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Study and Survey of Wireless Charging Technologies

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Abstract: Wired way of charging a traditional way and still in the market. The concept of charging of one low power device from other is when we connect mobile phone to our laptops using USB cable. What if, we can charge any low power device with other low power device wireless can be helpful in case of unavailability of weird chargers.

INTRODUCTION

Wireless charging also known as wireless power transfer, is the technology that enables a power source to transmit electromagnetic energy to an electrical load across an air gap, without interconnecting cords. This technology is attracting a wide range of applications, from low-power toothbrush to high-power electric vehicles because of its convenience and better user experience.

Compared to traditional charging with cord, wireless charging introduces many benefits as follows.

- Firstly, it improves user-friendliness as the hassle from connecting cables is removed. Different brands and different models of devices can also use the same charger.
- Secondly, it renders the design and fabrication of much smaller devices without the attachment of batteries.
- Thirdly, it provides better product durability for contact-free devices.
- Fourthly, it enhances flexibility, especially for the devices for which replacing their batteries or connecting cables for charging is costly, hazardous, or infeasible (e.g., body implanted sensors).
- Fifthly, wireless charging can provide power requested by charging devices in an on-demand fashion and thus are more flexible and energy-efficient.

Theoretic Foundation

The study of electromagnetism originates from 1819 when H. C. Oersted discovered that electric current generates a magnetic field around it. Then, Ampere's Law, Biot-Savart's Law and Faraday's Law were derived to model some basic property of magnetic field. They are followed by the Maxwell's equations introduced in 1864 to characterize how electric and magnetic fields are generated and altered by each other. Later, in 1873, the publication of J. C. Maxwell's book *A Treatise on Electricity and Magnetism* unified the study of electricity and magnetism. Since then, electricity and magnetism are known to be regulated by the same force. These historic progress established the modern theoretic foundation of electromagnetism.

Technical breakthroughs and Research Projects

The history has witnessed a series of important technical breakthroughs, going along with two major research lines on electric field and magnetic field. In 1888, H. R. Herts used oscillator connected with induction coils to transmit electricity over a tiny gap. This first confirmed the existence of electromagnetic radiation experimentally. Nikola Tesla, the founder of alternating current electricity, was the first to conduct experiments of wireless power transfer based on microwave technology. He focused on long-distance wireless power transfer and realized the transfer of microwave signals over a distance about 48 kilometers in 1896. Another major breakthrough was achieved in 1899 to transmit 10^8 volts of high-frequency electric power over a distance of 25 miles to light 200 bulbs and run an electric motor . However, the technology that Tesla applied had to be shelved because emitting such high voltages in electric arcs would cause disastrous effect to humans and electrical equipment in the vicinity .

Later, during 1920s and 1930s, magnetrons were invented to convert electricity into microwaves, which enable wireless power transfer over long distance. However, there was no method to convert microwaves back to electricity. Therefore, the development of wireless charging was abandoned.

It was until 1964, whenW. C. Brown, who is regarded as the principal engineer of practical wireless charging, realized the conversion of microwaves to electricity through a rectenna.

Solar power satellite (SPS), introduced in 1968, is another driving force for long-distance microwave power transfer . The concept is to place a large SPS in geostationary Earth orbit to collect sunlight energy, and transmit the energy back to the Earth through electromagnetic beam.

NASA's project on SPS Reference System prompted abundant technology developments in large-scale microwave transfer during 1970s and 1980s. During the same period, coupling based technology was developed under slow progress. Though inductive coupling for low-power medical applications was successful and widely applied in 1960s, there were not many technical boosts.

Wireless charging technologies:

Wireless charging technologies can be broadly classified into non-radiative coupling-based charging (Near field) and radiative RF-based charging(Far field).

Near field or non-radiative region: In this region the oscillating electric and magnetic fields are separate and power can be transferred via electric fields by capacitive coupling (electrostatic induction) between metal electrodes, or via magnetic fields by inductive coupling (electromagnetic induction) between coils of wire. These fields are not *radiative*, meaning the energy stays within a short distance of the transmitter. If there is no receiving device or absorbing material within their limited range to "couple" to, no power leaves the transmitter. The range of these fields is short, and depends on the size and shape of the "antenna" devices, which are usually coils of wire. The fields, and thus the power transmitted, decrease exponentially with distance, so if the distance between the two "antennas" *D*range is much larger than the diameter of the "antennas" *D*ant very little power will be received. Therefore, these techniques cannot be used for long distance power transmission.

Therefore the range of near field devices is conventionally divided into two categories:

Short range – up to about one antenna diameter: *D*range ≤ *D*ant. This is the range over which ordinary nonresonant capacitive or inductive coupling can transfer practical amounts of power.

Midrange – up to 10 times the antenna diameter: *D*range ≤ 10 *D*ant. This is the range over which resonant capacitive or inductive coupling can transfer practical amounts of power.

