Design and Demonstration of Dynamic Wireless Power Transfer System for Electric Vehicles

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Introduction

Research Motivation

- **Limits of the battery capacity and the charging technology**
- **The Inconvenience of static wireless charging**
- **The advantages of dynamic wireless charging**

Introduction

Background

- **Oak Ridge National Laboratory shows that the transmission power and efficiency are affected by the position of electric vehicle by the dynamic wireless experiment.**
- **The university of Tokyo has proposed to maximize the charging efficiency by real-time estimation of coupling factor changes to control duty cycle of DC/DC converter.**
- **By using parameter identification techniques, Chongqing University puts forward the energy flow model to solve the problem that the second side parameters are difficult to adjust when the primary side is controlled.**

Modeling of DWPT System

➢ Holistic Analysis

- ◆ **The LCC topology can decouple the output current from the load, bring the stable current and increase the power factor, which can reduce the difficulty of control and improve the efficiency of electric energy transmission.**
- ◆ **The LCC compensation network makes the system a constant current source and is suitable for lithium battery charging.**

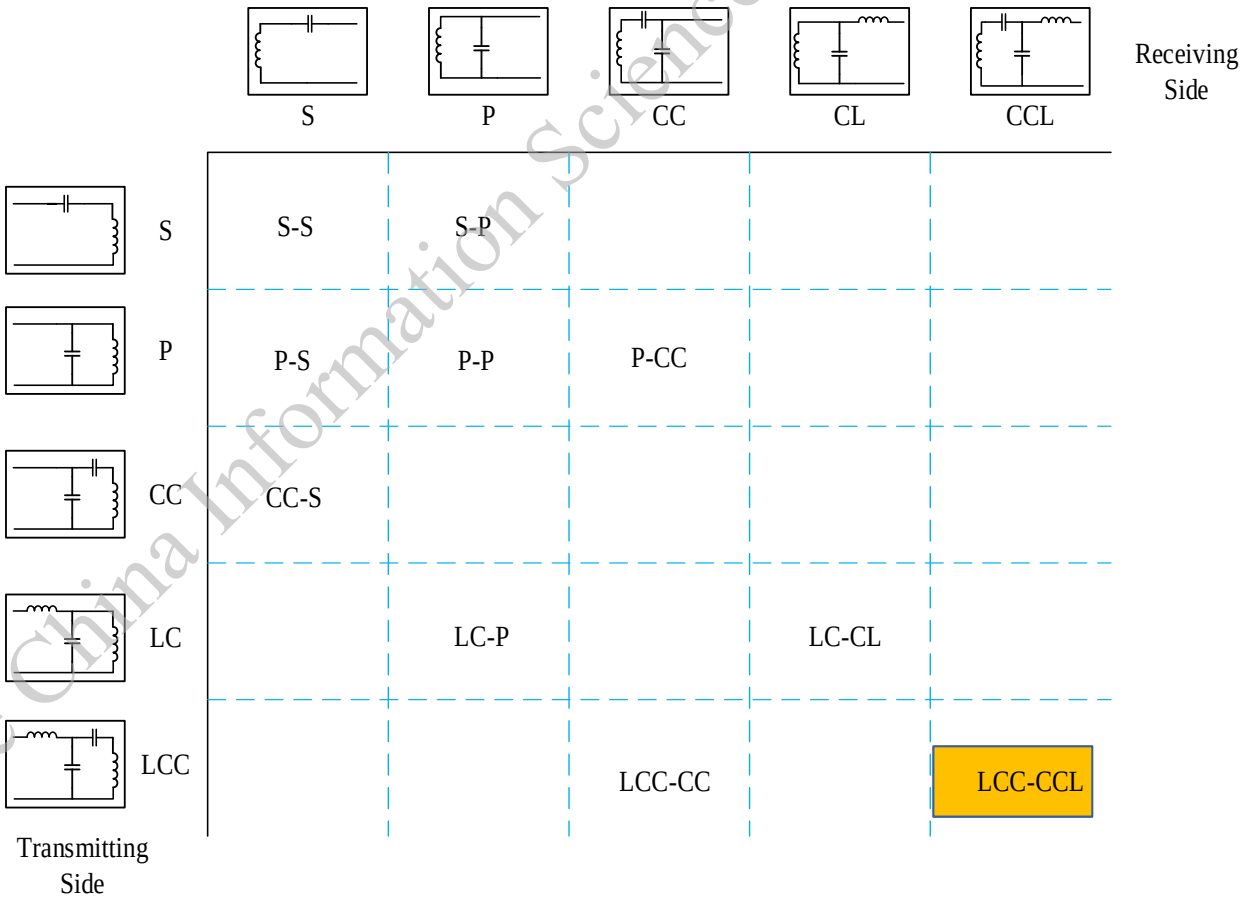


Figure 1 :Different combinations of compensation networks

Modeling of DWPT System

➢ Holistic Analysis

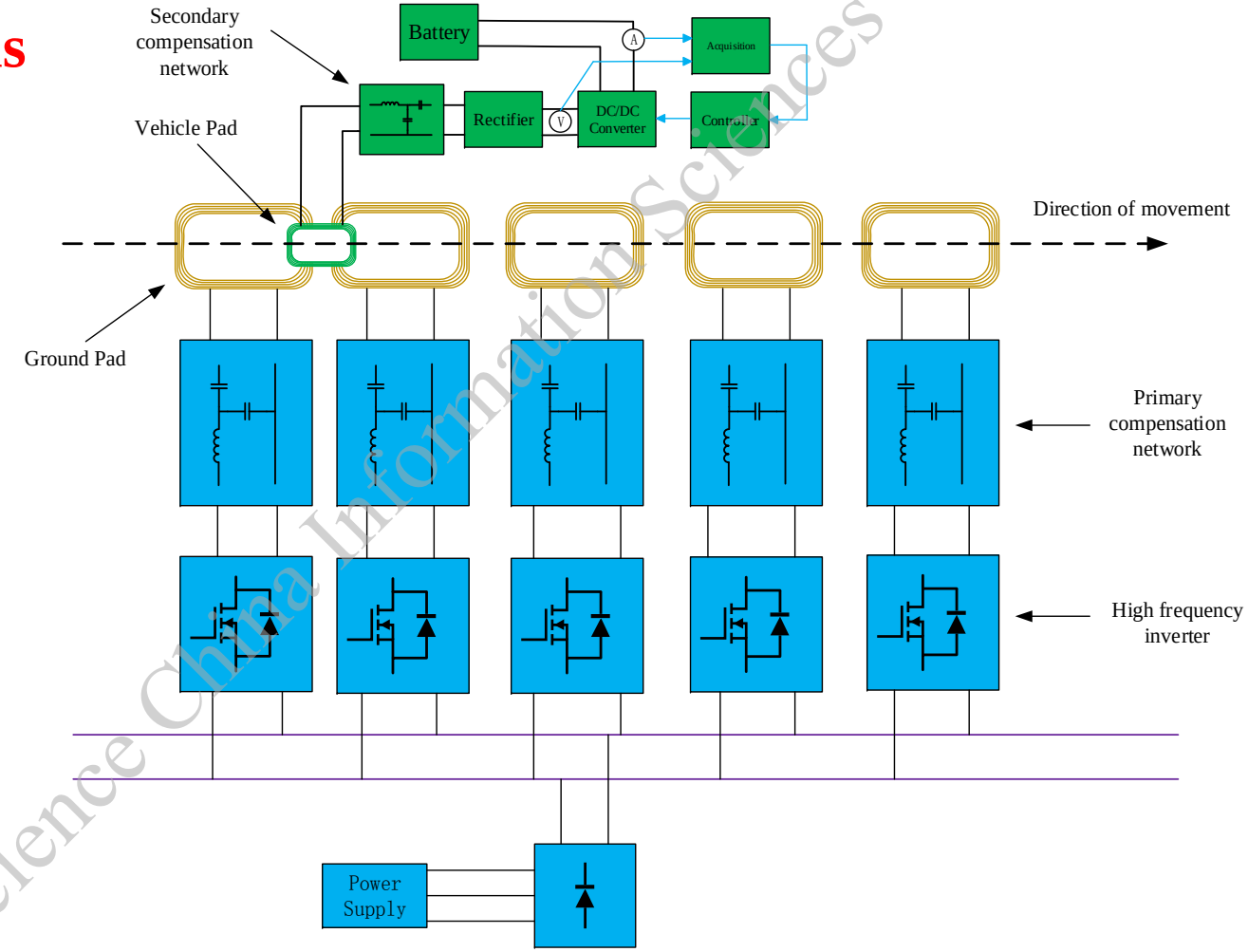


Figure 2 :The topology of dynamic wireless power transfer system

Modeling of DWPT System

➢ LCC Network Analysis

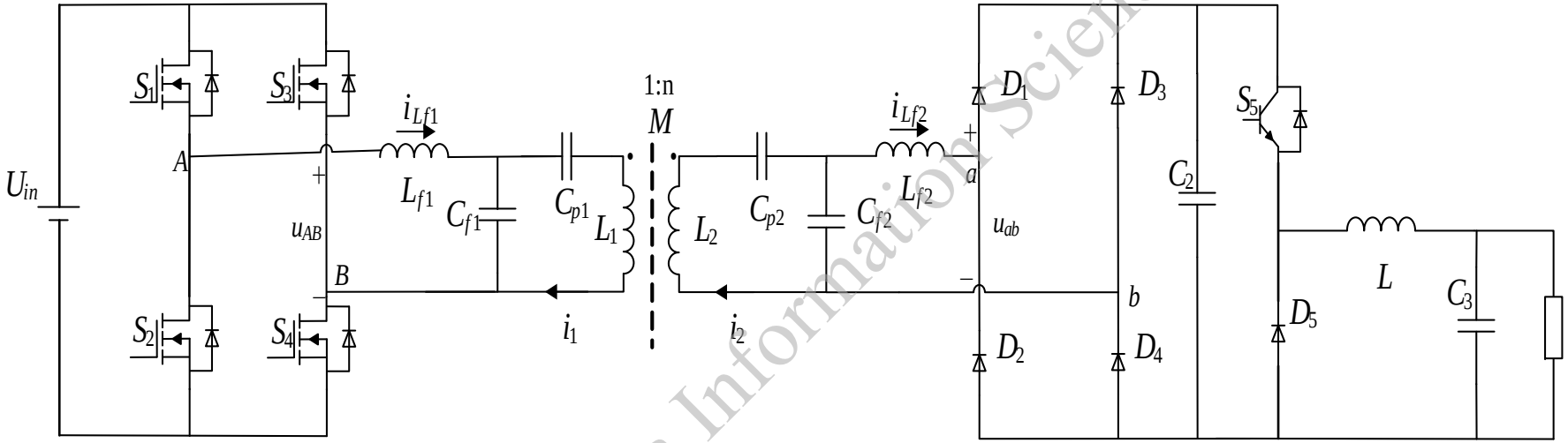


