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A Study of Wireless Power Transfer Techniques

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***Abstract*—In recent years, there has been a growing interest in wireless power transfer (WPT) that represents a promising technology for energizing low-power electronic devices. In this regard, particularly attractive is the use of WPT for recharging embedded devices, such as sensors for structural monitoring or implantable medical devices (IMD); in fact, these devices are difficult to access for the battery replacement or a direct connection to a power grid. More specifically, in the case of medical implants, the limited lifetime of the battery determines the necessity of periodically replacing the device through surgery. The use of WPT combined with a rechargeable battery could extend the lifetime of these devices up to 20 years, with obvious advantages for their users. According to these considerations, in the literature, several wireless power transfer methods and wireless links for either data or power transfer to medical implants have been discussed**

***Index Terms*—Wireless Power Transfer (WPT)**

1. INTRODUCTION

Wireless power transfer (WPT), wireless power transmission, wireless energy transmission (WET), or electromagnetic power transfer is the transmission of electrical energy without wires as a physical link. In a wireless power transmission system, a transmitter device, driven by electric power from a power source, generates a time-varying electromagnetic field, which transmits power across space to a receiver device, which extracts power from the field and supplies it to an electrical load. The technology of the wireless power transmission can eliminate the use of the wires and batteries, thus increasing the mobility, convenience, and safety of an electronic device for all users. Wireless power transfer is useful to power electrical devices where interconnecting wires are inconvenient, hazardous, or are not possible.

Wireless power techniques mainly fall into two categories, near field and far-field. In near field or non-radiative techniques, power is transferred over short distances by magnetic fields using inductive coupling between coils of wire, or by electric fields using capacitive coupling between metal electrodes. Inductive coupling is the most widely used wireless technology; its applications include charging handheld devices like phones and electric toothbrushes, RFID tags, and wirelessly charging or continuous wireless power transfer in implantable medical devices like artificial cardiac pacemakers, or electric vehicles.

In far-field or radiative techniques, also called power beaming, power is transferred by beams of electromagnetic radiation, like microwaves or laser beams. These techniques can transport energy longer distances but must be aimed at the receiver. Proposed applications for this type are solar power satellites, and wireless powered drone aircraft.

An important issue associated with all wireless power systems is limiting the exposure of people and other living things to potentially injurious electromagnetic fields.

Wireless power transfer is a generic term for a number of different technologies for transmitting energy by means of electromagnetic fields. The technologies, listed in the table below, differ in the distance over which they can transfer power efficiently, whether the transmitter must be aimed (directed) at the receiver, and in the type of electromagnetic energy they use: time varying electric fields, magnetic fields, radio waves, microwaves, infrared or visible light waves.

In general a wireless power system consists of a "transmitter" device connected to a source of power such as a mains power line, which converts the power to a time-varying electromagnetic field, and one or more "receiver" devices which receive the power and convert it back to DC or AC electric current which is used by an electrical load. At the transmitter the input power is converted to an oscillating electromagnetic field by some type of "antenna" device. The word "antenna" is used loosely here; it may be a coil of wire which generates a magnetic field, a metal plate which generates an electric field, an antenna which radiates radio waves, or a laser which generates light. A similar antenna or coupling device at the receiver converts the oscillating fields to an electric current. An important parameter that determines the type of waves is the frequency, which determines the wavelength.

Wireless power uses the same fields and waves as wireless communication devices like radio, another familiar technology that involves electrical energy transmitted without wires by electromagnetic fields, used in cellphones, radio and television broadcasting, and WiFi. In radio communication the goal is the transmission of information, so the amount of power reaching the receiver is not so important, as long as it is sufficient that the information can be received intelligibly. In wireless communication technologies only tiny amounts of power reach the receiver. In contrast, with wireless power transfer the amount of energy received is the important thing, so the efficiency (fraction of transmitted energy that is received) is the more significant parameter. For this reason, wireless power technologies are likely to be more limited by distance than wireless communication technologies.

Wireless power transfer may be used to power up wireless information transmitters or receivers. This type of communication is known as wireless powered communication (WPC). When the harvested power is used to supply the power of wireless information transmitters, the network is known as Simultaneous Wireless Information and Power Transfer (SWIPT); whereas when it is used to supply the power of wireless information receivers, it is known as a Wireless Powered Communication Network (WPCN).

In the United States, the Federal Communications Commission (FCC) provided its first certification for a wireless transmission charging system in December 2017.

