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2KW WIRELESS POWER TRANSFER FOR CHARGING VEHICLE BATTER

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***Abstract*—In this project, the development of a 2-kW high-efficiency Wireless Electric Vehicle Charging (WEVC) system that employs the quasi-resonance method (QRM) to transmit power to the battery side is the main goal. To encourage the use of environmentally friendly Electric Vehicles (EVs) with reduced operating costs, charging infrastructure development and the creation of Electric Vehicle Supply Equipment (EVSE) is crucial. The use of Wireless Power Transfer (WPT) technology has the potential to make charging automated, user-friendly, and secure, promoting the widespread adoption of electric vehicles. The project suggests an organized method for utilizing the Finite Element Method (FEM) to build a high coupling, misalignment-tolerant Inductive link (IL) composed of main and secondary charging coils.**

For the primary and secondary sides, different coil geometries are used, each with advantages and disadvantages in terms of weight, cost, and coupling. The development of Wireless Charging Systems (WCS) has faced a number of difficulties, but overcoming these barriers might revolutionize commercial deployment and improve the efficiency of EVs. The suggested WEVC system utilizing QRM technology may be able to provide an answer for EVs' efficient and dependable power transmission needs, increasing customer interest in EVs.

Index Terms*—Wireless Electric Vehicle Charging, Quasi Resonance Method, Electric Vehicle Supply Equipment, Electric Vehicles, Wireless Power Transfer, Finite Element Method, Wireless Charging Systems.

I. Introduction

In addition to their eco-friendliness and affordable operating costs, EVs have become increasingly popular across the globe. To encourage their use, however, the creation of EVSE and charging infrastructure is crucial. The present charging techniques, including conductive charging, have some problems including risks, vandalism, and annoyance to consumers. To get around these restrictions, a new alternative technology called WPT has been developed. With WPT technology, energy can be transferred from the source to the load without making direct contact.

With the use of this technology, consumers' perceptions of electric vehicles and charging stations might be considerably improved, making them more practical, secure, and effective. Electromagnetic induction is used in WPT. Theoretical explanations of how it works are based on Lenz's Law and Faraday's Law of Electromagnetic Induction. A copper coil inside generates an alternating magnetic field when an alternating current (AC) passes through it. In the ferromagnetic material, this magnetic field induces an electric current. The copper coil's copper turns and the frequency of the alternating current determine the intensity of the magnetic field and the quantity of current induced. The power supply, control module, and inverter are all included on the printed circuit board (PCB).

This research is focused on developing a high-efficiency WEVC system that can transmit 2 kW of power to the load side utilizing the quasi-resonance method. The technology includes a contactless coupler and a power electronics system that convert grid-supplied 50Hz AC to DC and subsequently to 23kHz AC prior to the wireless stage. Since the primary and secondary sides are so far apart, there is a weak coupling between them, making it necessary to manage reactive power effectively in order to transfer the desired amount of power. To guarantee excellent efficiency, resonant components are employed on both sides. It is done so by using an inductive coupling (IC) transformer, which creates galvanic isolation between the source and the load.

To maintain the charger functioning at a certain voltage and the necessary current required by the battery, the output parameters at the load side are controlled. This ensures load protection. The suggested WEVC system can revolutionize the commercial deployment of EVs and provides an effective, user-friendly, and secure method for charging EVs.

II. OBJECTIVES

The main objective of the present study is to transfer load by wireless power transfer.

The specific objectives of the study are:

1. Transferring 2kw load from primary to secondary to load side by using the Qausi resonance method
2. Simulation results

III. Methodology Of The Study

The research is both analytical and descriptive. The majority of the secondary data that formed the foundation of the current investigation. The necessary secondary data were gathered from a variety of government publications, papers, etc.

