A REVIEW ON CONTACTLESS ENERGY TRANSFER SYSTEM

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ABSTRACT: **-**The aim of this paper is a review on power electronics based contactless energy transfer systems. Various techniques of the contactless energy transfer systems are divided according to a medium used for energy transfer and presented in the following groups: radiative and non-radiative contactless energy transfer systems. The basic principles and the latest developments of these techniques with special focus on resonant inductively coupled solutions have been systematically described in this paper. The advantages and limitations have been briefly examined, and the application field where each technique is particularly suited has been indicated.

KEYWORDS: Radio Frequency Identification, Electro Magnetic Force, Solar Power Satellite, Micro Power Transmission, Wireless Power Transmission.

I.INTRODUCTION

Contactless energy transfer is the transmission of electrical power from a power source to a consuming device without using conductors or solid wires. It was a generic term that refers to a number of different power transfer technologies that use time-varying electromagnetic fields. Contactless energy transmission is useful to power electrical devices in cases where interconnecting wires are hazardous, inconvenient, or are not possible[1]. In wireless power transmission, a transmitter device connected to a power source, for example mains power lines, transmits power by electromagnetic fields across an intervening space to one or more receiver devices, where it is converted back to electric power and utilized. As per the studies most of the electrical energy is transferred through wires, but most of the electrical energy losses takes place during transmission time.

Contactless energy transfer techniques divided into two categories, that is radiative and non-radiativeornear-field and far-field techniques. In the non-radiative techniques power is transferred over short distances by magnetic fields using inductive coupling between coils of wire or in a few devices by electric fields using capacitive coupling between electrodes[1].Applications for this type are electric toothbrush chargers, RFID tags, smartcards, and chargers for implantable medical devices like artificial cardiac pacemakers, and inductive powering or charging of electric vehicles like trains or buses. A current focus is developing wireless systems to charge mobile and handheld computing devices such as digital music players, cell phones, and portable computers without being tethered to a wall plug. In radiative or far-field techniques it is also called power beaming. In this technique power is transmitted by beams of electromagnetic radiation, like microwaves or laser beams. These techniques can transmit energy to longer distances but must be aimed at the receiver. Applications for this type are solar power satellites, and wireless powered drone aircraft.

Contactless energy transmission is refers to a number of different technologies for transmitting power by means of time-varying electromagnetic fields. Also in general a contactless energy system consists of a transmitter device connected to a source of power such as mains power lines and which converts the power to a time-varying electromagnetic field[2]. And it consist of one or more receiver devices which receive the power, then convert it back to DC or AC electric power which is consumed by an electrical load. By some type of antenna devices input power in the transmitter is converted to an oscillating electromagnetic field. The antennas are also known as coupling devices. The antenna used here is may be a coil of wire which generates a magnetic field, or a metal plate which generates an electric field, or an antenna which radiates radio waves, or a laser which generates light. The receiver consists of a similar antenna which will converts the oscillating fields to an electric current. An important parameter which is used to determines the type frequency's' in hertz of the oscillations. The frequency determines the wavelength of the waves which carry the energy across the gap$\lambda=c/f$,where '**c**' is the velocity of light.

II.CLASSIFICATION OF CONTACTLESS ENERGY TRANSFER

The electric and magnetic fields were created by charged particles such as electrons. A stationary charge will creates an electrostatic field around it. A steady current of charges or DC will creates a static magnetic field around it. The above fields will contain energy, but it cannot carry power because they are static. However the power can be carry by time-varying fields. The accelerating electric charges, such as they are found in an alternating current of electrons in a wire, create time-varying electric and magnetic fields around them. These fields can exert oscillating forces on the electrons in a receiving antenna, and it may cause them to move back and forth. These represent an alternating current which may 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, which may depends on distance from the antenna. The characteristics of these regions are different, and different technologies are used for transmitting power.

