used to apply to a rover to explore the presence of ice in the bottom of craters of the moon where no sunlight is available. On the other hand, the solar energy generated by the radiation is converted into the electric energy. This energy next will be converted to the laser light and then transmitted to the rover working at the bottom of the crater.

III. RECENT TECHNOLOGIES

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.

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.

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.

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.

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**.**

IV. APPLICATION OF WIRELESS POWER TRANSMISSION

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.

V. CONCLUSIONS

The concept of wireless power transmission is presented. There recent technological applications that make the human life more beneficial in the present world have been discussed. Three new standard of wireless power technology that is already in competition with each other is also one of the talks of the topic in near future when other more standards are coming soon. Among these three wirelesses charging standards, which are going to be

win in the race that will be defined by their recent great applications. From the comparison table it shows that A4WP standards which has the huge magnetic field and large charging distance must be keep ahead this technology then other standards whereas Qi and PMA also improving very fast. 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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