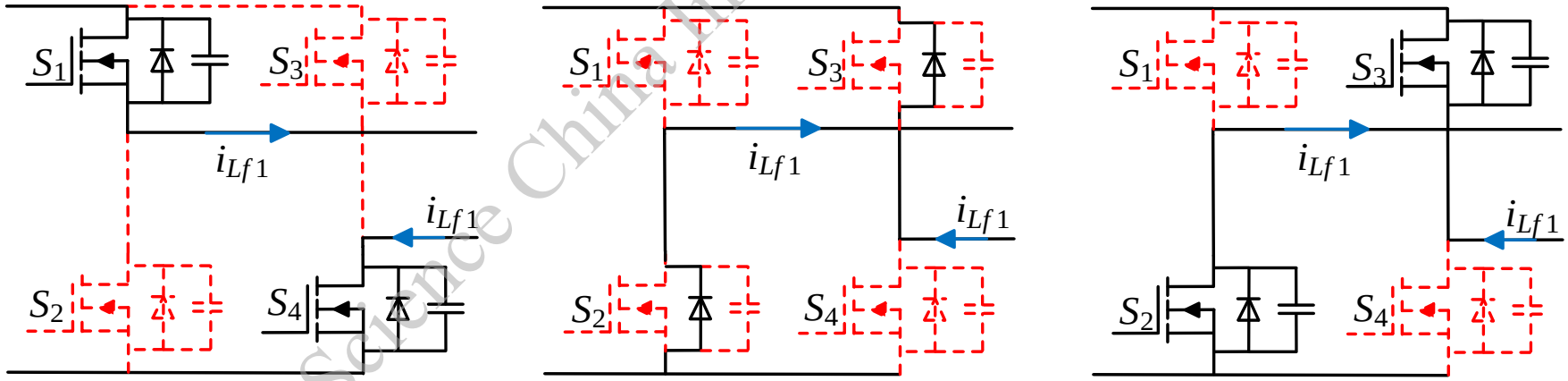
Figure 3:The system model

- **Make the system work at the unit power factor**
- **Let the resonant frequency of system independent of the coupling factor and load.**
- **Enable the MOSFET to realize the soft switch**
- **Improve the efficiency and reliability of the whole system**

Modeling of DWPT System

➢ Soft-switching Analysis

- **The system works at high frequency, the switch tube will be on and off frequently, and the switching loss is the main energy loss in the circuit.**
- **In order to improve efficiency, the switching loss must be reduced and soft switching should be achieved. The conditions for this function are that the resonant network should be inductive**



(a) S_1、S_4 turn on

(b) the body diode of S_2 and S_3 conduct

(c) S_2、S_3 turn on

Figure 4: The principle for zero voltage switching

