Contactless Energy Transfer Systems

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ABSTRACT

The main purpose of this paper is to introduce the Contactless Energy Transfer (CET) systems and its state of art naming current applications. The wireless power transfer consists of a technology capable of transferring energy contact-less. It is not a new technology but is gaining importance nowadays in many cases where the use of wires are an impediment [1].

1 Historical development

The first attempt to get a wireless power transfer was made by Nikola Tesla in the late nineteenth century, who wirelessly lights up phosphorescent lights using a method called "electro-dynamic induction" [2]. Due to the fact that power transfer methods are more demanding than signals transfer systems, power transfer did not experience the same development [3].
The first reported researches on energy transport by inductive coupling dates in the 1960s, and the first applications like wireless toothbrushes appeared in the 1990s. Power transfer systems are currently evolving rapidly since the Wireless Power Consortium created the protocols related to inductive CET systems in 2008 [3].
The CET systems can be classified depending on the gap between both parts of the system. It can be found Near-field methods and Far-field methods, discussed in the following chapters of this paper.

2 Near-field methods

The simplest way of contactless energy transfer is non - resonant inductive transfer, also known as transformer, based on two coils with different voltage. The variable current will lead to development of the alterable magnetic field as well as a magnetic flux which will lead to induced voltage. Because of the change of the value of the initial current in the first coil, on the second coil the current will be induced. The described process is based on Faraday's law.
However, this is not the most efficient way of transferring energy, it depends on the geometry and magnetic field is stronger if the coils are closer so it can transfer energy only on low distances. Resonant inductive way of transmitting energy is much more efficient and is divided into capacitive CET systems and inductive CET systems [4].

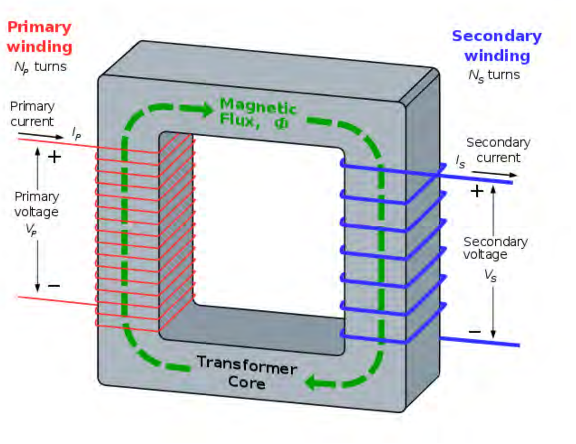

Fig. 1 Idealised single-phase transformer also showing the path of magnetic flux through the core. (source: BillC at English Wikipedia.)

2.1 Capacitive CET systems

The capacitive CET system is based on getting displacement current. It consists of energy source, high frequency resonant power converter DC/AC, metal plates, AC/DC converter and load. Firstly, electrical energy goes through high frequency power converter and than splits to two metal plates from which it goes to secondary plates where alternating electric field forms. For direct current, capacitors represent the break of the circuit, while for alternating electric field circuit closes through displacement current. Currents go again through converter and the power is transferred to load. The power of this type of CET system is 5 - 50 W [5].

2.2 Inductive CET systems

The inductive CET system is based on previously described transformers. What is added to it is primary DC/AC resonant converter, resonant circuits and secondary AC/DC converter. The converted electric en-

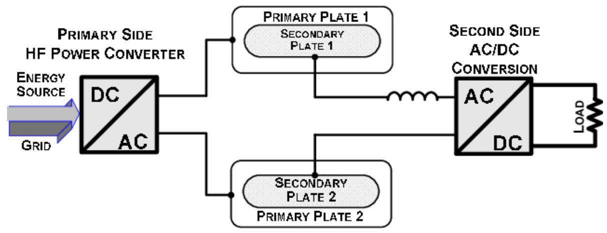

Fig. 2 Basic principles of capacitive CET system [5]

ergy runs through the transformer and again through secondary converter to load. The power depends on which transformer is used. If there is a need for low power than transformers with higher gap between coils are used as described at the beginning. In contrary, if there is a need for high power transfer, transformers with low gap between coils are used consisting of magnetic cores [3, 5].