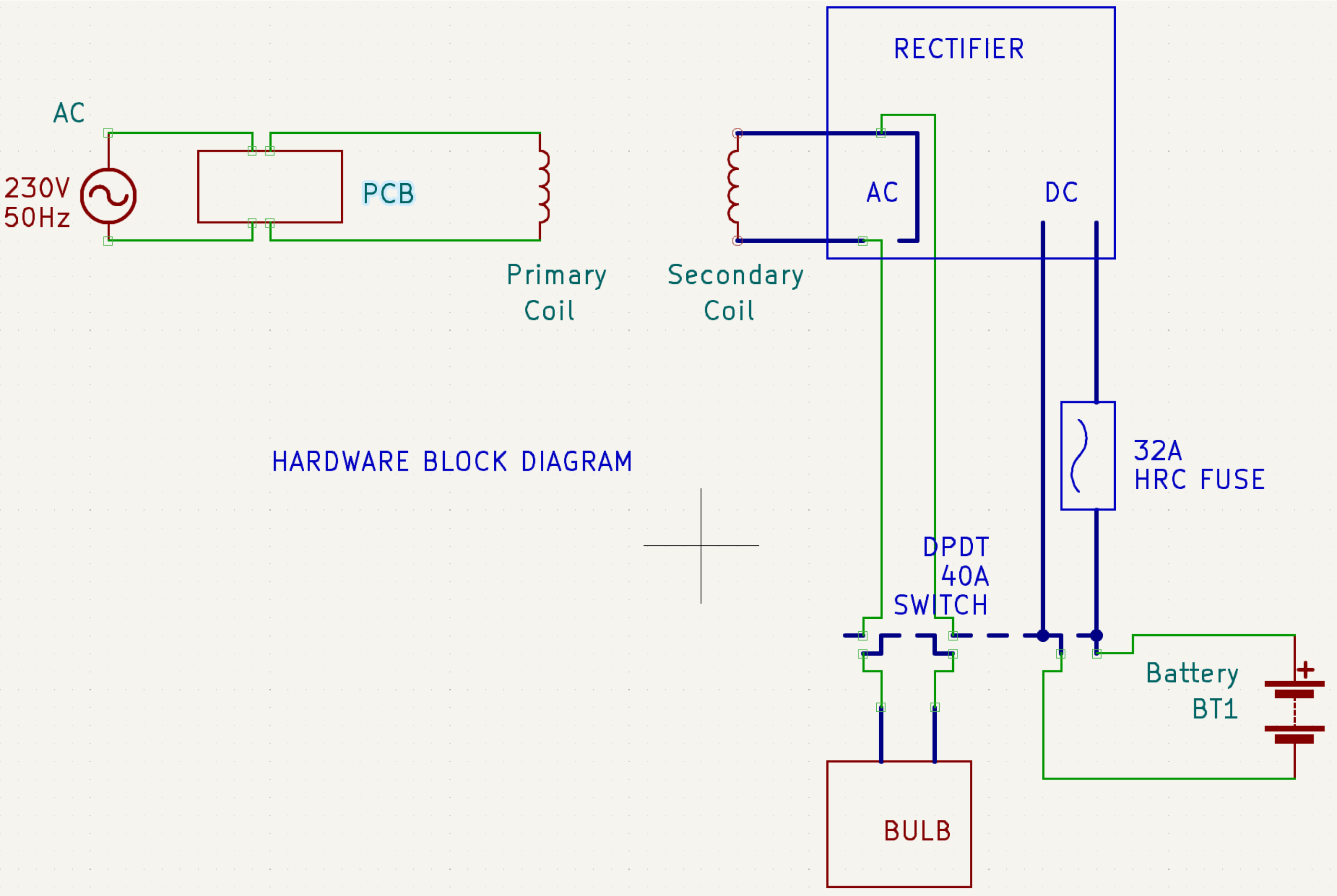
IV. Proposed System

Normally, a boost converter, a filter capacitor, and a rectifier make up the power supply. The rectifier changes the mains AC voltage to a DC voltage. The filter capacitor reduces ripple by smoothing the DC voltage. To power the inverter, the boost converter raises the DC voltage to a greater level. An induction cooker's control unit often incorporates a microprocessor, which regulates the inverter's operation and keeps track of the cookware's temperature. From the touch panel, the microcontroller receives user input and instructs the inverter to change the power output.

The high-frequency alternating current (AC) that the inverter produces is what creates the electromagnetic field. A driving circuit, a set of power transistors, and a high-frequency transformer are the standard components of an inverter. To produce a high-frequency AC signal, the driver circuit manages the switching of the power transistors. The AC signal's voltage is increased by the high-frequency transformer to a level high enough to generate an electromagnetic field. The quasi-resonance technique is used in the planned WPT for EV battery charging. It consists of a PCB, a car battery, a rectifier, and coils for the transmitter and receiver.

Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS), resonance phenomena, are two methods that may be used to switch in this manner. By turning transistors on and off at very low voltages or currents, soft switching lowers switching losses and noise. To balance the multiple waveforms, though, more sophisticated control circuits are needed. With half-bridge and full-bridge converters being suited for greater powers, soft-switching converters may be created utilizing a single electronic switch or many switches. Resonant and quasi-resonant converters are what these devices are known as.

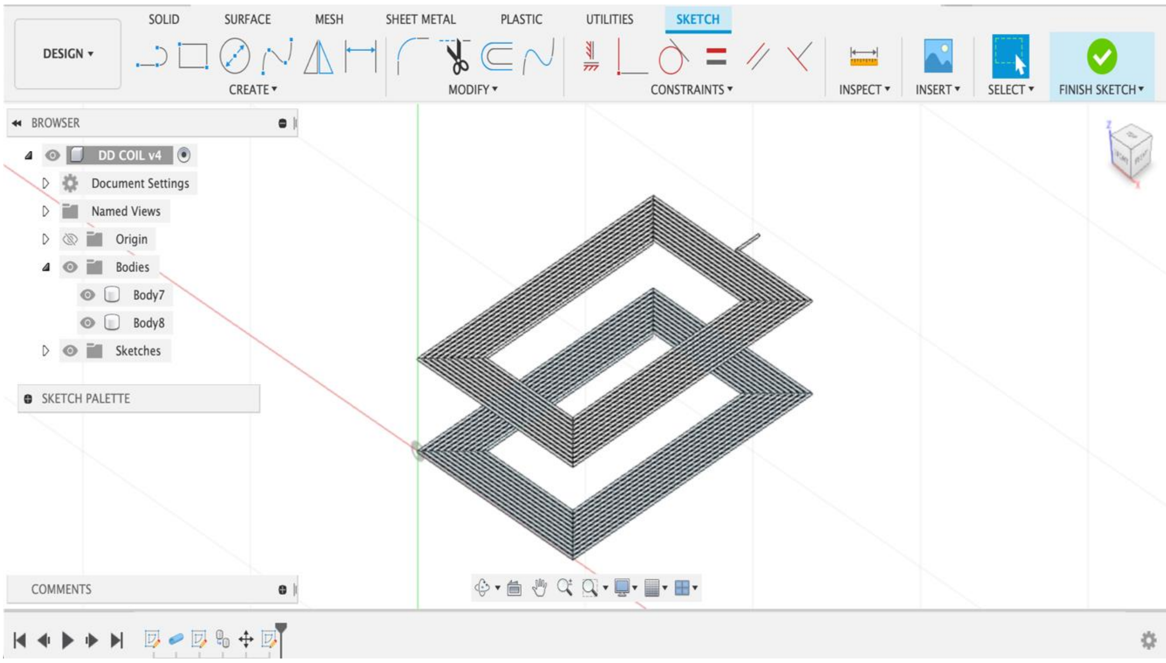
Soft switching decreases losses and high-frequency noise, but it also adds more electronic parts and complicates circuits.



FigIV.1: Block diagram of proposed Hardware

V. Design And Implementation

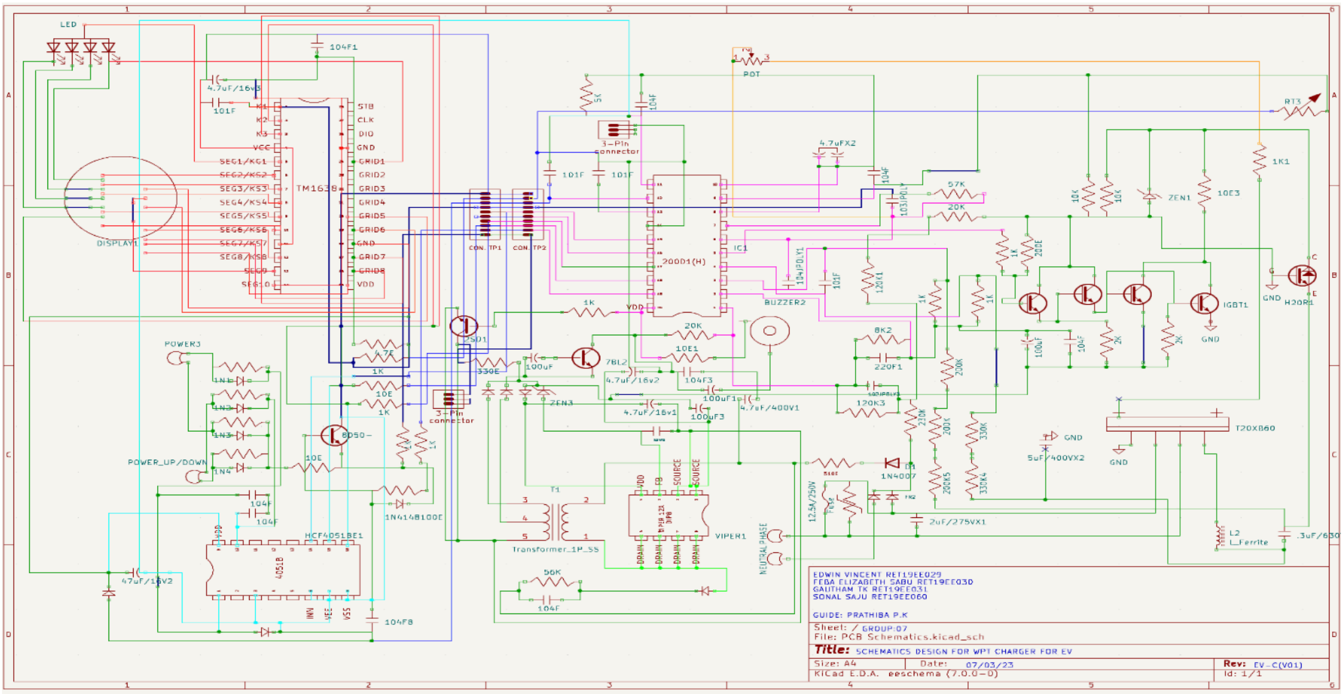
Two coils are utilized in this design, one serving as the primary coil and having 22 turns of 20-gauge wire and 20 meters in length, and the other serving as the secondary coil and having the same characteristics. The primary coil is linked to a power source, which creates an electromagnetic field that induces a voltage in the secondary coil. To convert AC to DC, which is subsequently delivered to the car battery, the secondary coil is linked to a rectifier bridge.