Modeling of DWPT System

➢ Magnetic Field Analysis of Main Coil

- ◆ The two rectangular coils are connected in series and energy is transmitted by electromagnetic induction.
- ◆ A strip of ferrites on one side of the coil can provide a magnetic circuit to the magnet flux and avoid to produce magnetic losses on the metal floor or other positions of the electric vehicle.
- ◆ When the direction of the current in the coil is shown in Figure 6 (b), the magnetic flux generated by two rectangular coils is wider than that of a single coil, and the magnetic field is larger.

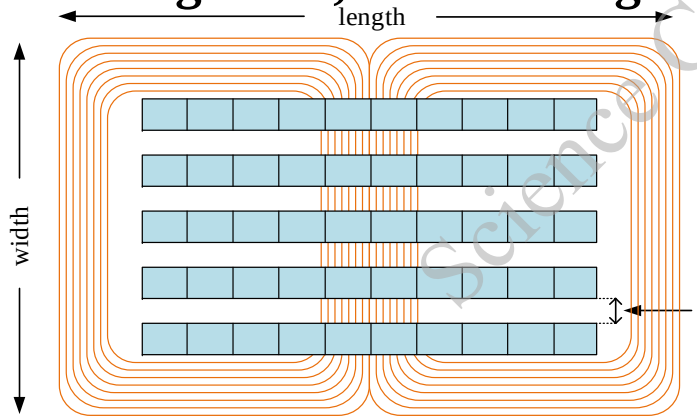


Figure 5： The structure of a double rectangular coil and ferrites

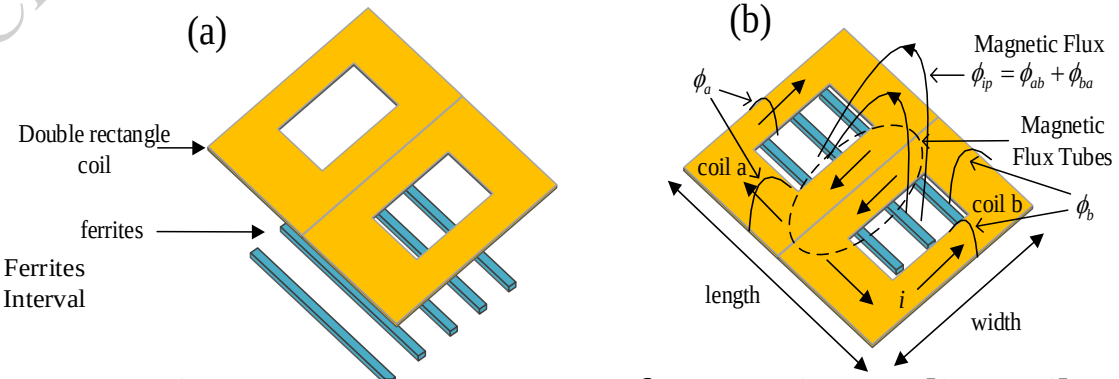


Figure 6： The structure of magnetic coupling coil. (a) device structure; (b) magnetic field distribution.

