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Wireless Charging of Electric Vehicles by Solar Powered Charging Station

Rajbansi Devmani Kamalbahadur*, S. Prabhu Ram, Konar S. Suresh, M.R.Venugopalan, R.Karthikeyan

Department of Electrical and Electronics Engineering, Velammal Institute of Technology, Chennai, Tamil Nadu, India

Abstract : Burning of fossil fuel is one of the major reasons for polluting the environment. This pollution and depletion of fossil fuel has opened up the market of electric vehicles and an emergence of use of renewable sources of energy. In electric vehicles, plug-in based charging method has major drawbacks such as charging a vehicle at a time, less reliability and spatial issues. To overcome these problems, this paper proposes the use of wireless power transfer (WPT) method for charging electric vehicles in parking stations and charging docks using solar energy, due to its numerous advantages. This paper also consists of detailed analysis of parallel-parallel compensator for increasing the effectiveness of WPT.
Keywords : Renewable energy, WPT, ICPT, resonance, PP compensation.

Introduction

Wireless power transmission has attracted lots of researches due to several benefits which it offers[1]. The major advantages of wireless power transfer are charging up multiple devices, convenience, almost zero affect due to weather conditions, no pollution, no chemical hazard, reducing the battery size of the receiver coil. The recent applications are PMA technology, Qi technology and Alliances for Wireless Power technology (A4WP)[2].

Even though the concept of wireless power transfer is not new its efficiency and power transmission at a considerable distance is a major concern. The advancement in power electronics offers to explore the field of wireless power transmission in recent trends[3]. The transfer of power is based on the principle of Electromagnetic induction. The variable flux in primary coil links the secondary kept at some distance and hence emf is induced in the secondary coil. Inductively coupled power transfer is most widely used method for short distances. Compensator plays an important role in both the primary side and the secondary side [4]. The compensator consists of AC capacitors tuned in to resonate with the inductance at the supply frequency. The compensator removes the harmonic in the primary and secondary coil.

Existing system:

In current scenario fossil fuel, based vehicles are used for transportation, which causes huge amount of green house gases emission, and the fossil fuels are in a verge of extinction. To avoid this electric vehicles were introduced, but the major issues with electric vehicles is its charging related issues, such as long charging time, charging one vehicle at a time, insulation requirement in charging cable.

Proposed method:

This paper proposes the concept of WPT at public parking places for charging the electrical vehicles. (Figure 1) shows the model of the proposed system. The block diagram in (figure 2) consist of the three major parts of this model the transmitter, the receiver and the track. The design for the coupler for static and dynamic charging of electric vehicles. The charging pad to reduce the wastage of flux losses. This paper also states the effect of compensator in both the primary and secondary coil.