FigV.1: The Coil Was Designed Using Fusion 360

The PCB for this system is made in a manner resembling an induction cooker. The PCB is made up of a rectifier circuit, a resonant circuit, and a power supply circuit. The main and secondary coils, as well as a capacitor used to adjust the system's resonant frequency, make up the resonant circuit.

A rectifier bridge and a filter capacitor make up the rectifier circuit. The secondary coil's induced AC voltage is transformed into a DC voltage by the rectifier bridge, which is subsequently filtered by the capacitor to reduce ripple.



FigV.2: Schematic Designed for PCB Using Kicad

VI. The System Theoretical Analysis

Quasi-Resonance Method (QRM)

The Quasi-Resonance Method (QRM) is a method for wirelessly transferring electricity from a source to an object. Two coils are utilized in this technique, one of which is the primary coil and the other the secondary coil. The gadget that requires electricity is linked to the secondary coil, which is connected to the primary coil, which is connected to a power source. An electromagnetic field is created when electricity is given to the main coil; this electromagnetic field causes a voltage to be induced in the secondary coil. The gadget may be powered by the induced voltage.

Resonance is the foundation of the QRM method.

When the frequency of the energy being transmitted and the system's resonant frequency coincide, resonance occurs. When the frequency of the electromagnetic field produced by the main coil coincides with the resonant frequency of the secondary coil, resonance takes place in the context of WPT.

The following formula may be used to determine the coils' resonance frequency:

$$f = 1/(2\pi\sqrt{LC} \quad \longrightarrow (1)$$

where L is the coil's inductance and C is its capacitance, and f is the resonance frequency. Magnetic coupling is another principle used in the QRM method. When the secondary coil experiences a voltage as a result of the first coil's magnetic field, magnetic coupling has taken place. By changing the distance between the two coils and the number of turns in each coil, the degree of magnetic coupling between them may be increased.

An input voltage source Vi, resonant tuning capacitors Cp and Cs, linked inductors Lp and Ls, and analogous series resistances Rp and Rs, respectively, may all be used to construct the WPT system model, as illustrated in Fig. 7. In order to compute the leakage inductance Ll and the magnetizing inductance Lm values from two connected inductors, k is the coupling factor between the two coils.

$$\begin{aligned} L_M &= k\sqrt{L_P L_S} = kL \\ L_L &= L - L_M = (1-k)L \end{aligned} \longrightarrow (2)$$

The input capacitor, Cin, filters the rectified AC input voltage to create the bulk voltage, Vbulk, which will be the converter's power stage's input. The power stage should be based on the minimal bulk voltage Vbulkmin, which is at the valley of the Vbulk ripple at the lowest AC input, Vacmin, for a dependable and durable design.

It is advisable to select this component first because the power stage is so dependent on this lowest voltage operating point and the input capacitor for an offline supply occupies a significant amount of space on the printed circuit board due to its voltage rating.

For this initial component, trade-offs must be taken into account. Lower bulk voltage and larger peak currents are the results of using the smallest and least expensive input capacitor. These increased currents will put additional strain on the MOSFET, the transformer, and the output capacitor. A bigger input capacitor isn't the best option either because the shortened charge time will result in a greater peak current consumption from the mains. The input capacitor will need to be physically bigger and rated for this ripple current. Using an input capacitor that will keep the input voltage ripple between 20 and 30 percent is a reasonable compromise. As shown in Table 2, the minimal bulk voltage estimates for this design example

$$\begin{aligned} V_{\text{BULK min}} &= 0.7 \times \sqrt{2} \times V_{\text{AC min}} \\ V_{\text{BULK min}} &= 84 \text{ V} \end{aligned} \longrightarrow (3)$$

Utilizing the energy balance equation, the input capacitor is determined to produce this voltage, taking into account that energy gained during the capacitor charge time will be transferred to the power stage during the capacitor discharge time.

$$\frac{1}{2} \times C_{IN} \times \left[\left(\sqrt{2} \times V_{\text{AC min}}\right)^2 - V_{\text{BULK min}}^2\right] = P_{IN} \times t_{\text{DISCHARGE}} \longrightarrow (4)$$

Referring to Figure 3, you can see that the capacitor discharge time is the length of time it takes for the capacitor voltage to fall from its peak value to the desired minimum bulk voltage. This allows you to calculate discharge. Equation 8 is used to compute the discharge time using the minimum line frequency and timing parameters.

$$\begin{aligned} t_1 &= \frac{T_{\text{LINE}}}{2\pi} \times \sin^{-1}\left(\frac{V_{\text{BULK min}}}{\sqrt{2} \times V_{\text{AC min}}}\right) \\ &= \frac{T_{\text{LINE}}}{2} + t_1 \\ t_{\text{DISCHARGE}} &= t_2 - \frac{T_{\text{LINE}}}{4} \qquad \longrightarrow (5) \\ f_{\text{LINE}} &= 47 \text{ Hz} \\ T_{\text{LINE}} &= 21 \text{ ms} \\ t_{\text{DISCHARGE}} &= 7.95 \text{ ms} \end{aligned}$$

$$C_{IN} = \frac{2\times P_{IN}\times t_{DISCHARGE}}{(\sqrt{2}\times V_{AC\ min})^2 - V^2_{BULK\ min}}$$
$$P_{IN} = \frac{P_{OUT}}{\eta} \longrightarrow (6)$$
$$C_{IN} = 27\mu F$$

Naturally, the design specification depicted in Table 2 calls for a small, inexpensive converter as the final product. You would anticipate that the actual capacitor utilized in the design would be the next lower standard value available given this and the fact that 27 F is not a standard value. This corresponds to 22°F. It is prudent to establish the real minimum bulk voltage and iterate the computations beginning at the t1 equation, though, because a lower-than-calculated input capacitor is used.