Modeling of DWPT System

➢ Magnetic Field Analysis of Main Coil

- **The excitation AC current of the coil adopts the frequency of 85kHz.**
- **The vertical distance of the transmitting and receiving coils is 200mm.**

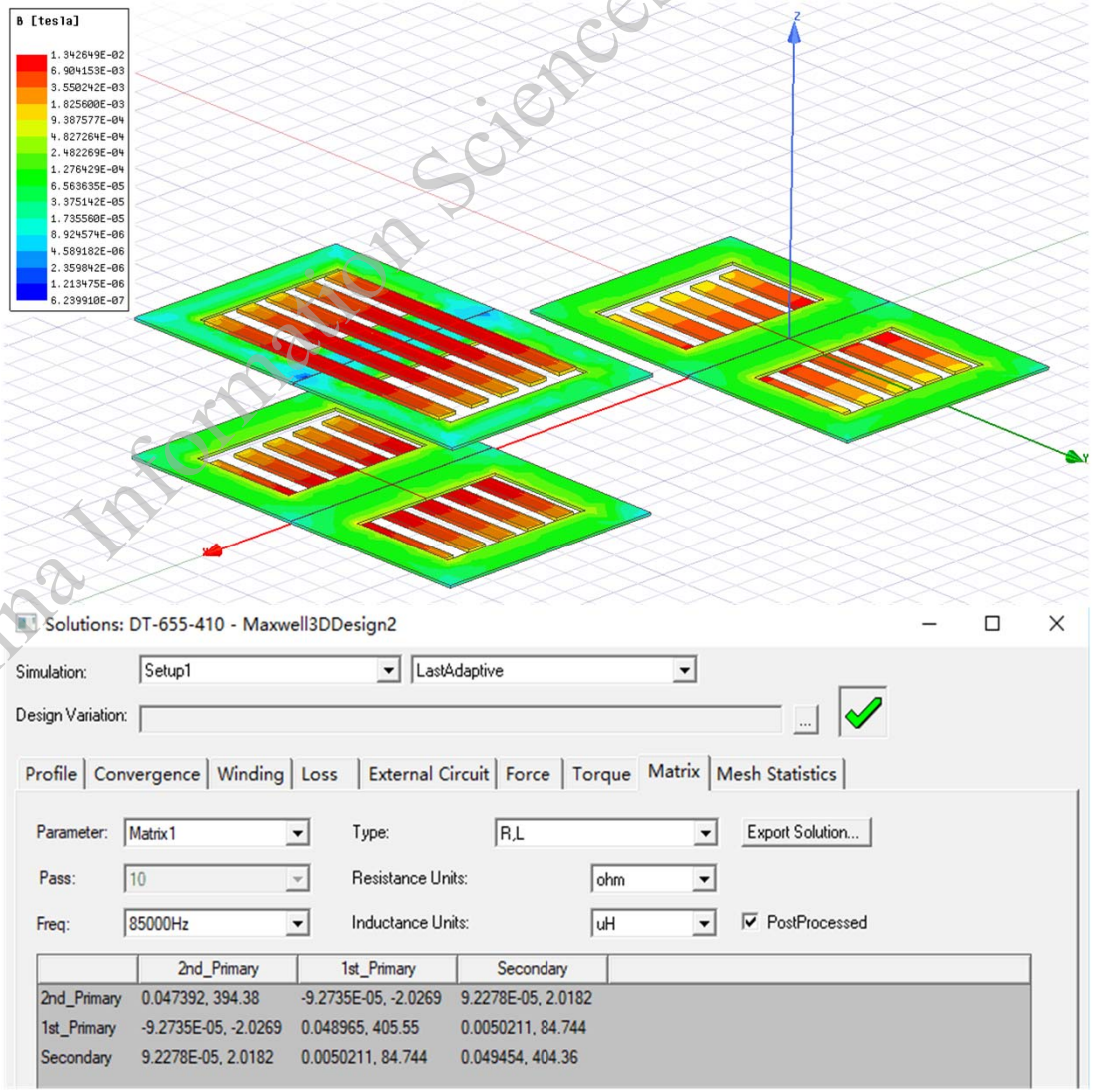


Figure 7: Magnetic simulation results

Controller Design

- A double-loop PID control is proposed to improve the power and efficiency.
- The input voltage of the DCDC converter tracks the output of outer loop controller. The inner loop controller outputs signal is to control IGBT.