2. WIRELESS POWER TRANSFER TECHNOLOGIES

Inductive Coupling

It is a short range technology with low directivity. It uses the frequency range of few Hz to MHz for the transmission and uses wire coils as antenna devices. It is mainly used in Electric tooth brush and razor battery charging, induction stovetops and industrial heaters.

Resonant inductive coupling

It is a mid range technology with low directivity. It uses the frequency range from KHz to MHz for the transmission and uses tuned wire coils and lumped element resonators as antenna devices. It is mainly used in Charging portable devices(Qi), biomedical implants, electric vehicles, powering buses, trains, MAGLEV, RFID, smartcards.

Capacitive Coupling

It is a short range technology with low directivity. It uses the frequency range from KHz to MHz for the transmission and uses metal plate electrodes as antenna devices. It is mainly used in Charging portable devices, power routing in large-scale integrated circuits, Smartcards, biomedical implants.

Magnetodynamic coupling

It is a short range technology and uses the frequency range of few Hz for the transmission. This method uses rotating magnets as antenna devices. It is mainly used in Charging electric vehicles, biomedical implants.

Microwaves

It is a long range technology with high directivity. It uses the frequency range of GHz for the transmission and uses Parabolic dishes, phased arrays, rectennas as antenna devices. It is mainly used in Solar power satellite, powering drone aircraft, charging wireless devices.

It is a long range technology with high directivity. It uses the frequency range of GHz for the transmission and uses Lasers, photocells and lenses as antenna devices. It is mainly used in Charging portable devices, powering drone aircraft, powering space elevator climbers.

3. FIELD REGIONS

Electric and magnetic fields are created by charged particles in matter such as electrons. A stationary charge creates an electrostatic field in the space around it. A steady current of charges (direct current, DC) creates a static magnetic field around it. The above fields contain energy, but cannot carry power because they are static. However time-varying fields can carry power. Accelerating electric charges, such as are found in an alternating current (AC) of electrons in a wire, create time-varying electric and magnetic fields in the space around them. These fields can exert oscillating forces on the electrons in a receiving "antenna", causing them to move back and forth. These represent alternating current which can be used to power a load.

The oscillating electric and magnetic fields surrounding moving electric charges in an antenna device can be divided into two regions, depending on distance Drange from the antenna. The boundary between the regions is somewhat vaguely defined. The fields have different characteristics in these regions, and different technologies are used for transferring power.

Near Field or Non Radiative Region

This means the area within about 1 wavelength (λ) of the antenna. In this region the oscillating electric and magnetic fields are separate[16] 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

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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" Drange is much larger than the diameter of the "antennas" Dant very little power will be received. Therefore, these techniques cannot be used for long range power transmission.

Resonance, such as resonant inductive coupling, can increase the coupling between the antennas greatly, allowing efficient transmission at somewhat greater distances, although the fields still decrease exponentially. Therefore the range of near-field devices is conventionally divided into two categories:

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

Mid-range – up to 10 times the antenna diameter: Drange ≤ 10 Dant. This is the range over which resonant capacitive or inductive coupling can transfer practical amounts of power.

Near Field Techniques include inductive coupling, Resonant inductive coupling, capacitive coupling, Resonant capacitive coupling and Magenetodynamic coupling.

Far Field or Radiative Region

Beyond about 1 wavelength (λ) of the antenna, 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: λ = 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 near-field devices above, which use lower frequencies, radiate almost none of their energy as electromagnetic radiation. Antennas about the same size as the wavelength Dant ≈ 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. From the Rayleigh criterion, to produce the narrow beams necessary to focus a significant amount of the energy on a distant receiver, an antenna must be much larger than the wavelength of the waves used: Dant >> λ = c/f. Practical beam power devices require wavelengths in the centimeter region or below, corresponding to frequencies above 1 GHz, in the microwave range or above. Far Field Techniques include Microwaves and Lightwaves for transmission.

4. ENERGY HARVESTING

In the context of wireless power, energy harvesting, also called power harvesting or energy scavenging, is the conversion of ambient energy from the environment to electric power, mainly to power small autonomous wireless electronic devices. The ambient energy may come from stray electric or magnetic fields or radio waves from nearby electrical equipment, light, thermal energy (heat), or kinetic energy such as vibration or motion of the device. Although the efficiency of conversion is usually low and the power gathered often minuscule (milliwatts or microwatts), it can be adequate to run or recharge small micropower wireless devices such as remote sensors, which are proliferating in many fields. This new technology is being developed to eliminate the need for battery replacement or charging of such wireless devices, allowing them to operate completely autonomously.

CONCLUSION

A study of wireless power transfer is discussed and the different techniques are explained in this paper.

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