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論　文　要　旨
Thesis Abstract

(yyyy/mm/dd) 2016 年 07 月 01 日

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主論文題名 (Title)

13.56MHz high power and high efficiency inverter for dynamic EV charging systems.

内容の要旨 (Abstract)

Recently, Electric Vehicles (EVs) are a promising solution for reducing CO_2 emission and air pollution in the big cities. However, until now, the EVs have been not so attractive to consumers due to the short running distance, long charging time and high battery cost. The dynamic charging solution has been proposed to reduce the energy dependence and battery cost of EVs. As the demand of that systems, a 13.56 MHz high power inverter with the efficiency of over 95% is required. With the previous researches, there are three major research challenges have been recorded. At very high switching frequency such as 13.56 MHz, the influence of the parasitic elements in the circuit is the first challenge because it strongly affect both of power and drive circuit of the inverter. Consequently, the inverter may be damaged or unstable. Secondly, the switching and gate drive power loss in the inverter are also the challenge when it proportionally increase with the switching frequency. At 13.56 MHz, it is difficult to obtain the extremely high efficiency such as 95%. Finally, the high output power required is another challenge due to the low rate-parameters and the challenges in the parallel connecting of the high speed switching devices. To overcome these challenges, a number of the analyses and proposed design are presented in this dissertation.

Firstly, the effect of the parasitic elements in the high switching frequency half-bridge inverter is analyzed and evaluated in detail based on the perspective of the ringing loop in the circuit. Based on these, an optimized PCB design is proposed to minimize the parasitic inductance in the ringing loop of the inverter. With the improved PCB, the experiment results show that, the peak voltage and the amplitude of the ringing current in the circuit is reduced. However, the ZVS condition and the stability of the inverter at high input voltage condition are not achieved due to the high frequency ringing in the circuit. Therefore, a ringing damping circuit is proposed. The high stability and the low power loss on the proposed damping circuit is the advantage to obtain high efficiency of the inverter. In the experiment results, the ringing current in the circuit is damped. A 1.2 kW output power is obtained with the efficiency of 93.1%. This is an improvement in the 13.56 MHz inverter. However, it does not meet the required efficiency of the inverter for the dynamic EV charging systems due to limited switching speed of the silicon-MOSFET.

Secondly, to improve the efficiency of the inverter, the GaN HEMT device is used. In an experiment, the inverter using GaN HEMT obtains the efficiency of 97.5% which shows the potential to meet the required efficiency of the inverter for the dynamic EV charging systems. However, the output power of the inverter is limited due to the low rate current of the GaN HEMT. And the parallel connection of GaN HEMT devices at 13.56 MHz is very difficult because of the strong unbalance dynamic current distribution. Therefore, a design using multiphase resonant inverter is proposed.

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The proposed module design, the proposed power loss analysis method to obtain highest efficiency and the proposed drive circuit design have been addressed in detail. In experiment, a 3 kW inverter with the efficiency of 96.1% is achieved that significantly improves the efficiency of 13.56 MHz inverter. A 10 kW inverter with the efficiency of over 95% will be developed by following this proposed design in near future.

Finally, the 13.56 MHz high power inverter with the efficiency of over 95% can be realizable. However, the Class DE operation mode which is used in multiphase resonant inverter requires exact parameter of load, resonant circuit and several turning in the experiment process. Therefore, it is still difficult to apply in the dynamic charging systems where the parameters of the coupling system will always change in the operation. The inverter behavior analysis and the further researches to keep the soft switching condition in the operation with the dynamic coupling system are necessary in the future work.

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