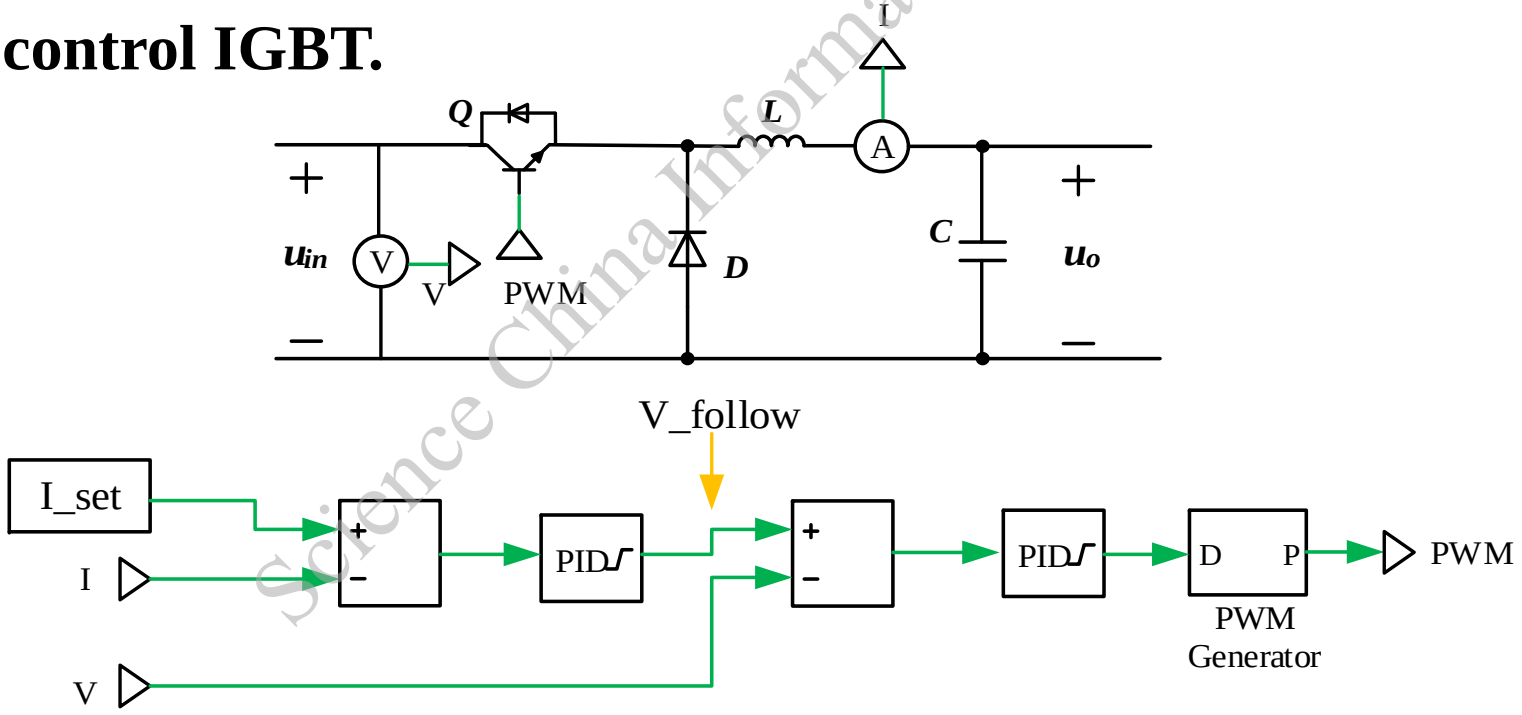


Figure 8: Double closed-loop control system

DWPT Demonstration

Figure 9 :The dynamic wireless charging system

DWPT Demonstration

- When the receiving coil gradually deviates from the transmitting coil, the fundamental frequency content of the output current decreases.
- The turn-off current of MOSFET is always positive, and it can realize the ZVS of MOSFET, which greatly increases the reliability and efficiency of the system.