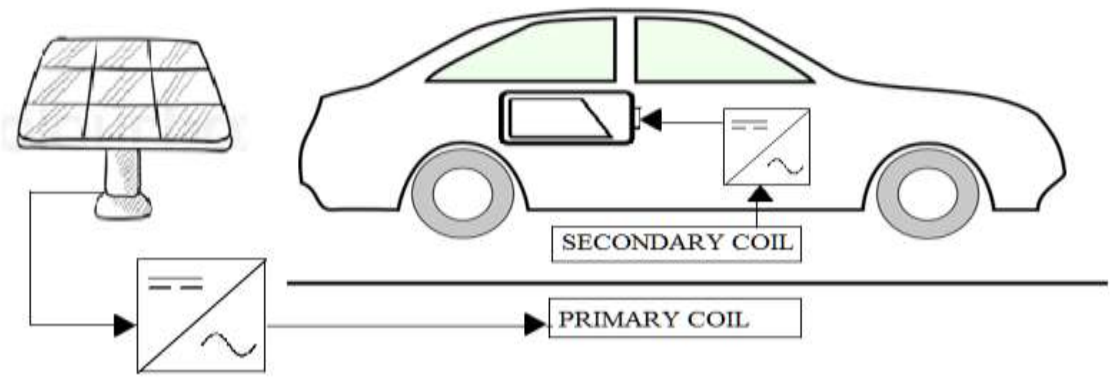


Figure 1: Prototype model of WPT for electric vehicle

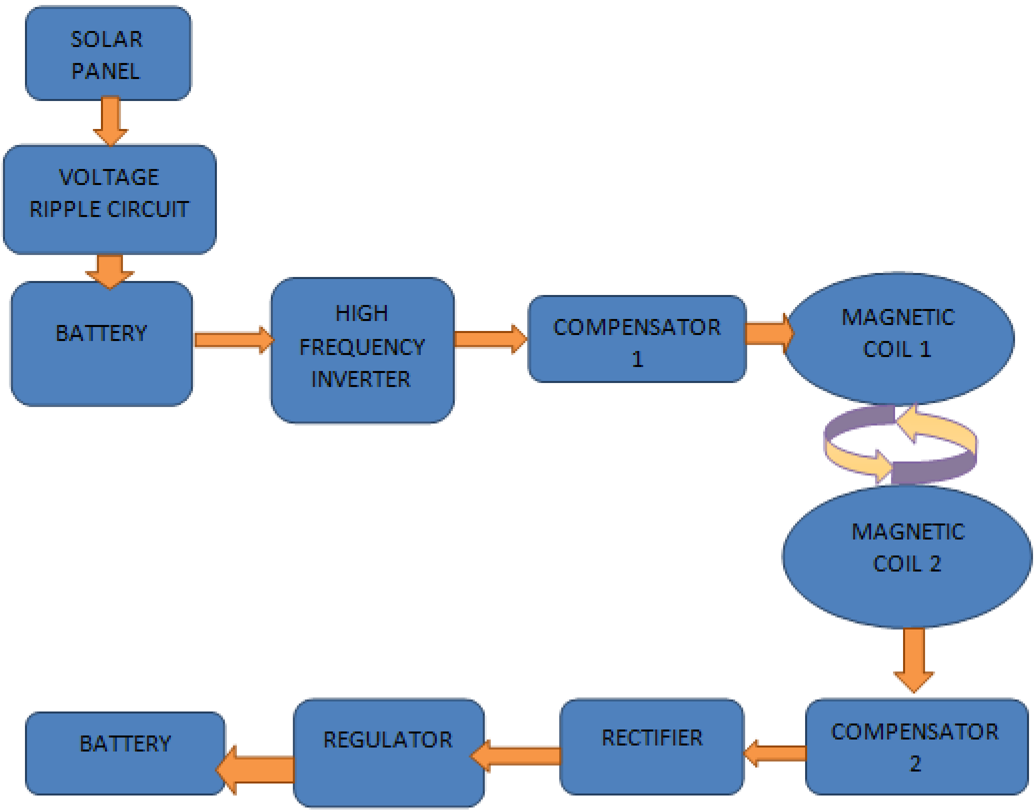


Figure 2: Block diagram of proposed method

The solar panels are kept at a height, which provides shades to the vehicles and generates the supply for this model. It uses the solar energy and coverts it into electrical energy through photovoltaic effect. The voltage ripple circuit removes the ripples from the input supply and provides a constant dc supply voltage and it is stored in a battery, which supplies the high frequency inverter. The high frequency inverter generates high frequency AC current by using power electronic switches. According to Ampere circuital law, this high frequency ac current flowing in the primary coil produces variable flux in the vicinity. The primary coil, which is made up of copper wire, is placed on a track below the parking station floor. A compensator circuit is connected in parallel to the coil in this model, which cancels the inductive power at resonating frequency and eliminates the harmonics. The track consists of aluminum shielding which concentrates the flux to the receiver. The receiver is basically a secondary coil placed at the bottom of electric vehicles. Due to the electromagnetic induction principle, emf is induced in the secondary coil. A compensator is connected in parallel to the secondary coil, which forms a resonating tank circuit in order to remove the harmonics and the ripple contents. The secondary is connected to the full bridge rectifier which converts AC to DC. A regulator circuit is used to get a constant DC supply, which charges the battery of the electric vehicle.

Compensator theory.