III. NON-RADIATIVE OR NEAR-FIELD

This type of techniques means the area within about one wavelength (λ) of the antenna. In this region the oscillating electric and magnetic fields are separateand power can be transferred viamagnetic fields by inductive couplingor via electric fields by capacitive coupling or electrostatic induction between metal electrodes or electromagnetic induction between coils of wire. These fields are not radiative, that is which means the energy stays within a short distance of the transmitter. If there is no receiving device or an absorbing material within their limited range to couple to, then no power leaves to the transmitter. The range of these fields is short, and depends on the shape and size of the "antenna" devices, which may be coils of wire. The fields, and thus the power transmitted, decrease exponentially with respect to the distance.

A. Inductive coupling

Inductive power transfer is the transmission of power between coils of wire by a magnetic field. The transmitter coil and receiver coils together form a transformer. An alternating current through the transmitter coil (L1) creates an oscillating magnetic field (B) by the Ampere's law. The magnetic field passes through the receiving coil (L2), and thenit induces an alternating EMF by the Faraday's law of electromagnetic induction, which will creates an AC current in the receiver. The induced alternating current may either directly drive the load, or be rectified to direct current (DC) by using a rectifier in the receiver, which drives the load [1].

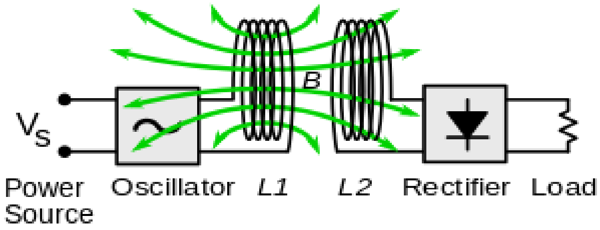

Fig.1 Inductive Coupling

The fig.1 shows the inductive coupling. The inductive coupling is the oldest and most widely used wireless power technology and the only one so far which is used in commercial products[4]. It is used in inductive charging stands for cordless appliances used in the wet environments to reduce the risk of electric shock, for example electric toothbrushes and shavers.It is also used to charge electric vehicles such as electric cars and to either charge or power transit vehicles like buses and trains. The power transferred increases with frequency and the mutual inductance M between the coils. A widely-used figure of merit is that the coupling coefficient $K = M/\sqrt{L1\ L2}$. This dimensionless parameter is equal to the fraction of flux through the inductor L1 that passes through the inductorL2. If the two coils are on the same axis and close together then all the magnetic flux from L1 passes through L2, also k = 1 and the link efficiency approaches to 100%. For greater separation between the coils, results more of the magnetic field from the first coil misses the second, and the lower k and the link efficiency are approaching to zero at the large separations. In order to achieve high efficiency, the coils must be very close together. Ordinary inductive coupling can only achieve high efficiency when the coils are very close together, usually adjacent. In most modern inductive systems resonant inductive coupling is used, in which the efficiency is increased by using resonant circuits. This can achieve high efficiencies at greater distances than non-resonant inductive coupling[5].

B. Resonant Inductive Coupling

It is the combination of inductive coupling and resonant. The resonance will makes the interaction of two objects very strongly. The power is coupled into the transmitter resonator, and out of the receiver resonator into the rectifier, by small cois. Resonant inductive coupling is a form of inductive coupling in which power is transferred by magnetic fields (B) between two resonant circuits or tuned circuits that is one circuit in the transmitter and the other in the receiver. 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[2]. The maximum power can be 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 widely incorporated in the modern inductive wireless power systems. One of the possibilities envisioned for this technology is wireless power coverage. 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. The fig.2 shows the resonant inductive coupling.

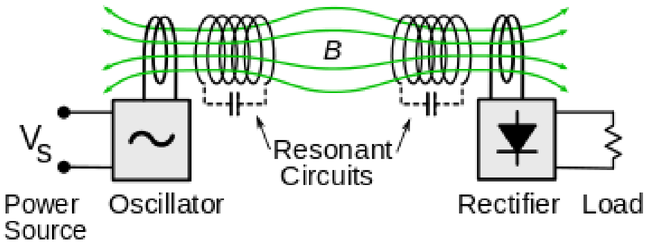

Fig.2 Resonant Inductive Coupling

Although the efficiency is not always shown explicitly in publications on new topologies, as a general rule the best energy converter is that the most efficient one. The efficiency is one of the important reason why the resonant and especially, series loaded series resonant (SLSR) power converters are constantly gaining popularity.

