Experimental Investigation of Contact Currents in the Vicinity of a Wireless Power Transfer System in 100 kHz Band

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Abstract - **Wireless power transfer systems (WPT) produce high electromagnetic (EM) fields. There are concerns about EM exposure due to WPT systems especially for electric vehicle (EV) which uses relatively high power (up to 7.7 kW). Concerning biological effects due to EM exposure, there are two kink of effects; direct and indirect. The direct effect is related to heat or nerve stimulation while the indirect effect is related to contact currents. We performed an experimental investigation of contact currents induced in a metal plate situated close to a 100 kHz-band WPT. We distinguished two different types of exposure conditions such as ungrounded and grounded conditions, although the contact currents are conventionally considered in such a case when a human body touches to an ungrounded metal object, such as a school bus under EM exposures from broadcast stations. It was indicated that the contact currents of the ungrounded condition may exceed the guideline limit.**

Index Terms — **Wireless power transfer, exposure, contact current, compliance procedure.**

1. Introduction

Recently, the development of power supply using Wireless Power Transfer (WPT) technology is expanding especially for electric vehicle (EV). WPT systems produce relatively high electromagnetic (EM) fields due to high power, e.g., up to 7.7 kW for EVs. Therefore, it is essential to check compliance of each WPT product with EM safety guidelines such as published by International Commission of Non-Ionizing Radiation Protection (ICNIRP) and Institute of Electrical and Electronic Engineers (IEEE) [1-3]. In the EM safety guidelines, there are two kinds of effects; direct and indirect. The direct effect is known as thermal and stimulus effects. Contact current is one of the mechanism of indirect effect.

Contact current is defined as current passed into a biological medium via a contacting electrode or other source of current. Conventionally, the contact currents are considered in such a case when a human body touches to an ungrounded metal object, such as a school bus under EM exposures from broadcast stations. As a result, the difference in potentials between the bus and ground causes currents flowing into the human body. In contrast to the above-mentioned situation, the exposure condition is quite different for WPT systems since only EM near-fields are of concern and their far-field strengths are very low. We performed experimental investigation of contact currents with a metal plate situated close to a 100 kHz-band WPT system. We considered the contact current with not only ungrounded metal but also grounded metal.

2. WPT system and Measurement Conditions

We have fabricated a WPT system operating in 100 kHz band for application of EV charging. Dimensions of transmitting and receiving coils are as follows; inner and outer radii are 24 cm and 45 cm, respectively, and each coil is winded 44 turns. Transmitting and receiving coils are both loaded with a capacitance of 2.1 nF. A 50 Ω load is connected at the end terminal of the receiving coil. Spacing between transmitting and receiving coils is fixed to 0.2 m in all measurements. Using a Network Analyzer (E5071C, Agilent), resonance frequencies of our fabricated WPT system are measured as 110 kHz and 125 kHz and the power transmission efficiencies were approximately 95% and 96%, respectively. Measurement system consists of a signal generator (33210A, Agilent), a power amplifier with 50-dB gain (BSA0110-100, BONN Elektronik GmbH), a 10-dB attenuator for protection of reverse currents from the WPT system, a 30-dB attenuator (58-30-33, Weinschel Engineering) for dissipating the power before flowing into a power sensor (E9304A, Agilent) and a power meter (E4419B, Agilent). Metal plates with a dimension of 200 cm x 100 cm, 120 cm x 120 cm, and 80 cm x 100 cm are placed close to the WPT system. Contact currents are measured by using two type of contact current meters; one is Narda 8870 which simulates a grasping contact and the other made by Japanese company, TRC Co, is embedded with equivalent circuit of human impedance of Japanese population [4].

We consider two different exposure situations; ungrounded and grounded conditions as illustrated in Fig. 1. It is noteworthy that the mechanisms of contact currents in the ungrounded and grounded condition are different. For the ungrounded condition, contact currents occur by potential difference between a metallic body under EM exposure and the ground plane, which is actually due to incident electric field. Contact currents are induced by magnetic flux passing through a loop area created by a human touching a grounded metal for the ground condition. The distance between the ground plane and the metal is fixed to 7.5 cm for the ungrounded condition. An input power of the WPT system is 1 W.