ICPT uses the principle of electromagnetic induction for transmission of energy from primary to secondary coil, but due to a huge air gap between the primary and the secondary coil lot of flux doesn't link the secondary coil. To save this flux loss and hence the energy, resonance condition can be used and hence obtain the maximum power transfer between the primary and the secondary for a given distance. For this compensators are used which consist of ac capacitors connected with the respective coil in series and parallel. Depending on this connection the basic compensation topologies are [5]: Series-series topology, Series-parallel topology, Parallel-parallel topology. Parallel-series topology. The capacitor C1 in primary is used to cancel reactive part of the circuit seen by the source, achieving zero displacement. Thus the inductive power in the primary coil is being cancelled by the capacitive power, thus the primary coil impedance is equivalent to the net resistance in the primary circuit. The capacitor C2 in the secondary side is chosen to operate in resonating condition, thus the net inductance in the secondary coil is cancelled by the secondary compensator, and hence achieving maximum power transfer. The operating frequency must be the resonating frequency of circuit, which is determined by the inductance of the coil and capacitance of the compensator given by the equation (1). The resonating frequency of the primary and the secondary must be the same. Thus the operating frequency determines the capacitance of the compensator and is limited by maximum frequency of the inverter f_{max}.

$$f = 1/2\pi\sqrt{LC} \qquad \ldots(1)$$

In lower power levels, when cross-section of wire is not a important parameter, the Parallel-Parallel (PP) compensation is advantageous to operate at larger distances at the same operating frequency[6]. Parallel-Parallel topology is given in (figure 3).

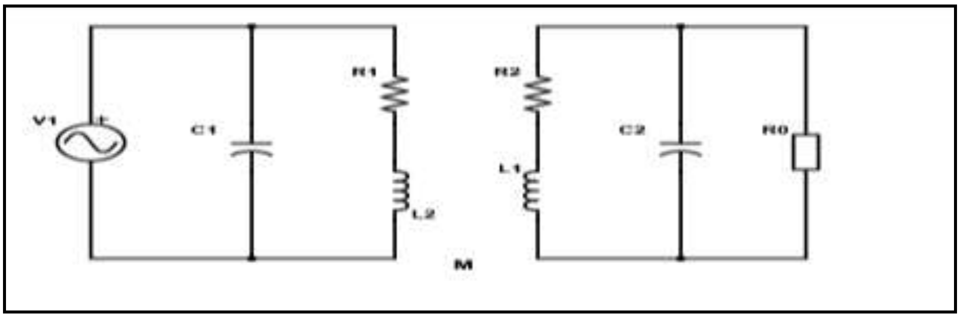


Figure 3: Equivalent circuit of PP compensation

Implementation Platform

Implemented system

The hardware consists of a 24V Solar panel which is connected to the voltage ripple circuit. The voltage ripple circuit removes the ripples and gives out a constant voltage output. This output from the voltage ripple circuit is used to charge the battery which is used as source to charge the battery using wireless power transfer. The battery serves as the input for the primary coil which is present in the charging pad. The dc power is fed to the primary coil through the high frequency inverter circuit. The high frequency converter consists of a

BA129 transistor which is triggered by Arduino Uno at high frequency. This converts dc input from the battery to high frequency ac which is passed through the primary coil. Then a high frequency ac is generated in secondary coil which is present in the base of the car whose battery is to be charged. This high frequency ac is converted into dc by a full bridge rectifier. This dc is passed through the regulator to get constant dc output which is used to charge the battery.

Validation and Result Analysis of Compensation

To understand the importance of compensation the uncompensated system is studied first. Figure 5 and Figure 6 shows the primary and secondary voltage waveform of an uncompensated system on both the sides respectively. The waveform shows peaky spikes and consists of distorted waveform consisting ripples. Figure 7 and figure 8 shows the waveform of a compensated system on both the primary and secondary circuit, the waveform is obtained at resonating condition and the harmonics are removed. To achieve maximum power transmission resonance condition must be achieved, thus compensation is provided on both the sides and its corresponding waveform is being obtained. Figure 9 and figure 10 shows the compensation only on the primary and secondary side respectively and its corresponding output voltage.