The model of the SLSR consists of two separate equivalent circuits which is derived from the complete equivalent circuit. The two equivalent circuits represent the approximated behaviour of the primary and the secondary sides of the converter sections. Through this approach, the ideal converter analysis can be directly applied, to making it easier to obtain the converter output characteristics and thus allowing a faster evaluation of the converter performance.

Due to the circuit complexity, this type of approach is more effective to allow a rapid evaluation of the converter variables for large variations of the operation regimes.

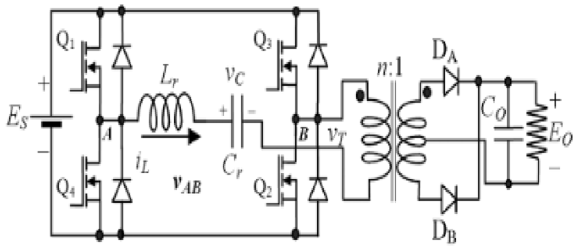

Fig.3 Basic power circuit

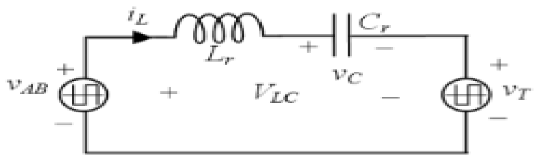

Fig.4 Equivalent circuit

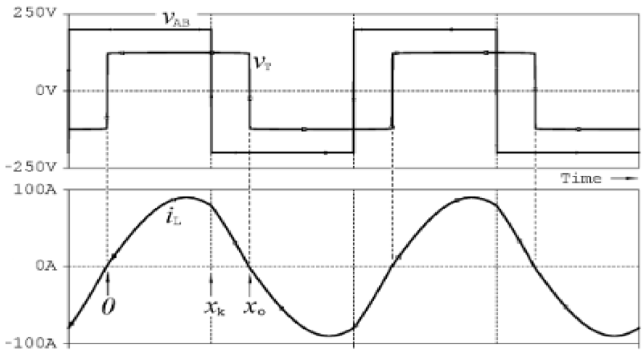

Fig.5 Typical state variables waveforms

C.Modes Of Operation

A general power circuit of the ideal SLSR converter is presented in Fig.3. One of the possible modes of operation is characterized by alternate closing of the switches Q_1 and Q_2 (respectively Q_3 and Q_4) at a frequency above the resonant frequency. That is in a super-resonant mode. The other techniques of switching can be selected for the same topology and some variations of the topology are known as well. But in general, the circuit of figure represents the most important idea to guarantee zero voltage switching (ZVS) for all possible modes of operation.For the non-ideal SLSR consider a converter with a loosely coupled transformer. It would be convenient to apply the normalized notation used and where an ideal transformer is assumed in the analysis. The normalization of voltages, currents, frequency, etc. serves well the aim of obtaining generalized expressions that can be used to describe any specific converter. The analysis of the ideal converter will be results in the calculations of the state variables i_L and v_C as illustrated by the equivalent circuit in Fig4. Providing that the output capacitor c_o will sufficient to maintain a constant output voltage during at least one switching period, the load can be replaced by an ideal voltage source E_o. The output rectifier diodes D_A and D_B will conduct the positive and negative half-waves of the resonant current, also imposing at the transformer primary terminals an alternating square wave voltage v_T, it's polarity always opposes the direction of the resonant current. The amplitude of the voltage v_T is equal to the transformed voltage nE_0, where is the transformer ratio. The operation of the idealized SLSR converter is, therefore, the equivalent to the excitation of an LC circuit by the combination of two alternating square voltages v_T and v_{AB}, may be in out of phase. The voltage v_{AB} is generated by the switching action of the switches Q_1, Q_2, Q_3 and Q_4 and its amplitude is equal to the input voltage E_S. Together with the voltage v_T, the voltage v_{AB} is presented in Fig.5. The excitation voltage V_{LC} for the LC resonant circuit is formed by the addition of the voltage sources $v_{AB}$and v_T hence, during the switching period this voltage assumes consequently the values: E_S-E_0, $-E_S-E_0$, $-E_S+E_0$ or E_S+E_0. In the frequency mode (FM) of regulation, the current in the resonant LC circuit is continuous. This means that during the four different time intervals of operation, corresponding to the four different values of the excitation voltage V_{LC}, the value of current in the LC loop has no interruption. This requires that all the voltages are from now on, divided by the input voltage. So the normalized output voltage is denoted as $q=E_0/E_S$. The normalization of the currents is done by multiplying their real value by Z_r/E_S, where the Z_r is the characteristic impedance.

