UNIVERSITY OF FLORIDA

Non-Contact Energy Delivery with Integrated DC-AC Inverter for PV System and Wireless Charging Applications

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Description: Innovative non-contact energy delivery method will be used in photovoltaic energy generation system to accelerate the system deployment. Instead of delivering electric power using cables penetrating through building structures, magnetic field coupling allows power to be transferred wirelessly through building walls and roofs. In the meantime, the DC electric energy from photovoltaic cells is converted to AC energy. This enables the photovoltaic system to be quickly set up or relocated, and the collected solar energy from outdoor system can be conveniently delivered to indoor appliances. Techniques to achieve high efficiency at high power delivery through different building structures will be studied for this plug-and-play architecture.

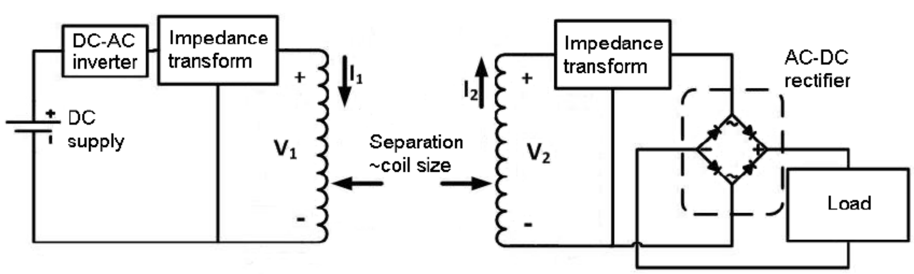
In addition, the technique and the system can also be used for non-contact charging of electric vehicles. The transmitter/charger can be placed as a mat on garage floor or parking space. The receiver inside vehicle will pick up the energy delivery through magnetic coupling. This eliminates the need of connecting charging wires to vehicles and exposed metal contacts, which is a safer method of charging electric vehicles.

Budget: $252,000
Universities: UF

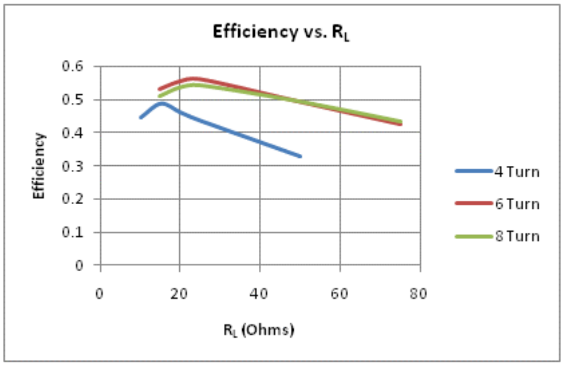
Progress Summary

Wireless power transfer systems can be categorized into three groups: near field, midrange, and far-field. Far field techniques involve radiative transfer of electromagnetic energy over large distances. Near field techniques rely on the inductive coupling of nearby coils (a few mm) to transfer power. Midrange systems extend the distance of near field transmission to the meter range by the use of resonant circuits and structures.

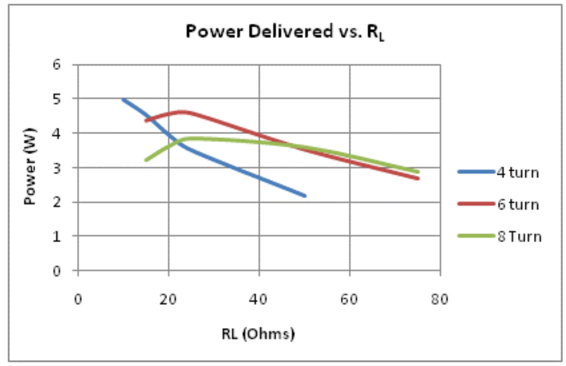
In the previous annual report, we described the design and experimental results of extending the magnetic induction electric energy delivery system from a close distance of 1 cm to 50 cm. The results demonstrated that 50% end-to-end efficiency can be achieved when the two coils are separated by 50 cm. In this report, the distance is further extended to 1 m, and the peak efficiency reaches about 60%. Further experiments were conducted to evaluate the system's performance with different number of turns in coil and different loads. For the system with 1 m x 1 m coils separated by 1 m, 6-turn coils give the best result.



Wireless Power Transfer System Block Diagram



Overall System Efficiency



Power Delivered to Load

2010 Annual Report

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Two prototype systems were designed and built:
I. First Prototype System
<u>Design</u>

Fig. 1 shows the block diagram of the first prototype system and a picture of the test setup. The DC-AC inverter provides the AC power to be transmitted to the receiver. The inverter is a class E switch-mode power amplifier. Following the inverter is an impedance transformation network, the purpose of which is to maximize power transfer and efficiency by transforming the impedance looking into the transmitting coil. The transmitting coil follows, which is in turn inductively coupled to the receiving coil. Both transmitter and receiver coils were constructed using Litz wire to reduce resistive losses from proximity and skin effects. The receiving coil is connected to the second half of the transformation network, a series or parallel capacitor, and followed by a rectifier and a receiver load. It is found that the series-series topology is best for midrange power transfer. Both coils have the same size of 1 m x 1 m and use six turns of 48 AWG Litz wire on each.