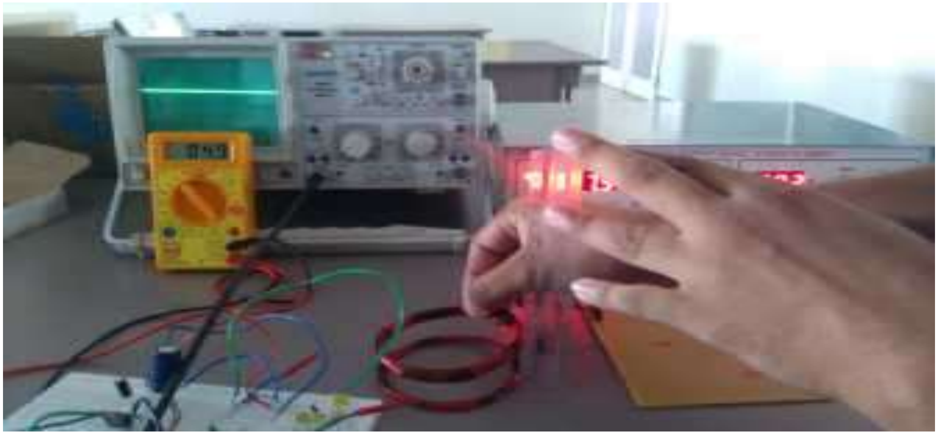


Figure 4: Real-time testing of the Model

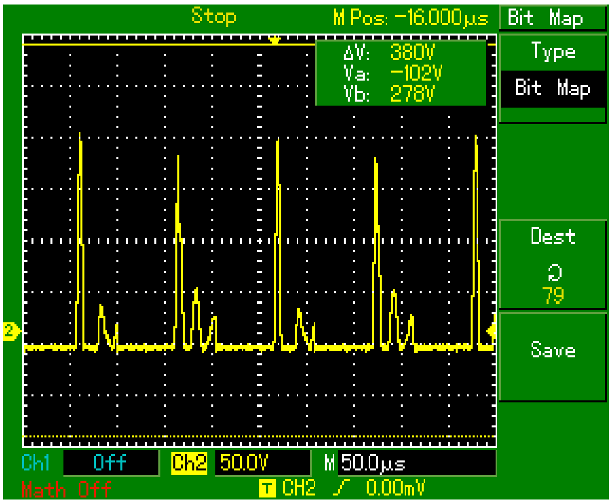


Figure 5: DSO Output Voltage of Primary coil without compensation and its parameters.

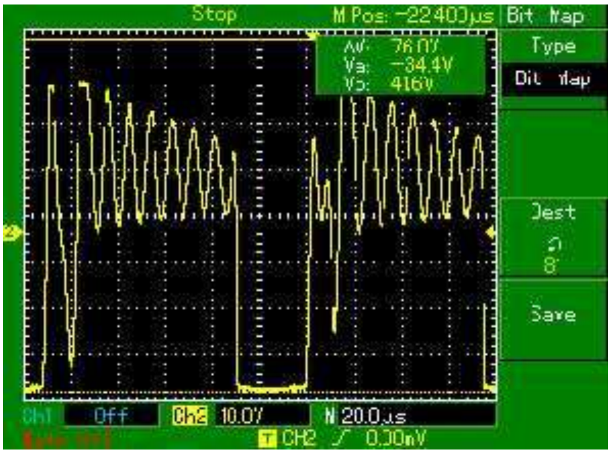


Figure 6: DSO Output Voltage of Secondary coil Voltage without compensation and its parameters.