IV.RADATIVE OR FAR-FIELD

Beyond about one wavelength (λ) of the antenna, the electric and magnetic fields are perpendicular to each other and they propagate as an electromagnetic wave, for examples are radio waves, microwaves, or light waves. This part of the energy is radiative, which means that 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 the lost to the system. The amount of power emitted as electromagnetic waves by an antenna depends on the ratio of the antenna's size D_{ant} to the wavelength of the wave'sλ, which is determined by the frequency. That is $\lambda = c/f$. At low frequencies f where the antenna is much smaller than the size of the waves, $D_{ant} << \lambda$, 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 $D_{ant} \approx \lambda$ such as monopole or dipole antennas radiate power efficiently, but the electromagnetic waves are radiated in all directions, 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[6].

Far field methods achieve longer ranges, often multiple kilometre ranges, where the distance is much greater than the diameter of the device. The main reason for longer ranges with radio wave and optical devices is the fact that electromagnetic radiation in the far-field can be made to match the shape of the receiving area using high directivity antennas or well-collimated laser beams. The maximum directivity for antennas is physically limited by diffraction. In general, visible light from lasers and microwaves from purpose-designed antennas are the forms of electromagnetic radiation best suited to energy transfer. The dimensions of the components may be dictated by the distance from transmitter to receiver, the wavelength and the Rayleigh criterion or diffraction limit, used in standard radio frequency antenna design, which also applies to lasers. Airy's diffraction limit is also frequently used to determine an approximate spot size at an arbitrary distance from the aperture[6]. Electromagnetic radiation experiences less diffraction at shorter wavelengths with higher frequencies so, for example, a blue laser is diffracted less than a red one.

The Rayleigh criterion dictates that any radio wave, microwave or laser beam will spread and become weaker and diffuse over distance; the larger the transmitter antenna or laser aperture compared to the wavelength of radiation, the tighter the beam and the less it will spread as a function of distance (and vice versa)[7]. Smaller antennae also suffer from excessive losses due to side lobes. However, the concept of laser aperture considerably differs from an antenna. Typically, a laser aperture much larger than the wavelength induces multi-modes radiation and mostly collimators are used before emitted radiation couples into space. Ultimately, beam width is physically determined by diffraction due to the dish size in relation to the wavelength of the electromagnetic radiation used to make the beam. Microwave power beaming can be more efficient than lasers, and is less prone to atmospheric attenuation caused by dust or water vapour. Then the power levels are calculated by combining the above parameters together, and adding in the gains and losses due to the antenna characteristics and the transparency and dispersion of the medium through which the radiation passes. That process is known as calculating a link budget.

V. SUMMERY AND CONCLUSION

Contactless energy transmission is the transmission of electrical power from a power source to a consuming device without using solid wires or conductors. . As per the studies most of the electrical energy is transferred through wires, but most of the electrical energy losses takes place during transmission time. Contactless Energy Transfer techniques can be generally divided into two based on medium used: non-radiative and radiative (near-field and far-field). The basic principles and the latest developments of these techniques have been described in this paper. The advantages and limitations have been briefly examined, and the application field where each technique is particularly suited has been indicated. The contactless energy transfer is highly efficient and its maintenance cost is veryhigh. But it has high initial cost. Alsobetter than the conventional wired energy transfer. In contactless energy transfer the losses are less. In near future world will be completely wireless.

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