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A Survey on Wire Free Power Transmission in Biomedical Implants

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ABSTRACT: Wire free transmission technique for the implantable devices is one of the main applications of Wireless Power Transmission (WPT). This paper deals with the techniques used for wireless power transmission in the field of biomedical implanted devices. The power transmission efficiency of resonance inductive method is higher than inductive power transmission method. The four coil system is used in the resonance method, the primary and secondary are independent to the source and load resistances. The health hazards and malfunction due to low power are the major problems in this field.

KEYWORDS: inductive, resonance-inductive, WPT, implantable devices, transcutaneous cables

I. INTRODUCTION

The Wireless Power Transmission (WPT) is a technique used for the wire free transmission purpose. Nikola Tesla, the man who dreamed about power transmission. Nikola Tesla invented a coil (Tesla Coil) to produce electromagnetic waves with about 8 Hz frequency transmitted between the earth and its ionosphere for transferring the power [1].

There are two methods used for power transmission. They are near field and far field transmission. The power can transfer to very short distance is called near field transmission. The near field power transmission technique is mainly two types, inductive and resonant power transmission. The main emerging applications of WPT's are battery-free implanted devices for biomedical engineering, contact less RFID for security application and transportations, and wire free charging and powering of electronic vehicles and electronic devices [2].

Previously, transcutaneous power cables were used for implantable devices. Surgical procedures for replacement and potential risk of leakage of batteries are the major disadvantages [3]. Compared to batteries, WPT is an alternative method for powering implantable devices. If it implanted properly, consequently produce increased implant robustness and miniaturization of the device. Inductive coupling method is used for power transmission in the biomedical field. In this field WPT was first used to power an artificial heart and since then has applicable for all the implantable devices [4]. An inductive power transfer system consists of two coils that are referred to as primary and secondary. Coupling between coils depends on the amount of magnetic flux linkage between the primary and secondary coils. The distance between the primary and secondary and length of the coils helps to increase the amount of magnetic flux. If the primary and secondary coils are not well aligned the Power Transmission Efficiency (PTE) will drop down.

II. INDUCTIVELY POWERING FOR IMPLANTABLE BIOMEDICAL DEVICES

In this method, primary coil transfers the energy into secondary coil. In between these coils multiple layers of human tissues are existed. When the energy receives the secondary coil, the implanted devices will rectify and regulates as a dc supply. Power amplifier is driven continues the power transmission in the primary side. Class E power amplifiers have been widely used for high frequency transmission. This is more efficient for high frequency operations [5]. M.A. Adeeb, et.al presented a concept of "an inductive powering and backward data communication link based on COTS (Commercial Off-the Shelf) Components". The test result shows that inductive link can transmit power to a distance of 1.16cm with 125mV at 5V [6]. The link efficiency described as the power of secondary coil by the power of primary coil.

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The challenging task for the researchers is to increase the link efficiency. If the inductive based system is used in an implantable biomedical application, misalignment of the coil may occur at any time. It will cause a reduction in the coupling efficiency of the system. Three types of misalignment can happen, change in coil spacing, lateral misalignment or angular misalignment. The coupling of both coils is the coupling factor (k) defined by

$$k = M \times \sqrt{(L_T \times L_R)}$$

Where

k= coupling factor

M= mutual inductance.

L_T =self inductance of the transmitting coil.

L_R = self inductance of the receiving coil.

III. RESONANCE- BASED POWERING FOR IMPLANTABLE BIOMEDICAL DEVICES

Resonance based power delivery is an alternative WPT technique. In this techniques, it uses four coils; driver, primary, secondary and load coils. These methods concentrate on high power transfer for implantable devices. For the high power transfer, it requires big coils. Resonance method uses large transmitter coils for multiple implantable devices. One coil can transfer the whole power for internal devices. Resonance method uses inductive coupling between the driver and primary coils, same as for the secondary and load coils. Anil Kumar RamRakhyani and his friends presented a concept of resonance based power transmission. In their paper shows that, the distance between primary and secondary coils varies from 6mm to 52mm. These distances are relatively large for high power transmission. The efficiency was lays above 70%, at the 32mm operating distance [7]. The two coil based coupling efficiency is given by [8 and 9],

$$\eta = \frac{k^2 Q_p Q_s}{1 + k^2 Q_p Q_s}$$

Where

k= mutual coupling

Q_p = Q factor of primary coil

Q_s = Q factor of secondary coil

The efficiency of the four coil system is given by [7],

$$\eta \cong \frac{k_{2s}^2 Q_2 Q_s}{1 + k_{2s}^2 Q_2 Q_s}$$

Where

k_{2s} = coupling coefficient between primary and secondary coils

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Q_2 = Q factor of coil 2 (primary)

Q_3 = Q factor of coil 3 (secondary)

This approximate equation is similar to the two coil system. In the four coil system, the primary and secondary are independent of the source and load resistances. This helps to increase the power transfer efficiency compared to two coils based power transfer system. The researchers propose Litz wires for coil, it commonly reduce the ac resistance.

IV. COMPARISON TABLE

Factors	Inductive Coupling	Resonance- Inductive Coupling
Range	Short	Mid
Directivity	Low	Low
Frequency	Hz-MHz	KHz-GHz
Transmission System	Wire coils	Wire coils with resonators
Applications	Electric tooth brushes, induction stove tops and industrial heaters, biomedical implants, etc	Charging portable devices, biomedical implants, powering vehicles, etc

V. MAJOR PROBLEMS IN THE FIELD OF BIOMEDICAL POWER TRANSMISSION

Health hazards are the major problems in this field, a strong magnetic field is needed for high power applications which would damage the tissues due to excessive heat. This is the violations of safety requirements of the federal regulations. The distances variations and misalignments between the coils are the main causes to reduce the efficiency [10]. The too little power leads to malfunction and it will affect the human body organs.

A large coupling factor improves the transfer efficiency and reduces losses and heating up devices. A tightly coupled coil always gives higher efficiency and produces less heat. There are 2 conditions for tightly coupled coils;

A. The coils have the same size and

B. The distance between the coils is much less than diameter of the coils

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VI. CONCLUSION

Biomedical fields, uses two types of wireless power transmission techniques. They are: inductive and resonance inductive power transmission. Inductive power transmission uses two coil system and resonance methods uses four coil systems. Compared to inductive methods, resonance inductive methods provide high efficiency. Multi-coil transmission methods are also possible in this technique. The major challenges in the implantable devices are health hazards and low efficiency due to misalignment.

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