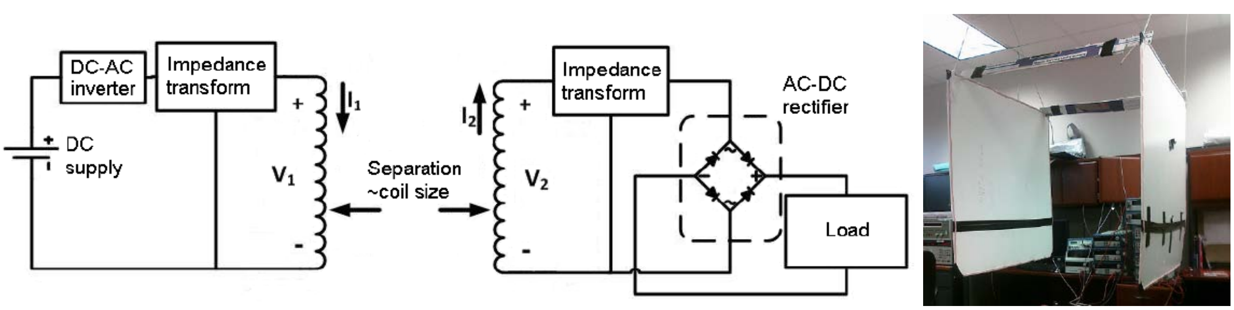
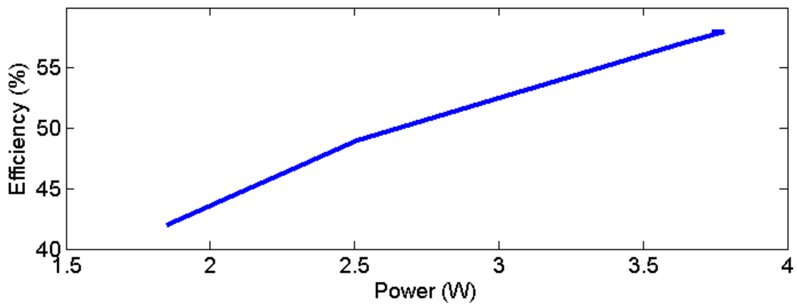


Fig. 1: Wireless electric energy delivery system diagram and picture of test setup (coils are wound around the while cardboards separated by 1 m).

Test Results

Fig. 2 shows measured efficiency versus delivered power when load resistance changes from 75Ω to 18Ω. The peak efficiency is about 57.9% and the peak power delivery is about 3.78 W. Transmitted power was measured using a current probe (Agilent N2783A), a voltage probe (Agilent N2863A), and an oscilloscope (Agilent DSO 5034A). The accuracy is estimated to be around 5%. Received power was measured using a DC electronic load (BK 8500). The estimated accuracy for received power is about 0.8%.



II. Second Prototype System

System Design

In the test setup of the first prototype, the two coils were hung from the ceiling. In that case the distance between coils cannot be varied and precisely adjusted. A better test setup using wooden forms was designed and built. It allowed the distance between coils to be adjusted freely and precisely during experiment. Fig. 3 shows the physical arrangement of the test setup. The system physically consists of two 1 meter by 1 meter coils of varying numbers of turns, wound with 1725 strand 48 AWG litz wire, on the wooden forms.

The system diagram of the second prototype is the same as in Fig. 1. Fig. 4 shows a simplified schematic for the wireless power transmission system. The transistor, along with L_{DC}, C_t, L_{out} and C_{out} comprise a class E amplifier which drives the transmit coil. C_1 and C_2 are chosen such that $L_1 - C_1$ and $L_2 - C_2$ are resonant at the operating frequency. The supply voltage is 20 V. The system was characterized at different frequencies based on the number of turns (4 turns - 760kHz, 6 turns - 510kHz, 8 turns - 439kHz).

Fig. 3: Test setup of the second prototype built on wooden forms

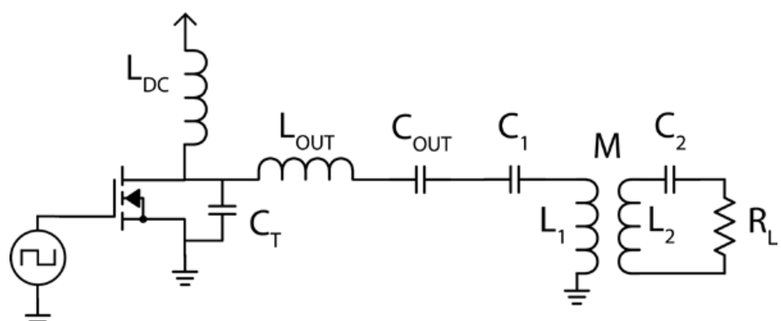


Fig. 4: Simplified System Schematic

Test Results

Fig. 5 shows the system efficiency for varying loads using different numbers of turns per coil. For each curve the number of turns indicated is identical for both coils. It can be seen that the system efficiency reached the maximum with 6 turns. Adding more turns after that does not improve the efficiency.