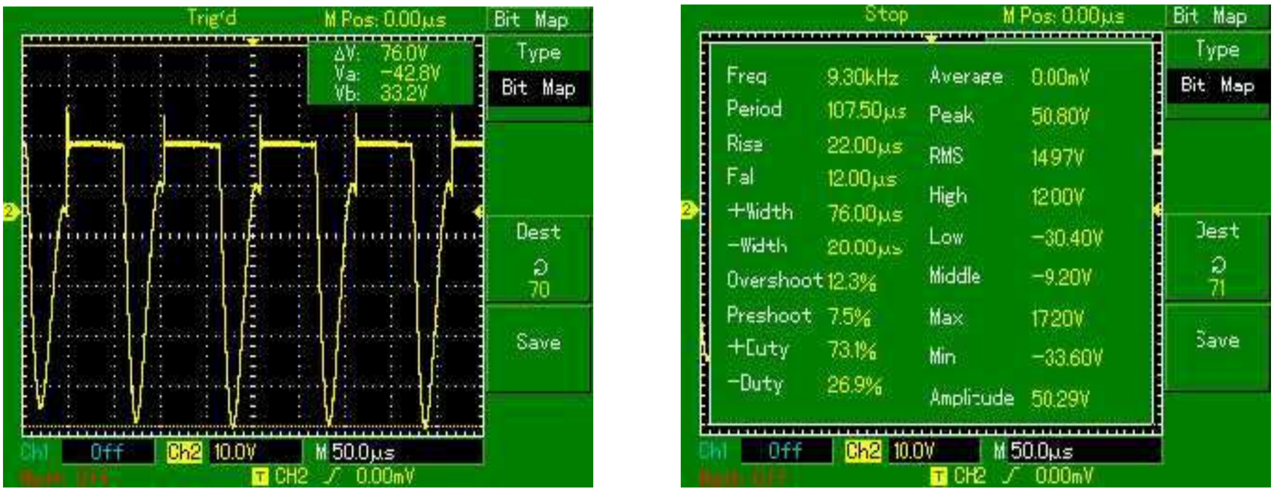


Figure 7: DSO Output Voltage of Primary with compensation and its parameters

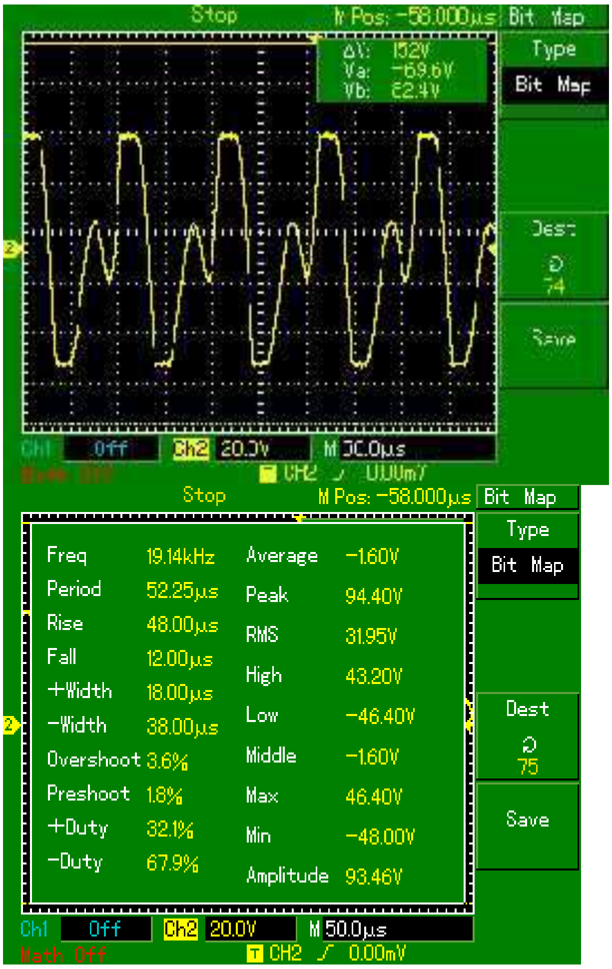


Figure 8: DSO Output of Secondary with compensator and its parameters.

Figure 9: DSO Output Voltage with only Primary Compensated and its parameters.