The computed CIN value converges with the real CIN utilized after a few repetitions and thus establishes the actual minimum bulk voltage. Determine Vbulkmin in Equation 10 to start (and ultimately finish) the iteration.

$$V_{BULK\ min} = \frac{\sqrt{2\times C_{IN}\times(C_{IN}\times V^2_{AC\ min} - P_{IN}\times t_{DISCHARGE})}}{C_{IN}} \longrightarrow (7)$$

$$C_{IN} = \frac{Q}{\Delta V} = \frac{t_{CHARGE}\times I_{CINpeak}}{\sqrt{2}\times V_{ACmin} - V_{BULK\ min}}$$
$$t_{CHARGE} = \frac{T_{LINE}}{4} - t_1$$
$$I_{CINpeak} = \frac{C_{IN}\times(\sqrt{2}\times V_{AC\ min} - V_{BULK\ min})}{t_{CHARGE}} \longrightarrow (8)$$
$$I_{CINrms} = \frac{I_{CINpeak}}{\sqrt{3}}$$

VII. SSL Resonant IPT Full System And Control

Following the decision to employ the compensation topology, the compensated ICT is now coupled to every other electronic component to create the resonant IPT full system, as depicted in Fig. VIII.1.

Matlab-Simulink is used to represent the entire system, and simulations in the time domain are run.

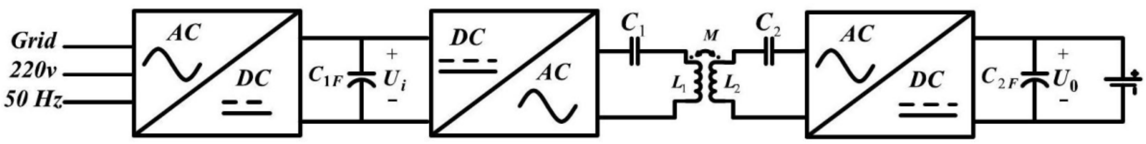


Figure VII.1 shows the key blocks of the IPT complete system with compensation

The open loop system of Fig. VII.1 is used as the starting point of the analysis without any parameter control. Throughout the simulation, all of the values are fixed. In addition, the DC-DC resonant converter is considered. This indicates that the DC source is used to start the system being examined, which is then passed over the filter's DC bulk capacitance. The additional phases are as follows:

DC/AC:
The complete bridge inverter of four power switches (IGBT or MOSFET) that is controlled by a driver provides this stage. Other inverter structures, such as the half-bridge or NPC (neutral point clamped 3-level inverter), may also be used to create it. The complete bridge inverter is the best one for resonant IPT systems, according to the author's assessment of these three inverters in [50] based on many factors including THD (total harmonic distortion), losses, and size.

AC/DC:
In order to maintain a pure (or almost pure) DC output voltage at the load, a complete bridge rectifier composed of four power DIODES is connected to the capacitor. Another inverter that operates in the manner of a rectifier with effective control between the primary and secondary may also be used at this step. Applying a command strategy for each inverter that is dependent on the power sign results in a chance for the power to flow from the output to the input (if necessary).

AC.

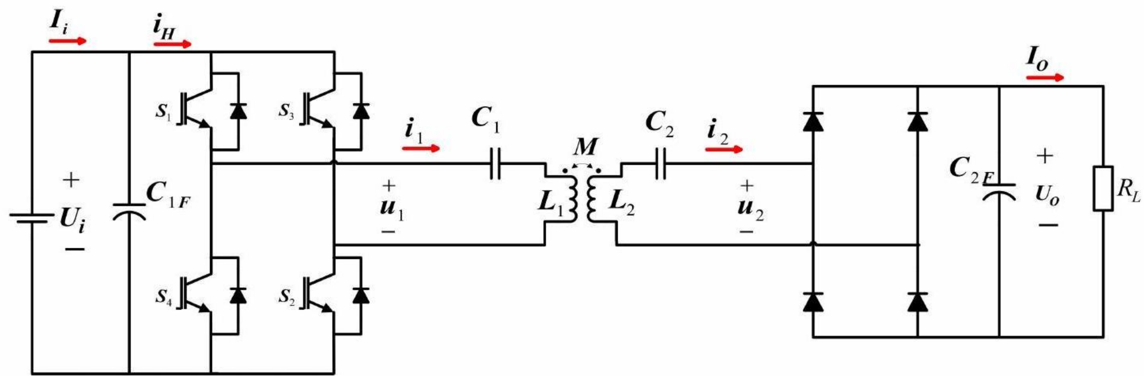


Figure VII.1 Electrical circuit of SS*L* compensated IPT system with resistive load

The simulation takes into account two different types of loads: a resistive load that represents the battery (RL) and a battery model that is presented by a voltage source VBat with a tiny series internal resistor (RIN). Resonant DC-DC converter can now be placed as seen in Fig. VII.1.

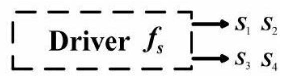
The simulation for this open loop system at the reference case is done (so a resistive load can be valid as a battery model as mentioned before, at least when the steady state is reached). The values are taken as: $d = 0.15m, sh = 0$, so from TABLE VI: $L_1 = 266.16\mu H$ and $L_2 = 256.79\mu$H and $M = 85.46\mu$H. Also, $f_s = f_0 = 20$kHz, $U_0 \cong 400$ V, $P_0 = 2$ kW, so $R_L = \frac{400^2}{2000} = 80\Omega$, and the input voltage from the value of ($1/G_v$) is: $U_i = \frac{U_o}{G_v} = \frac{400}{2.366} \cong 169$ V. $C_1 = 105.74nF, C_2 = 109.60nF, C_{1F} = C_{2F} = 300\mu F$ and the duty cycle of the inverter $D = 0.5$. Furthermore for the battery model: RIN = 0.1 Ω and VBat =400V. The results for the simulations