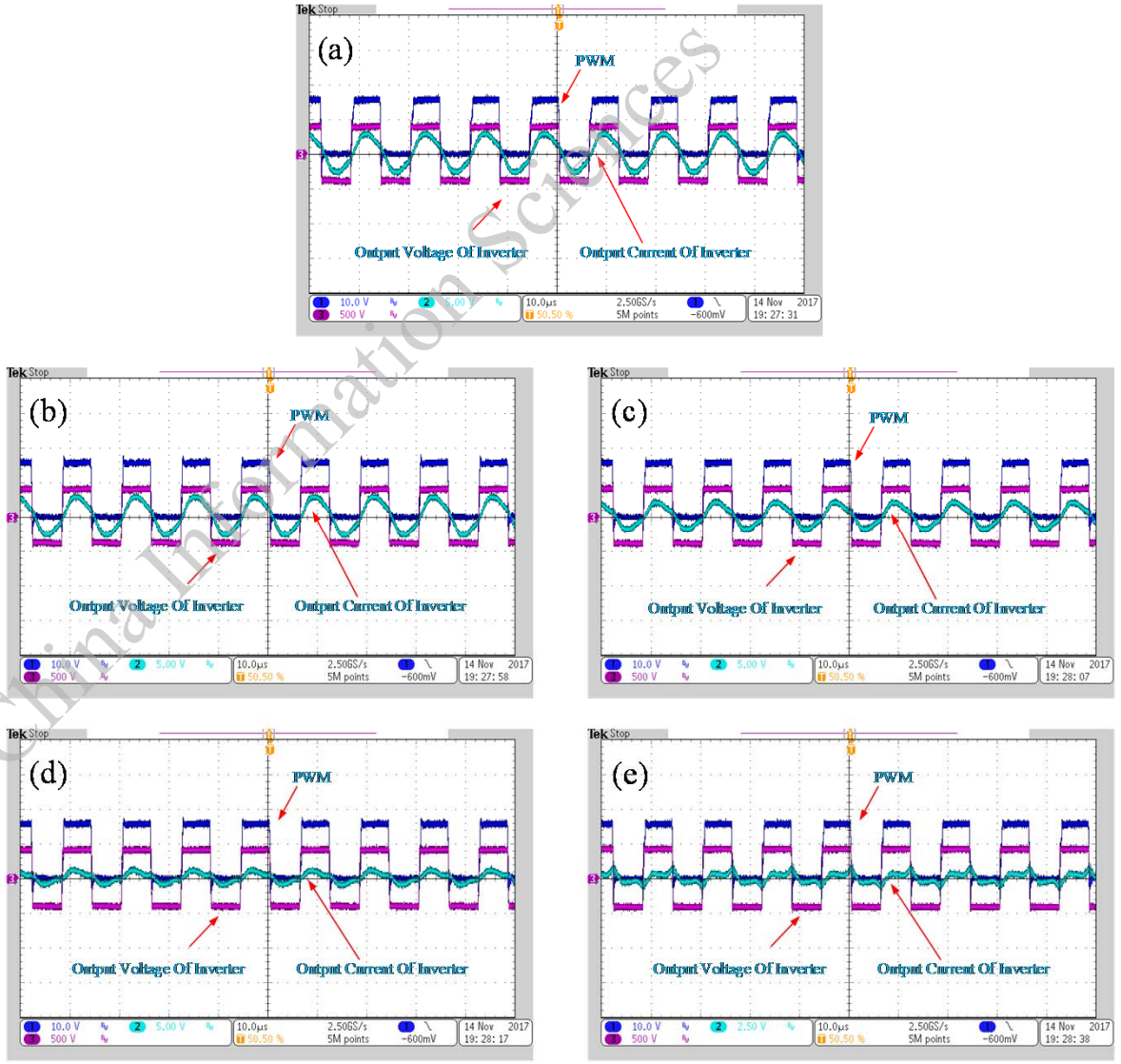


Figure 10:The output signal of inverter. (a) 0cm; (b) 10cm; (c) 20cm; (d) 30cm; (e) 45cm