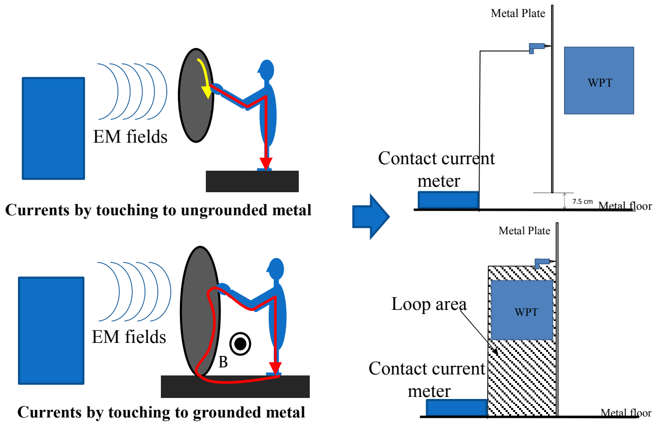

Fig. 1. Two conditions of contact current measurement.

3. Results

For the ungrounded condition, we measured contact currents when an ungrounded metal plate with a size of 200 cm x 100 cm is placed at 1 cm and 20 cm far from the WPT system. The contact currents for an input power of 1 W were about 0.67 mA and 0.23 mA for 1 cm and 20 cm, respectively, at 125 kHz. This is due to abrupt decrease of electric field strength when the distance is changed from 1 cm to 20 cm. Contact currents did not change much when we changed the size of the metal plate to 120 cm x 120 cm or 80 cm x 100 cm. If we scale an input power to 7.7 kW, contact currents will be as high as 58.8 mA and 20.2 mA for a distance of 1 cm and 20 cm, respectively. These values exceed the limit level described in the ICNIRP guidelines for general public case. Therefore, we need to measure contact current to assure compliance with the guidelines for each individual system.

For the grounded condition, we performed measurement of contact currents when a grounded metal plate with a size of 200 cm x 100 cm was placed as close as 1 cm to the WPT system. Distance of the contact loop area to the WPT was 8 cm and the input power was 1 W. We found that the contact currents for the grounded condition are much lower than those of the ungrounded condition, with a factor of more than 10 times, so we do not need to consider the grounded condition for the 100 kHz-band WPT system.

4. Conclusion

Contact currents were measured experimentally using our fabricated WPT system operating in 100 kHz band with input power of 1 W. Although the contact currents are conventionally considered in such a case when a human body touches to an ungrounded metal object, we considered contact currents with not only ungrounded metal but also grounded metal. As a result, the contact current for grounded condition was much lower than that for ungrounded condition. If we scale measured contact current to an input power of 7.7 kW for ungrounded condition , the values can exceed the limit level described in the ICNIRP guideline. This result indicates the necessity of evaluation of contact currents to assure compliance with the guidelines for each individual system.

Acknowledgment

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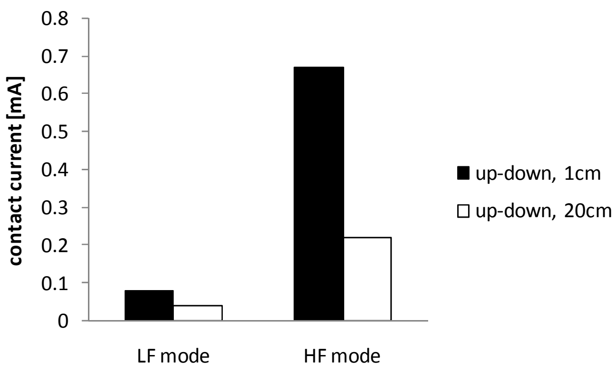

Fig. 2. Contact currents with ungrounded condition.

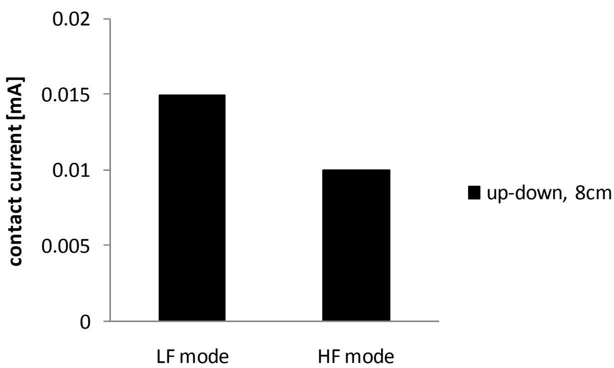

Fig. 3. Contact currents with grounded condition.