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Compensation topologies for wireless power transmission system in medical implant applications: A review

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ABSTRACT

This review paper addresses and discusses the challenge of selecting the best topology for a wireless power transmission (WPT) system for a medical implant application in order to improve power transfer efficiency (PTE). WPT systems using inductive and magnetic resonance coupling (MRC) have been introduced in recent years as a convenient and secure alternative to traditional wired charging systems. Compensation topologies are essential in MRC-WPT system to improve the PTE over certain distances. The fundamental topologies comprising series-series (SS), series-parallel (SP), parallel-series (PS), parallel-parallel (PP), and Series-Non resonant secondary (SN) or primary side series (PSS) are all explored and discussed. The theoretical analysis of power transfer efficiency using reflected impedance theory, as well as the selection of the most relevant topology depending on system requirement and application, are studied and addressed. Resonance frequency selection is necessary to identify the compensation capacitor for magnetically coupled WPT system. IEEE and ICNIRP safety regulations and guidelines for biomedical applications are reviewed and addressed.

1. Introduction

Wireless power transmission system (WPT) is a novel approach along with its benefits of becoming wireless, secure while recharging, as well as the able to accomplish in a humid and hazardous environment. WPT system applications comprise electric toothbrushes, mobile phones with charging platforms, LED lighting, wireless sensor networks, biomedical implant devices, electric vehicles (EVs) etc (Shevchenko et al., 2019; Stuart et al., 2021; Zhou et al., 2020).

WPT systems are mainly classified as far field and near field wireless power transfer systems. WPT systems in the far field operated on radiated electromagnetic waves whereas WPT systems in near field operate on non-radiative energy exchanges within electromagnetic fields at shorter distances. Energy is transmitted in near field WPT via electric or magnetic fields from primary or transmitting (Tx) coil to secondary or receiving (Rx) coil. Near field WPT system can be realized using either capacitive, inductive or magnetic resonance coupling. Capacitive coupling uses electric field to transfer the power with very low efficiency therefore inductive coupling or magnetic resonance coupling using magnetic field is generally used recently to transfer power with higher efficiency. In the presence of muscle tissues, loosely coupled inductive coupling with maximum spacing between primary and secondary coils is often used in biomedical implant applications. Because of the restricted biomedical implant dimension, the size of the secondary coil embedded inside the human body seems to be limited. In contrast to biological implants, applications such as wireless chargers for mobile handsets placed on charging pads and electric cars enable better coupling and secondary coil size limitations are also more relaxed (Barman et al., 2015; Houran et al., 2018; Moore et al., 2019).

Ampere's and Faraday's laws are the foundations of inductive power transmission systems. Alternating current with chosen frequency passing through the primary coil produce time-varying magnetic field that induced a voltage in secondary coil. Tightly coupled systems, such as transformers, and loosely coupled systems are the two forms of inductively coupled power transmission systems (Shadid and Noghanian, 2018; Z. Zhang et al., 2019).

The tightly coupled system is the traditional way of inductively transfer of power that achieves a perfect coupling coefficient as well as highly efficient transfer power with physical interaction. On the other hand, a loosely or uncoupled linked system is a contactless power transmission with a tiny air gap between both the primary and secondary coils that is acceptable for movable objects, such as battery re-

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