VIII. Simulation Results

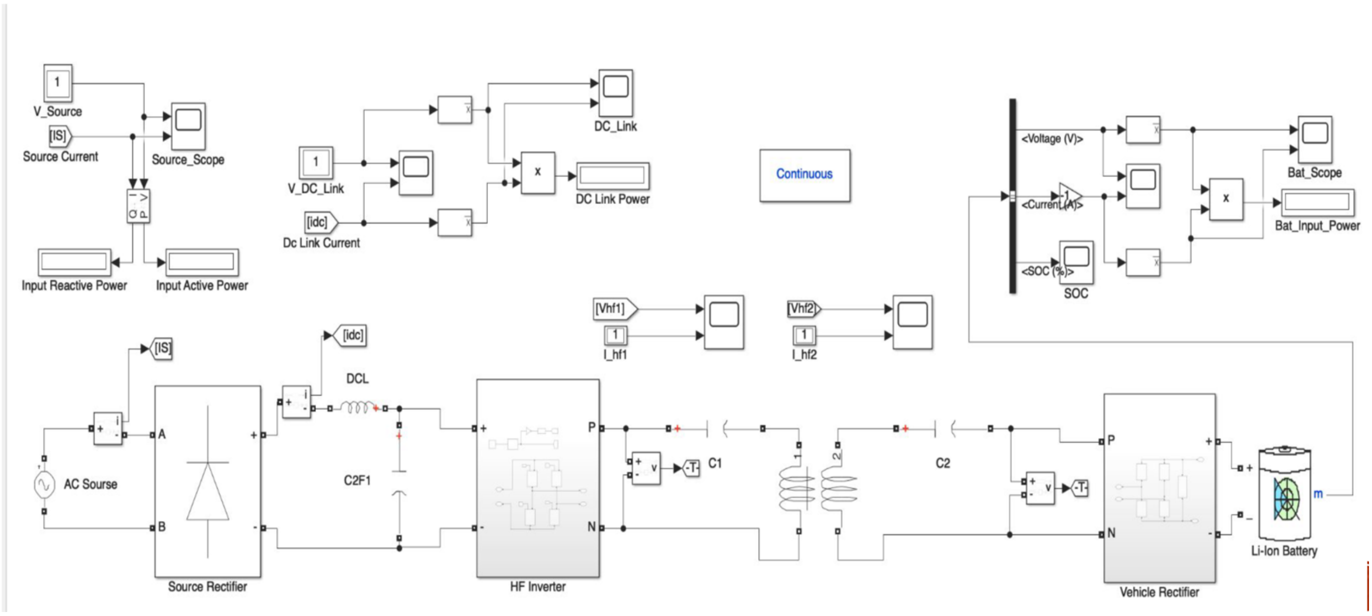
MATLAB/Simulink is used to analyze and simulate the entire IPT system, starting with the input DC stage and finishing with an equivalent load that displays the battery and a battery model. Second, there is the closed-loop system with feedback that aims to control the frequency of the system so that it coincides with the resonant one, where the power transfer is at its highest.

The goal of this project is to develop a high-efficiency wireless electric vehicle charging (WEVC) system utilizing the quasi-resonance method that can transmit 2 kW of electricity to the load side. The suggested technology consists of a contactless coupler and a power electronics system that transforms grid-supplied 50 Hz AC into DC and then 23 kHz AC prior to the wireless stage.

By demonstrating the system behavior in the time and frequency domains using a battery model load, this controller is proven to work with our IPT system. The simulation results for the reference scenario demonstrated a correct response that locates the resonant frequency and transfers the most amount of power possible.Even though the response time is almost imperceptibly slow, it is adequate in the case of static battery charging, which takes 3–4 hours to complete.