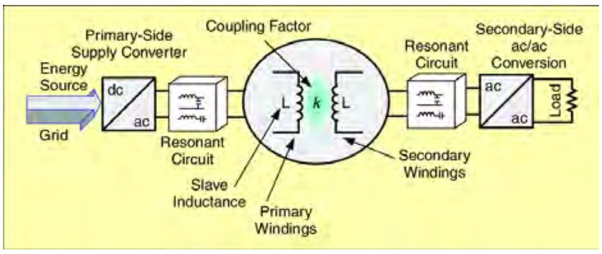

Fig. 3 The basic principles of the inductive CET system [5]

3 Far-field methods

Methods previously described are highly inefficient when it comes to long distances. The solution to this problem is using far-field methods. It can be subdivided in two main techniques.

3.1 Microwave energy transmission

Energy transmission using microwaves consists in sending an electromagnetic beam to a receiver. This energy will later be conducted to a rectenna or "rectifying antenna" which transforms the microwave energy into electricity. One of the disadvantages of this method is the losses along the distance the wave has to travel until arriving at its target. These losses, caused by the diffraction, could be minimized by using big aperture sizes of antennas. However, this solution means a substantial increase in both the cost and space required. Since diffraction depends on the wavelength of the transmitted wave, the frequency could be increased to minimize the diffraction effects, but this would have a negative effect since the atmosphere causes more absorption at smaller wavelengths. An example of the magnitudes involved in the NASA study of solar power satellites, which require a one-kilometer diameter for the transmitting antenna for a microwave beam at 2.45 GHz [6].

3.2 Laser energy transmission

Far distance energy can also be transmitted by sending a laser beam. This mechanism, also known as 'power beaming', consists of converting electrical energy into a laser beam, pointed to a photovoltaic cell that converts the electromagnetic energy of the laser into electric energy again.

Although this energy transmission method is pretty similar to the microwave case discussed in the last section, their biggest difference lies in the wavelength used. While microwave transmission uses wavelengths of the magnitude of the meter, laser energy mechanism works in the range of some hundred nanometers, taking advantage of the atmospheric transparency window in the visible or near field infrared spectrum as shown in Fig. 4 [6].

One of the most important advantage of this method is the lack of reduction in power when increasing the distance from the transmitter to the receiver thanks to the collimated monochromatic wavefront propagation. On the other hand, must be said that its efficiency can considerably decrease for many factors such as photovoltaic cells (40%-50%), atmospheric absorption and scattering by clouds[7].

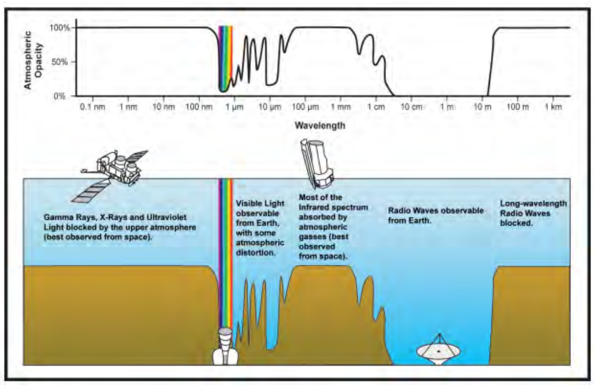

Fig. 4 Absorption spectrum of the atmosphere. (source: NASA)

4 Applications

For future terms of wirelessly transmitted energy, the applications seem to be infinite. From medical devices to satellites, from transportation systems and vehicles to household appliances. Developments in this field would certainly have a high impact in technology as known today and produce a before-after effect in some of the daily aspects of society.

Nowadays, near field methods are being used for development of products such as contactless-stands to charge smartphones. Applying these methods to a vehicle, it could be charged not only while being parked, but also while being driven in special charging lanes. This would solve some current range issues for some of the electrical vehicles present in the market today [1].

For the astronautics side, far-field energy transfers are the next step. Radiative electromagnetic waves, also known as microwaves, and lasers are viable options for energy transmission. Solar power satellites, which would absorb heat from the sun and convert it into microwaves, would produce power and send it down to earth, which would be received by special antennas, and from those antennas directly as electric power [1]. Empowering electrical aircraft in flight with this method could maybe be possible soon.

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