WIRELESS ENERGY TRANSFER USING RESONANT INDUCTIVE COUPLING

RAJESWARI BALASUBRAMANIAM

Department Of Electrical Engineering, SSN College of Engineering

Abstract ¨C This paper presents a concept of transmission of electrical energy from a power source to an electrical load without physical conducting medium. It is based on the well known principle of resonant inductive coupling and, in particular, resonant evanescent coupling [1] .This well known physics leads trivially to the result of energy efficient mid-range wireless energy-exchange. We establish that such a non-radiative scheme can lead to “strong coupling” between two medium distant states and thus could indeed be practical for efficient medium-range wireless energy transfer.

Keywords¡ª Evanascent near field waves, Wavelength, resonance, WPT (Wireless power transfer).

I. INTRODUCTION

One of the major issues in the power system is the losses occurring during the transmission and distribution of electrical power. As the demand increases day by day the power generation increases and simultaneously is the power losses. According to World Resources Institute (WRI) , India’s electricity grid has the highest transmission and distribution losses in the world ¨C a whopping 27%. Since the electrical wire grid carries energy almost everywhere, even a medium range wireless energy transfer would be extremely useful .Even in our day-to-day life the cables, connectors and chargers that we use are often a source of error. Moreover, charger and connectors are not always compatible with different terminal devices, so that each device type needs its own custom-tailored connector and battery charging solution. Wireless energy transmission can eliminate the need for cables and connectors in any equipment. It is the ideal solution when little board space is available and low costs are of paramount importance.

II. POSSIBLE METHODOLOGIES

A.INDUCTIVE COUPLING

Two devices are said to be mutually inductively coupled when they are configured such that change in current though one wire induces a voltage across the ends of the other wire by electromagnetic induction. This is due to the mutual inductance.

B.RESONANT INDUCTIVE COUPLING

RIC is the combination of both inductive coupling and resonance. Using the concept of resonance it makes the two objects to interact with each other very strongly. Inductance induces current in the circuit. The capacitor is connected in parallel to the coil. Energy will be shifting back and forth between magnetic field surrounding the coil and electric field around the capacitor. Here the radiation loss will be negligible

C.LASER Technology

The LASER Technology is another efficient way of wireless power transmission. It uses the same possibility as microwave wireless transmission but here energy emission is of high frequency and is coherent. Research organisations like NASA, ENTECH, and UAH have been working on this project as a means to transmit power wirelessly. The other great advantage of LASER power transmission is the aperture collection efficiency which is that antenna can be made small sized as these are the calumniated beams. LASER transmission does not get dispersed for long distance but it gets attenuated when it propagates though atmosphere.

D.OMNI-DIRECTIONAL ANTENNAS

This is the idea of implementing the means of wireless communication techniques onto wireless power transfer in which the same transmitter receiver pair must be able to transmit sufficient power.

III. DEMERITS OF VARIOUS TECHNIQUES

In the case of Inductive coupling the range is very small also the interaction is one-one only and finally efficiency of transmission is very less. When it comes to LASER technology, it requires existence of an uninterruptible line-of-sight and a complicated tracking system in the case of mobile objects. Omni-directional antennas (which work very well for information transfer) are not suitable for such energy transfer, because a vast majority of energy is wasted into free space.

IV. WHY CHOOSE RESONANT INDUCTIVE COUPLING?

- High efficiency (around 70.3%)
- Range of transmission is high
- One to many mode of transfer

. Simpler design

V. RESONANT INDUCTIVE COUPLING IN DETAIL

A slight modification to inductive coupling brings the concept of resonant inductive coupling. the common example for mutual inductance is a transformer where an alternating supply given to the primary induces an alternating flux this further induces emf on any conducting material in its vicinity (Faraday’s Law), but the major drawback with this technique is that a large amount of this power transmitted is lost in air if the range between the two coils increases. Any conducting material in its vicinity draws power which must not occur. So, in order to prevent these draw backs the transmitter and the receiver are made to couple through resonance. Resonance is a condition in which a system or device will oscillate at maximum amplitude at a certain frequency. At resonance, the stored electric energy and Stored magnetic energy are equal. Circuits consisting of inductors and capacitors have a certain resonant frequency at which the stored energy is released. At this frequency, maximum power transfer is conducted between two devices. For instance, if a large transmitting coil resonates at 1 MHz , then only devices that resonate at 1 MHz (or at frequencies within a small band around 1 MHz) can optimally receive energy from the transmitter.

Larger size coils can couple their magnetic fields at longer distances. In addition, larger size coils have larger values of inductance which results in a decreased resonant frequency. Similarly, larger electrodes can couple electric Fields at longer distances, and this increase in size results in larger capacitances, which also decreases the resonant frequency. So by operating at a “low-enough” frequency, the range of coupling energy (maximum distance between elements that can still facilitate coupling) can be significantly increased in comparison the necessary close distance of the coil. However, there is a trade off between the coupling distance and the size of the coupling device. The inductance and capacitance needs to be large enough to couple at a long istance without significantly increasing the size of the coupling devices. The quality factor (or Q-factor) is a dimensionless quantity that measures the amount of energy stored in the reactive components to the power lost due to resistance. A higher Q-factor means that less power is lost at resonance. Also, a device with a higher Q-factor results in a narrower band of frequencies in which energy will be released from its stored state at resonance.

For evanescent wave coupling at resonance, it is necessary to design the transmitter and receiver resonators with as high a Q-factor as possible (bandwidth as low as possible) so devices operating at frequencies close to the band around the resonant frequency will not be excited, but the band has to be large enough to account for frequency shifts in the handling and manufacturing of the device. The positive point of view of this approach is that the distance between coupling elements can be larger than that required in some current device-charging method. In addition, since the region of operation is not in the far-field, you do not have to worry about wasted power being radiated into free space.