Software used for simulation: MATLAB/SIMULINK



FigVIII.1: Simulation Designed Using MATLAB/SIMULINK

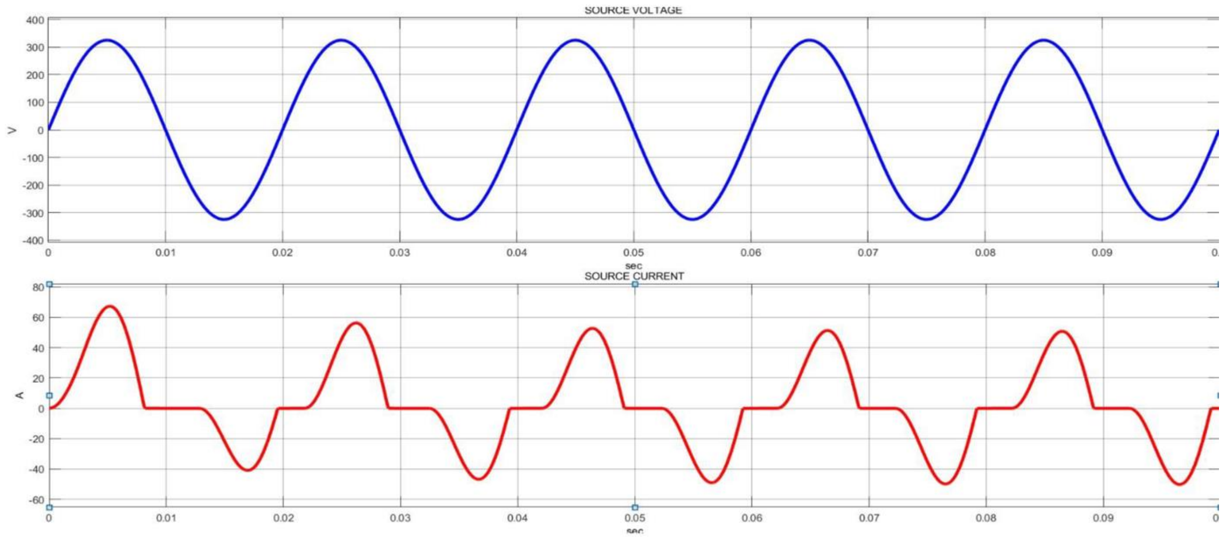


Figure VIII.2. Source Side Current/ Voltage

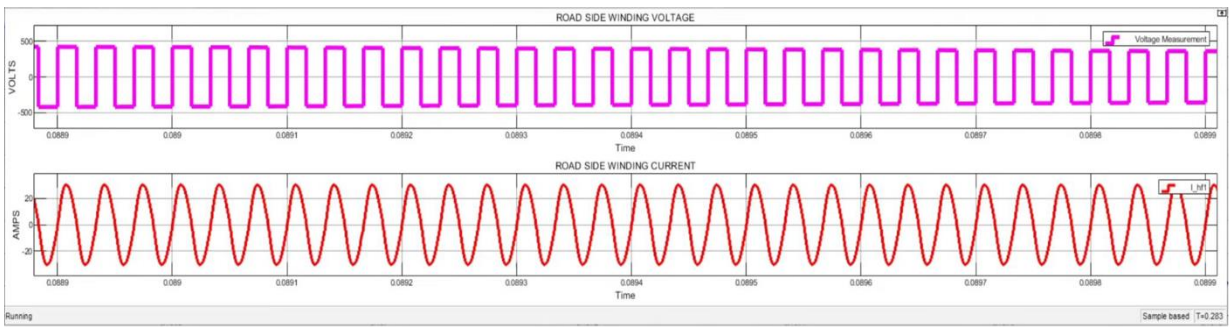


Figure VIII.3. Road Side Current/ Voltage

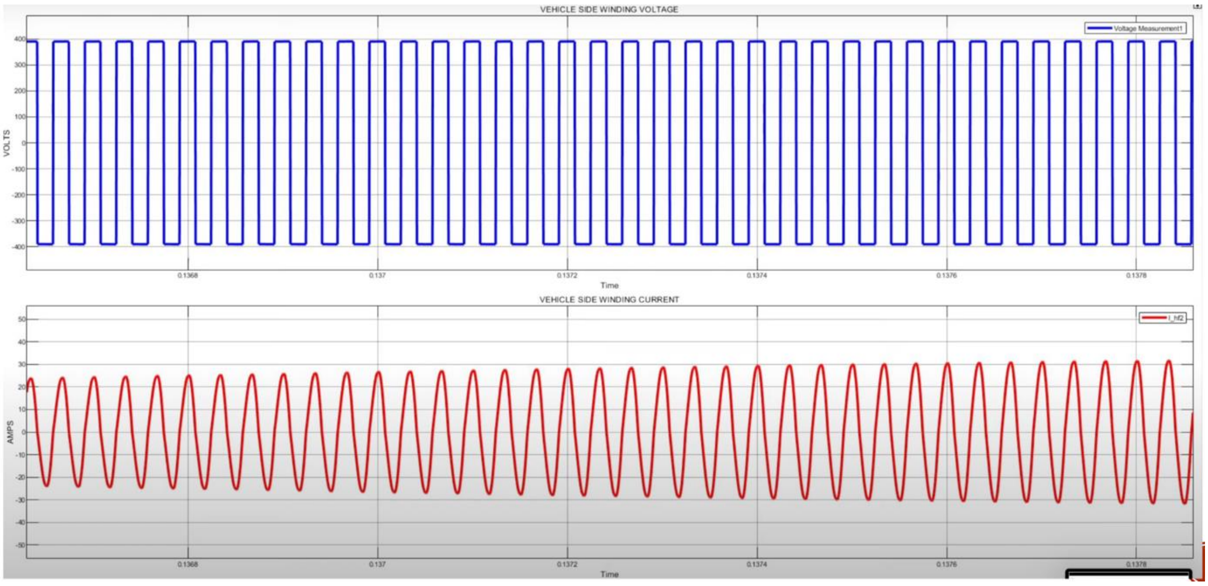


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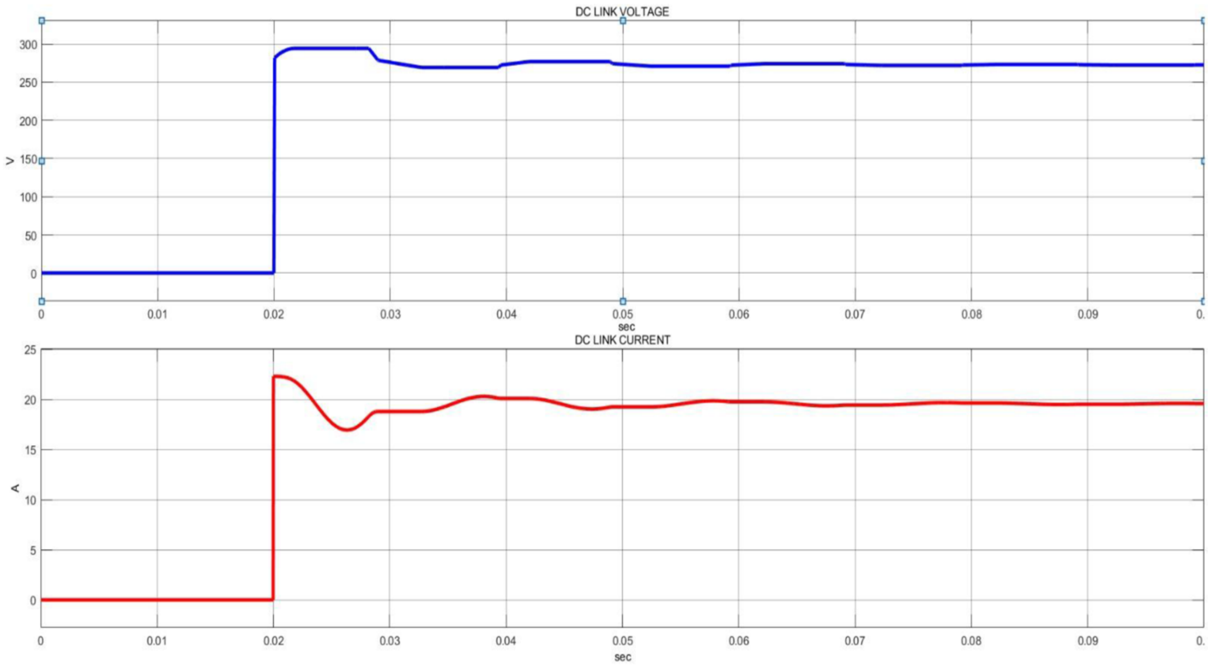
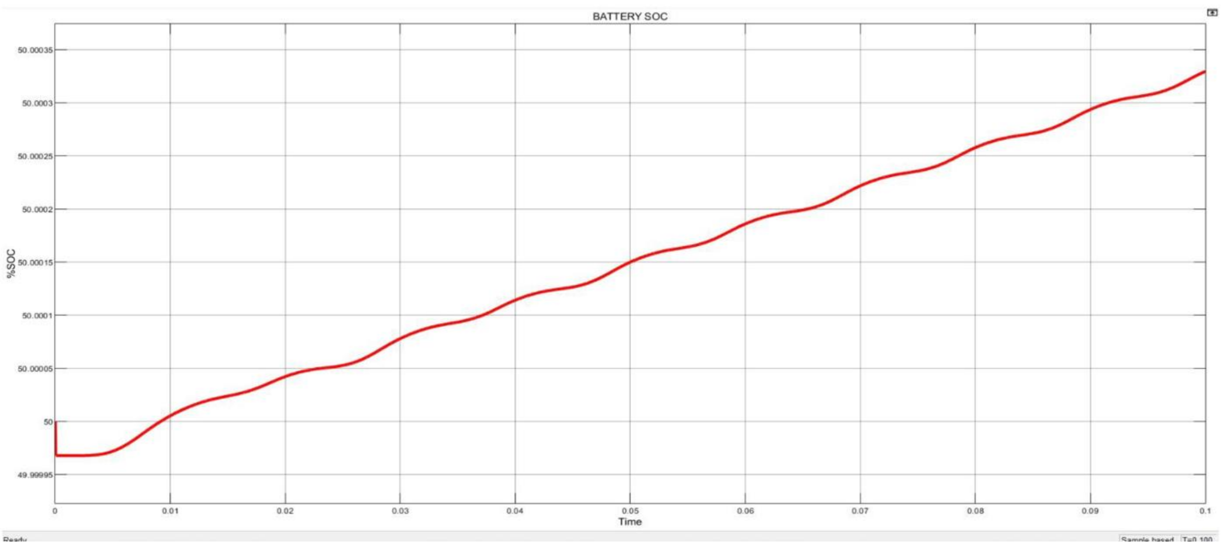
Figure VIII.4. Vehicle Side Current/ Voltage