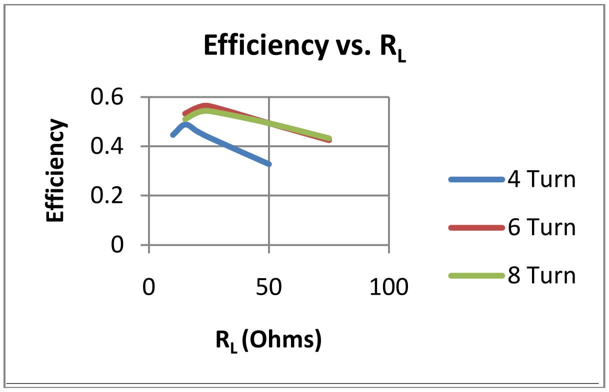


Fig. 5: Efficiency for varying loads

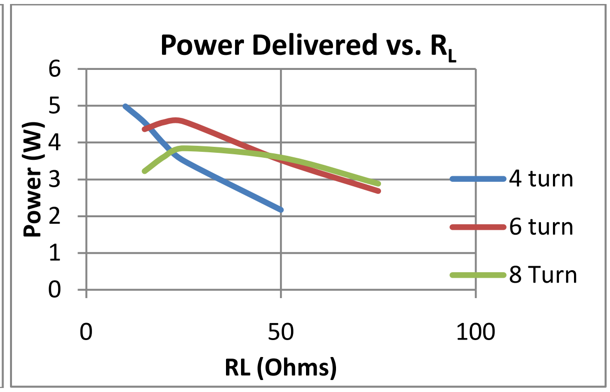


Fig. 6: Power delivered to varying loads

Fig. 6 shows the power delivered for the same range of load values as in Fig. 5. Similar to the trend in Fig. 5, adding more turns after 6 turns does not increase the power delivery. Therefore, it is concluded that for this design, 6 turns is the best.

Effect of Obstacles

For this system to be used to transmit power through a structure, the effect of possible metal obstacles between coils needs to be evaluated. Several experiments were conducted. For small objects there is almost no effect on performance. A 3 foot by 3 foot (almost the same size as the coil) piece of sheet aluminum is used to evaluate the effects of larger objects, shown in Fig. 7. The primary effect of the obstacle is the reduction of coupling between the coils. This has two related effects. First, the load, assuming it is constant at an optimized value in the unobstructed system, will no longer be matched to the system, causing a drop in efficiency. Also, the change in mutual inductance (M), and potentially also self inductance (L), can cause the class E amplifier to become mistuned, also reducing efficiency. Much of the efficiency lost can be recovered by retuning the circuit for the new values of L and M. Fig. 8 shows the comparison between the unobstructed system and a retuned system with an obstacle and Fig. 9 shows the power delivered in both cases. Much of the degradation in performance of the retuned system is due to the reduced coupling, which changes the optimum load value.

Fig. 7: Obstructed Wireless Power Transmission System

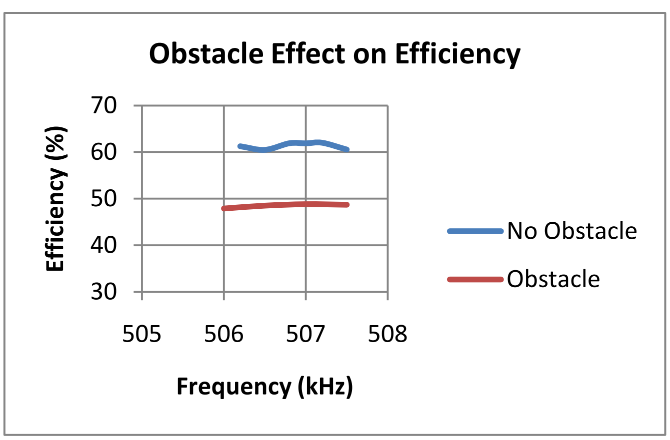


Fig. 8: Efficiencies of obstructed and unobstructed systems

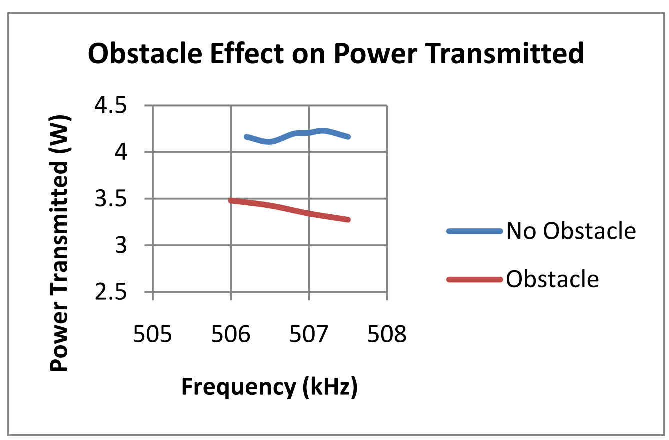


Fig. 9: Power delivered in obstructed and unobstructed systems