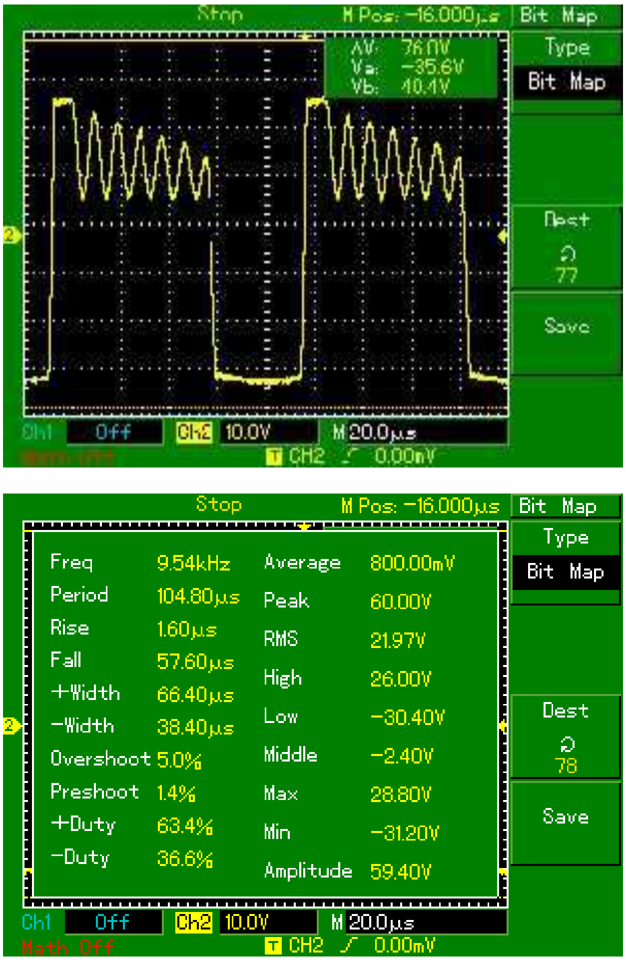
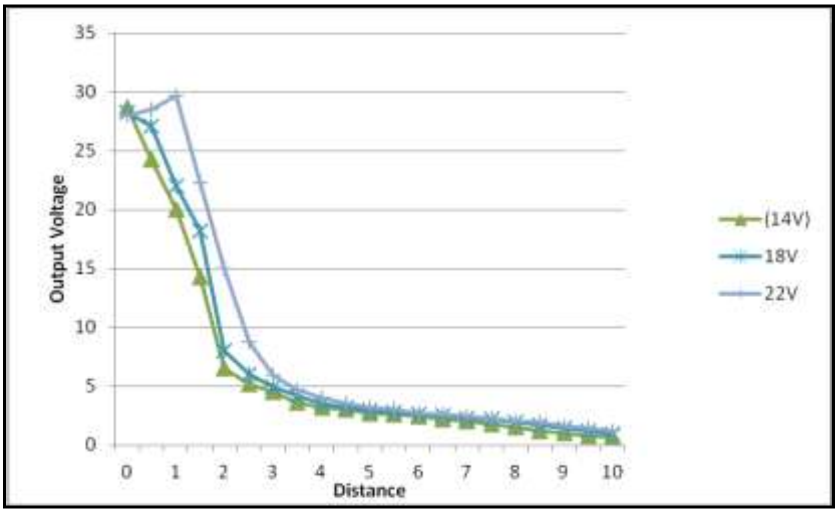


Figure 1 0 : DSO Output Voltage with only Secondary Compensation and its parameters.

Table 1 Output- distance (14, 18,22V Input supply)

Distance(cm	14V	18V	22V
0	28.7	28.3	28
0.	24.3	27.1	28.5
1	20	22	29.7
1.	14.3	18.2	22.3
2	6.5	8	15
2.	5.2	6	8.8
3	4.5	4.9	5.9
3.	3.6	4.2	4.7
4	3.2	3.5	4
4.	3	3.2	3.5
5	2.7	2.9	3.2
5.	2.6	2.8	3
6	2.4	2.6	2.7
6.	2.2	2.5	2.6
7	2	2.3	2.4
7.	1.8	2.2	2.3
8	1.5	1.9	2
8.	1.2	1.7	1.9
9	1	1.4	1.6
9.	0.8	1.2	1.4
1	0.7	0.9	1.2

The variation of the secondary rectified voltage at three constant input voltages (14V, 18V and 22V) at variable distance is being studied. From the Table 1 it is concluded that at 22V input supply, considerable rectified and hence regulated voltage can be obtained up to 35mm distance.



Graph 1. Voltage Vs. Distance graph.

Conclusion:

Fuel based transportation has caused huge pollution issues. The uses of electric vehicles in present situation provides an eco-friendly solution, but suffers from huge drawback when comes to charging. Thus ICPT principle is used to provide an advantageous alternative. This project thus provides a model, which can be used for wireless charging at various parking stations at public places powered by solar energy. This paper also dealt the effect of parallel-parallel (PP) compensator in both the load and source side and has analyzed the variation of output voltage with distance between the coils. The model is scaled in 100:1 ratio with power level up to 15 watts and considerable power is transmitted up to 35mm using PP topology which when scaled at real time will give better efficiency.

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