Basically there are three categories in near field region where you can apply the wireless transmission of power.

Near field Region (NFC) - 1. Inductive Coupling

2. Capacitive Coupling

3. Resonance Coupling

1. Inductive Coupling:

In inductive coupling, power is transferred between coils of wire by a magnetic field. The transmitter and receiver coils together form a transformer. An alternating current (AC) through the transmitter coil (L1) creates an oscillating magnetic field (B) by Ampere's law. The magnetic field passes through the receiving coil (L2), where it induces an alternating EMF (voltage) by Faraday's law of induction, which creates an AC current in the receiver. The induced alternating current may either drive the load directly, or be rectified to direct current (DC) by a rectifier in the receiver, which drives the load. A few systems, such as electric toothbrush charging stands, work at 50/60 Hz so AC mains current is applied directly to the transmitter coil, but in most systems an electronic oscillator generates a higher frequency AC current which drives the coil, because transmission efficiency improves with frequency.

The power transferred increases with frequency and the mutual inductance M between the coils, which depends on their geometry and the distance D_{range} between them. A widely-used figure of merit is the coupling coefficient $k = M/\sqrt{L_1 L_2}$. This dimensionless parameter is equal to the fraction of magnetic flux through L1 that passes through L2. If the two coils are on the same axis and close together so all the magnetic flux from L1 passes through L2, k = 1 and the link efficiency approaches 100%. The greater the separation between the coils, the more of the magnetic field from the first coil misses the second, and the lower k and the link efficiency are, approaching zero at large separations. The link efficiency and power transferred is roughly proportional to k^2. In order to achieve high efficiency, the coils must be very close together, a fraction of the coil diameter D_{ant}, usually within centimeters, with the coils' axes aligned. Wide, flat coil shapes are usually used, to increase coupling. Ferrite "flux confinement" cores can confine the magnetic fields, improving coupling and reducing interference to nearby electronics, but they are heavy and bulky so small wireless devices often use air-core coils.

2.Capacitive Coupling:

In capacitive coupling (electrostatic induction), the dual of inductive coupling, power is transmitted by electric fields between electrodes such as metal plates. The transmitter and receiver electrodes form a capacitor, with the intervening space as the dielectric. An alternating voltage generated by the transmitter is applied to the transmitting plate, and the oscillating electric field induces an alternating potential on the receiver plate by electrostatic induction, which causes an alternating current to flow in the load circuit. The amount of power transferred increases with the frequency and the capacitance between the plates,which is proportional to the area of the smaller plate and (for short distances) inversely proportional to the separation. Capacitive coupling has only been used practically in a few low power applications, because the very high voltages on the electrodes required to transmit significant power can be hazardous, and can cause unpleasant side effects such as noxious ozone production. In addition, in contrast to magnetic fields, electric fields interact strongly with most materials, including the human body, due to dielectric polarization. Intervening materials between or near the electrodes can absorb the energy, in the case of humans possibly causing excessive electromagnetic field exposure. However capacitive coupling has a few advantages over inductive. The field is largely confined between the capacitor plates, reducing interference, which in inductive coupling requires heavy ferrite "flux confinement" cores. Also, alignment requirements between the transmitter and receiver are less critical. Capacitive coupling has recently been applied to charging battery powered portable devices and is being considered as a means of transferring power between substrate layers in integrated circuits.

Resonance Coupling:-

Resonant inductive coupling (electrodynamic coupling, evanescent wave coupling or strongly coupled magnetic resonance) is a form of inductive coupling in which power is transferred by magnetic fields (B, green) between two resonant circuits (tuned circuits), one in the transmitter and one in the receiver (see diagram, right). Each resonant circuit consists of a coil of wire connected to a capacitor, or a self-resonant coil or other resonator with internal capacitance. The two are tuned to resonate at the same resonant frequency. The resonance between the coils can greatly increase coupling and power transfer, analogously to the way a vibrating tuning fork can induce sympathetic vibration in a distant fork tuned to the same pitch. Nikola Tesla first discovered resonant coupling during his pioneering experiments in wireless power transfer around the turn of the 20th century, but the possibilities of using resonant coupling to increase transmission range has only recently been explored. In 2007 a team led by Marin Soljačić at MIT used two coupled tuned circuits each made of a 25 cm self-resonant coil of wire at 10 MHz to achieve the transmission of 60 W of power over a distance of 2 meters (6.6 ft) (8 times the coil diameter) at around 40% efficiency.