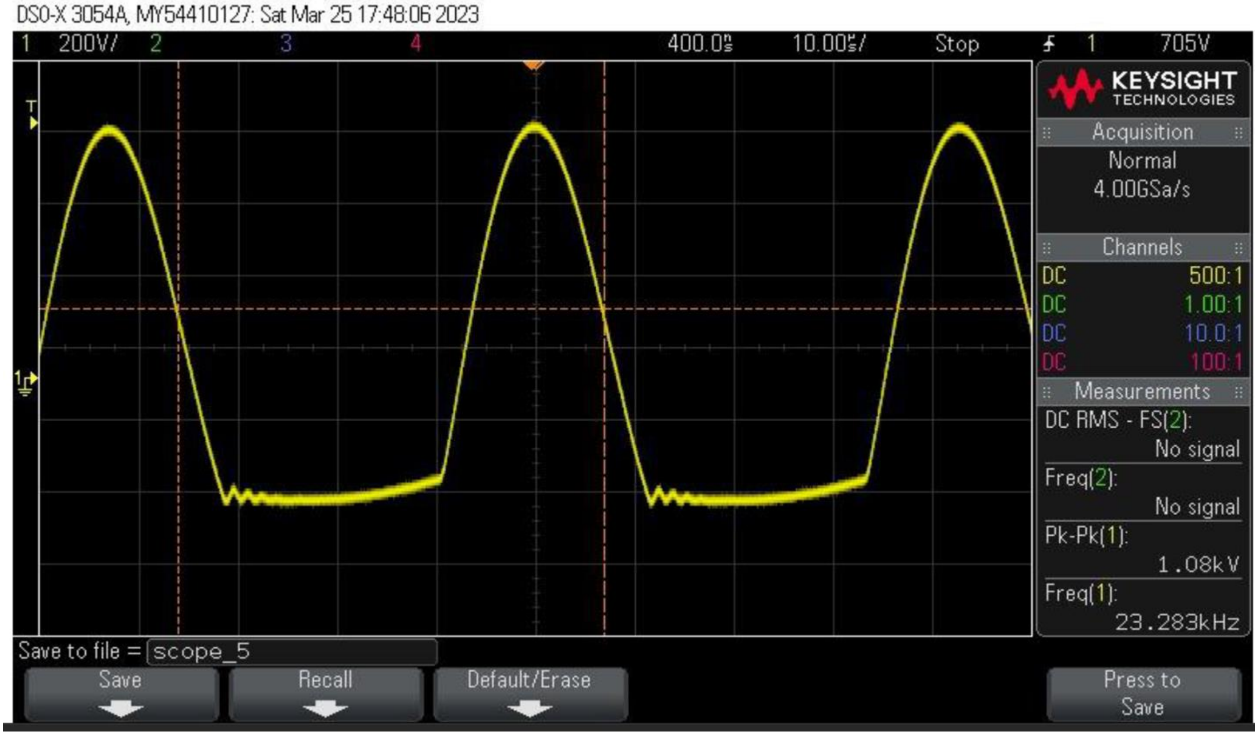
. Figure VIII.5. DC Link for Current/ Voltage



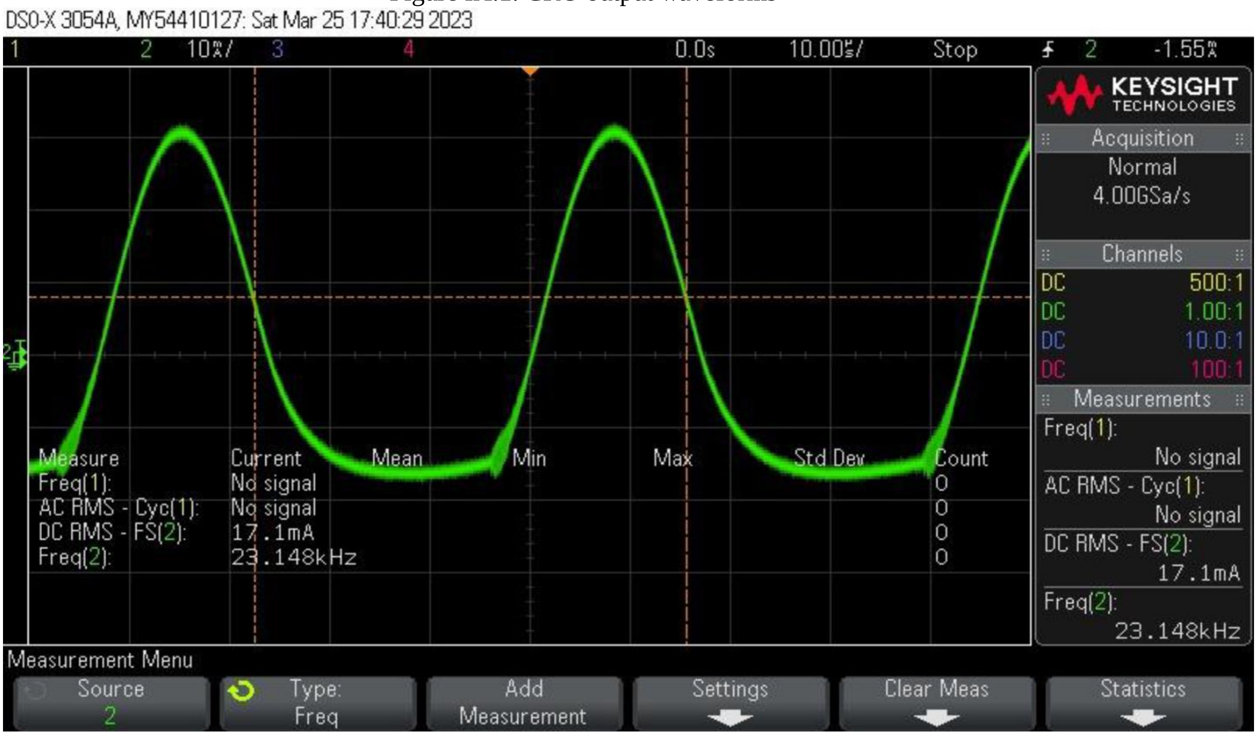
. Figure VIII.6 .Battery SOC

IX. Experimental Results

According to the hardware output findings for the project, the system can convert an AC input voltage of 230V 50Hz to a DC output voltage of 531V with a peak-to-peak voltage of 531V and a frequency of 23kHz at the secondary side. About 17.1 mA of output current was obtained at the secondary side. In the context of IEEE standards, which specify particular requirements for the design and operation of wireless power transfer systems, these findings are significant. Overall, the results show that the system can transmit 2 KW of wireless power, which is encouraging for wirelessly charging EV systems.