Any coil by default, due to its structure has inductive property. When a capacitor of suitable rating is connected in parallel to it, it forms an L-C oscillator circuit, if the oscillator of the transmitter syncs with the oscillator formed with the receiver then both are said to be coupled. Thus by resonance, the energy is directed(energy tunnel) only to those receivers that are resonatively coupled with the transmitter hence avoiding transfer to unwanted materials, enabling One-Many transfer .

The phenomenon of resonance also prevents the wastage of energy into air thereby increasing the transmission efficiency.

VI. USE OF NEAR FIELD CONCEPT IN RESONANT INDUCTIVE COUPLING

WHAT IS NEAR FIELD?

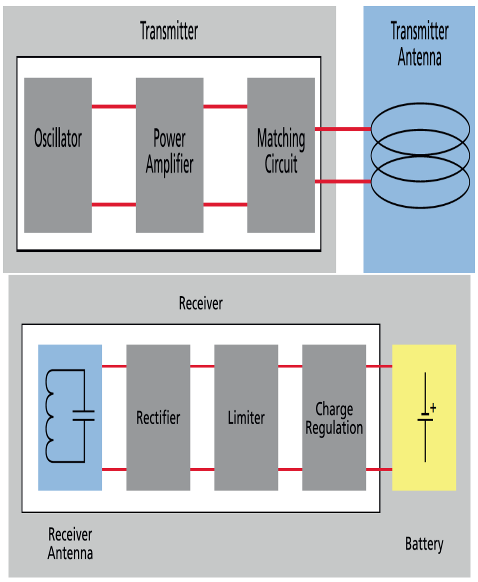
The near field (or near-field) and far field (or far-field) and the transition zone are regions of time varying electromagnetic field around any object that serves as a source for the field. The different terms for these regions describe the way characteristics of an EM field change with distance from the charges and currents in the object that are the sources of the changing electromagnetic (EM) field. The more distant parts of the far-field are identified with classical electromagnetic radiation.

The basic reason an EM field changes in character with distance from its source is that Maxwell's equations prescribe different behaviours for each of the two source-terms of electric fields and also the two source-terms for magnetic fields. Electric fields produced by charge distributions have a different character than those produced by changing magnetic fields. Similarly, Maxwell's equations show a differing behaviour for the magnetic fields produced by electric currents, versus magnetic fields produced by changing electric fields. For these reasons, in the region very close to currents and charge-separations, the EM field is dominated by electric and magnetic components produced directly by currents and charge-separations, and these effects together produce the EM **"near field."**

EFFECTIVENESS OF NEAR FIELD

In the near field region of an electromagnetic wave the electric field and the magnetic field are independent of each other. Therefore each will not affect the other by any chance.The electric field and the magnetic field are the strongest in these regions therefore transmission efficiency is drastically increased. Near field region is less than 1ƒÜ(wavelength) of the transmitted EM wave. The exact near field region is (ƒÜ/2ƒà) i.e. 0.159ƒÜ. so as the wavelength increases the near field region .If the antenna is of loop structure the magnetic field dominates in the near field region hence flux produced is also more therefore coupling and hence efficiency is more. The most important reason for using the near field is that, when receiver is placed in the near field, depending on the amount of field *absorbed by it, the power consumed across the* transmitter also varies (transformer action). Whereas in far field the energy absorbed by the receiver can remain constant only as power absorbed by transmitter is always constant irrespective of any disruption across the receiver.

VII. GENERALISED BLOCK DIAGRAM OF WIRELESS TRANSMISSION



Transmitter

The transmitter is built of an oscillator, a power amplifier and an antenna with a matching circuit. Given an optimal antenna design [2] the transmission power of the transmitter is minimized. If data communication with the supplied device is needed, the electromagnetic field is modulated. If several devices are supplied by the wireless energy transmission system they can be charged simultaneously with the same transmitter system.

Receiver

The receiver captures energy from the electromagnetic field produced by a stationary transmitter in order to transfer as much energy as possible, its antenna forms a resonant circuit with a capacitor .This antenna can be built using either foil or a few windings of plain copper wire depending on the application and the amount of space available. For the supply of the electronic system of the receiver, as well as for the charging of the battery, the induced AC signal needs to be rectified to produce a constant output voltage .In addition, a limiter is needed to protect the downstream circuit blocks against overvoltage and voltage spikes.

CHALLENGES

To sustain the constant power level, there are few challenges for WPT. This technology is young and many researches *are underway to incorporate the short* comings .Since the world is lit by electricity and every electrical device is fed with wires, it will be biggest challenge to implement the WPT technology. There should be a complete revolution in the electrical world for manufacturing and designing.

CONCLUSION

The Wireless Power Transmission is noble technology in principle put forward by NikolaTesla. WPT has the potential to change the face of this planet with its implementation with the revolution starting from electronics to the satellites. Ranging from charging the handset to changing the effect of global warming WPT has the answer. Though the practical implementation are limited at this stage due to lack of knowledge and technology, and limited frequency ranges yet the studies are on and there can be alternative to the Earth's burden of other harmful techniques. Currently wireless power transfer is the most marketable and sustainable alternative to the conventional techniques.

REFERENCES

[1] " Efficient wireless non-radiative mid- range energy transfer" by Aristeidis Karalis*, J.D. Joannopoulos, and Marin Soljačić. Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology

[2] "Design of Wireless Power Transfer and DataTelemetry System for Biomedical Applications" Ashraf Bin Islam University of Tennessee

[3] N. Tesla, "Apparatus for Transmitting Electrical Energy," U.S. Patent, 1902.

★★★