DWPT Demonstration

➢ Power and Efficiency

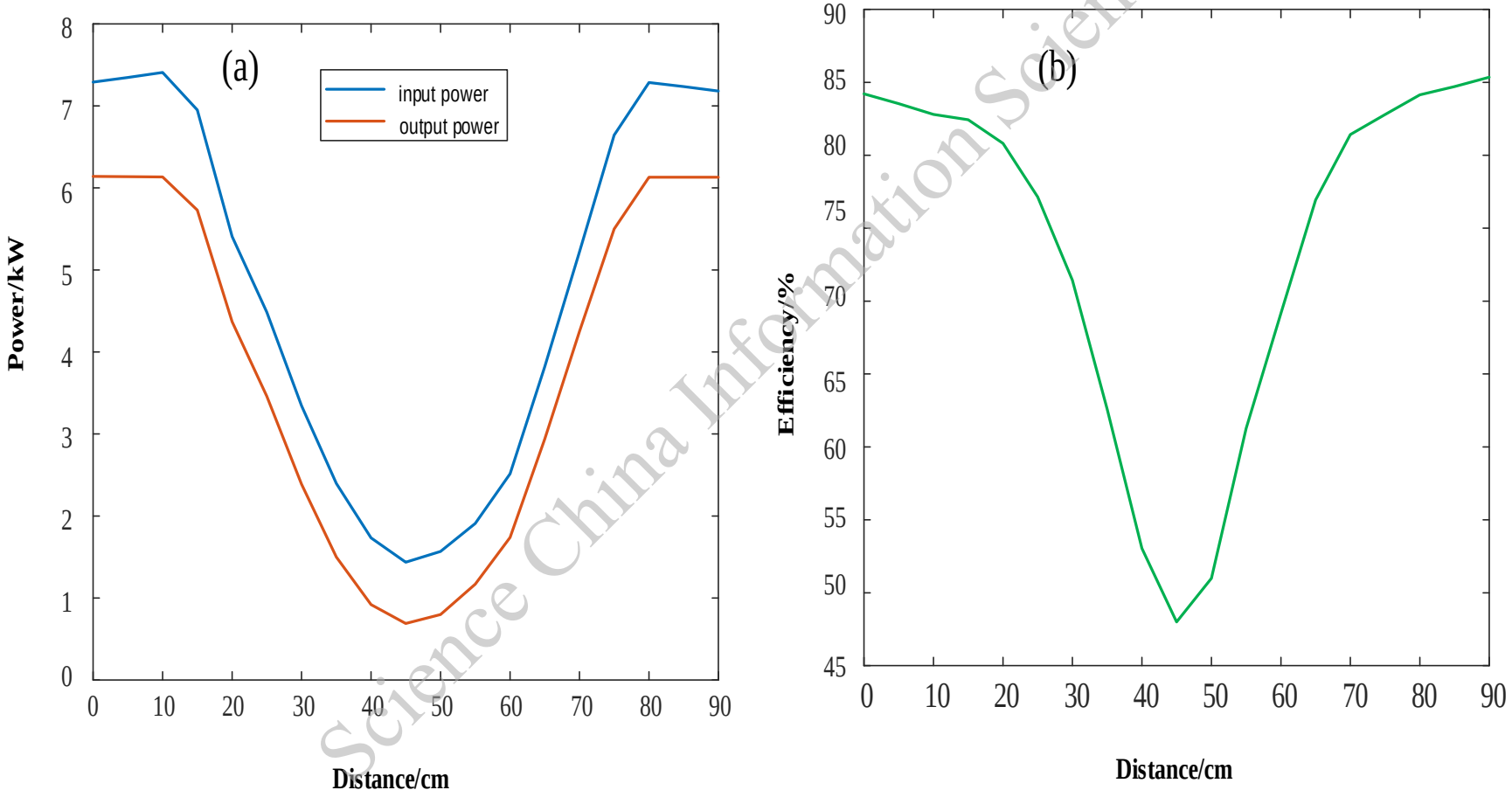


Figure 11: Experimental results of Power and Efficiency. (a) Power; (b) Efficiency

Conclusions

- **A design and demonstration of dynamic power transfer system is give, and the system topology, the soft-switching and magic field in the dynamic wireless power transfer system are analyzed.**
- **A double-loop PID control is proposed to improve the efficiency in the systems.**
- **From experiment results, the design and demonstration of dynamic wireless power transfer systems have good performance and effectiveness.**

Thanks !