. Figure IX.1. CRO output waveforms



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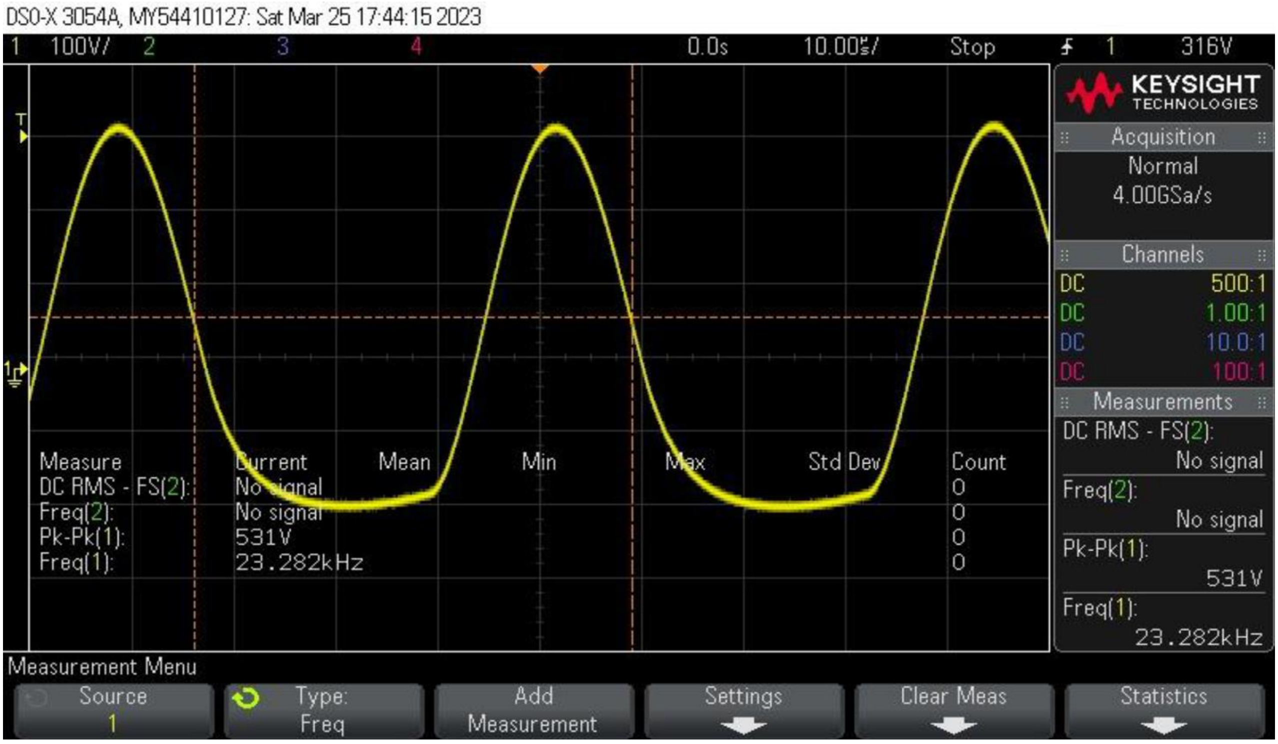

. Figure IX.3. CRO output waveforms

The goal of this project is to develop a high-efficiency wireless electric vehicle charging (WEVC) system utilizing the quasi-resonance method that can transmit 2 kW of electricity to the load side. The major voltage and current waveforms at this frequency exhibit virtually zero phases between the two waveforms, indicating that the frequency the controller detects is, in fact, the precise resonant frequency.

The suggested technology consists of a contactless coupler and a power electronics system that transforms grid-supplied 50 Hz AC into DC and then 23 kHz AC prior to the wireless stage. To achieve high efficiency, the employment of resonant components on both sides is required due to the significant distance between the primary and secondary sides. Galvanic isolation between the source and the load is provided by an inductive coupling (IC) transformer.

The Quasi-Resonance Method is a potential method for wireless power transmission that regulates the output parameters at the load side to maintain the charger working at a certain voltage with the necessary current requested by the battery, assuring load protection. Resonance and magnetic coupling are used in this technique to effectively transmit power from a source to a gadget

Table 1 Table Type Styles

PARAMETER	REQUIREMENT
Input Voltage	$V_{ACmin} = 85\ V_{RMS}$
	$V_{ACmax} = 537\ V_{RMS}$
Line Frequency	$f_{LINEmin} = 50$ Hz
	$f_{LINEmax} = 23$kHz
Output Voltage	$V_{OUT} = 5$ V
Output Current	$I_{OuT} = 2$ A
Output Peak Power	$P_{OUTpeak} = P_{OUTmax} = 10$ W
Cost	LoW
Efficiency	h > 0.8
Size	Small
EMI Compatibility	n/a
Safety Requirements	n/a
Temperature	Ambient, No Air Flow

Hold Up	No
Output Ripple	$V_{OUTripple} = 0.15$ V
OPP	
Overvoltage Threshold	$V_{OVP} = 6$ V
PFC	n/a
Reliability	Of Course
Load Transient	Of Course
Regulation	R 10%
Brown Out	$V_{BROWNouT} = 80$ V RMS

I. Conclusion

This project focuses on designing a high-efficiency wireless electric vehicle charging (WEVC) a system capable of transferring 2 kW power to the load side using the Quasi Resonance Method. The proposed system comprises a contactless coupler and a power electronics system, which converts 50Hz AC from the grid to DC and then to 23kHz AC before the wireless stage. The considerable distance between the primary and secondary sides necessitates the use of resonant elements on both sides to ensure good efficiency.

An Inductive Coupling (IC) transformer is used to provide galvanic isolation between the source and the load. The output parameters at the load side are regulated to keep the charger operating at a certain voltage with the desired current demanded by the battery, ensuring load protection. , the Quasi-Resonance Method is a promising technique for wireless power transfer. This method utilizes the principles of resonance and magnetic coupling to efficiently transfer power from a source to a device.

● The design and implementation of a 2kW wireless power transfer system using the QRM technique, with two coils wound with 22 turns of 20 gauge wire and 20 meters in length, and a PCB similar to that of an induction cooker, can efficiently transfer power wirelessly to a vehicle battery.

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