The concept behind resonant inductive coupling is that high Q factor resonators exchange energy at a much higher rate than they lose energy due to internal damping. Therefore, by using resonance, the same amount of power can be transferred at greater distances, using the much weaker magnetic fields out in the peripheral regions ("tails") of the near fields (these are sometimes called evanescent fields). Resonant inductive coupling can achieve high efficiency at ranges of 4 to 10 times the coil diameter (D_{ant}). This is called "mid-range" transfer, in contrast to the "short range" of non-resonant inductive transfer, which can achieve similar efficiencies only when the coils are adjacent. Another advantage is that resonant circuits interact with each other so much more strongly than they do with non-resonant objects that power losses due to absorption in stray nearby objects are negligible. A drawback of resonant coupling is that at close ranges when the two resonant circuits are tightly coupled, the resonant frequency of the system is no longer constant but "splits" into two resonant peaks, so the maximum power transfer no longer occurs at the original resonant frequency and the oscillator frequency must be tuned to the new resonance peak.

Resonant technology is currently being widely incorporated in modern inductive wireless power systems. One of the possibilities envisioned for this technology is area wireless power coverage. A coil in the wall or ceiling of a room might be able to wirelessly power lights and mobile devices anywhere in the room, with reasonable efficiency. An environmental and economic benefit of wirelessly powering small devices such as clocks, radios, music players and remote controls is that it could drastically reduce the 6 billion batteries disposed of each year, a large source of toxic waste and groundwater contamination.

Far field or radiative region:
the electric and magnetic fields are perpendicular to each other and propagate as an electromagnetic wave; examples are radio waves, microwaves, or light waves.This part of the energy is *radiative*, meaning it leaves the antenna whether or not there is a receiver to absorb it. The portion of energy which does not strike the receiving antenna is dissipated and lost to the system. The amount of power emitted as electromagnetic waves by an antenna depends on the ratio of the antenna's size Dant to the wavelength of the waves λ, which is determined by the frequency: $\lambda = c/f$. At low frequencies f where the antenna is much smaller than the size of the waves, Dant << λ, very little

power is radiated. Therefore the nearfield devices above, which use lower frequencies, radiate almost none of their energy as electromagnetic radiation. Antennas about the same size as the wavelength *D*ant ≈ λ such as monopole or dipole antennas, radiate power efficiently, but the electromagnetic waves are radiated in all directions (omnidirectionally), so if the receiving antenna is far away, only a small amount of the radiation will hit it.Therefore, these can be used for short range, inefficient power transmission but not for long range transmission. However, unlike fields, electromagnetic radiation can be focused by reflection or refraction into beams. By using a high gain antenna or optical system which concentrates the radiation into a narrow beam aimed at the receiver, it can be used for *long range* power transmission. Moreover, for the far field technique, the absorption of radiation does not affect the transmitter. By contrast, for the near-field techniques, the absorption of radiation influences the load on the transmitter. This is because, a transmitting antenna and a receiving antenna are not coupled for the far-field technique. While a transmitting coil and a receiving coil are coupled for the near field techniques.

Microwaves

Power transmission via radio waves can be made more directional, allowing longer distance power beaming, with shorter wavelengths of electromagnetic radiation, typically in the microwave range. A rectenna may be used to convert the microwave energy back into electricity. Rectenna conversion efficiencies exceeding 95% have been realized. Power beaming using microwaves has been proposed for the transmission of energy from orbiting solar power satellites to Earth and the beaming of power to spacecraft leaving orbit has been considered.

Lasers

In the case of electromagnetic radiation closer to the visible region of the spectrum (tens of micrometers to tens of nanometers), power can be transmitted by converting electricity into a laser beam that is then pointed at a photovoltaic cell. This mechanism is generally known as 'power beaming' because the power is beamed at a receiver that can convert it to electrical energy. At the receiver, special photovoltaic laser power converters which are optimized for monochromatic light conversion are applied.

Recent Technologies in market:

Not only in past there is craze for implementing wireless charging in today's market also. Many smartphones have come up with wireless chargers like Nokia Lumia 900 using the concept of inductive coupling. Samsung smartphone model also use their screen emitting light for charging. Apple has just filed a patent for hardware which could make the shake to charge concept a reality, at least in theory. They claim a unique design incorporating internal moveable magnets, and a flat printed circuit board coil.

Conclusion:

After the study of all the wireless technologies that is, near field or non-radiative and far field or radiative region. Among these for our project we will consider near field region technologies as it is more efficient and have safety measures i.e. non-harmful to humans and other living being. And among near field technologies i.e. inductive, capacitive and resonance. Inductive coupling is the key concept of the project as it doesn't make it bulky and it is more efficient.

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References:

[1] www.imsresearch.com
[2] www.pikeresearch.com
[3] C. S. Branch, "Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz," safe code 6, 2009.
[4] L. Xie, Y. Shi, Y. T. Hou, and A. Lou, "Wireless Power Transfer and Applications to Sensor Networks," *IEEE Wireless Communications*, vol. 20, no. 4, pp. 140-145, Aug. 2013.
[5] art of electronics.
[6]"Wireless energy transfer". *Encyclopedia of terms*. PC Magazine ZiffDavis. 2014. Retrieved December 15, 2014.