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# Pursuance of a passive filter for a multi-coil EV charger employing a solar connected system to enhance power quality

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**ABSTRACT**

This study describes the use of a passive filter to enhance power quality (PQ) of a multi-coil charger for (EVs) using a solar connected system. Wireless charging solutions have been developed as a result of the rising demand for EVs, which use multi-coil chargers to transfer power wirelessly. However, the high-frequency switching used in these chargers can cause power quality issues, such as harmonic distortion, which can affect the performance of the EV and the grid. To reduce PQ incidence effect during charging, a MATLAB model has been created here. The proposed system provides an innovative approach to addressing power quality challenges associated with electric vehicle charging infrastructure. The integration of a passive filter for multi coil wireless power transfer (MCWPT) can significantly improve power quality and promote the use of clean energy in the transportation sector. This study contributes to the development of sustainable solutions for addressing the challenges associated with electric vehicle charging infrastructure.



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## 1. INTRODUCTION

The worldwide market for electric vehicles has been growing quickly due to the increase in consumer demand in the past few decades for green modes of transport. To the power system, charging electric vehicles (EVs) might present a difficulty because it can result in power quality problems including spikes in voltage and interference from harmonics. Therefore, the implementation of power quality improvement techniques in electric vehicles charging infrastructure is crucial for the stable and the electricity grid's ability to operate reliably [1]. The design of base model can be visualized from the Figure 1 i.e., block diagram.

In this context, this paper proposes the implementation of a passive filter for power quality improvement of a multi-coil charger for EVs using a solar connected system. The passive filter is intended to lower the harmonic content and raise the PF of the charging system's [2], [3]. The solar connected system is employed to reduce the dependence on the grid and encourage the usage of renewable energy sources (RES). Depending on weather conditions and temperature the power is extracted from solar or grid to charge the battery of an electric vehicle [4]-[6]. This power is boosted up when solar is active while in the grid, power is rectified and then bucked to the required voltage. But, the outcome power from these converters is filtered to remove harmonics and noise comes due to converters using passive filter which is then travel through high frequency inverter where the switching frequency of 50 kHz is provided with the help of pulse width modulator which helps in improvement of the flux passage from transmission coil to receiving coil [7]-[10]. There remain possibilities of error in coil designing/manufacturing which is handled using resonant capacitors at both coils. The received power charges the battery of EV after being rectified.

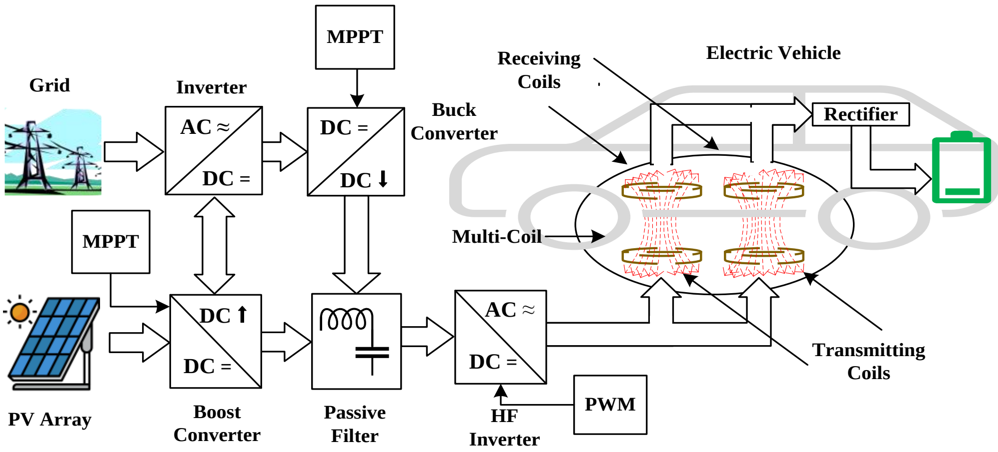



Figure 1. Block diagram

## 2. SYSTEM OVERVIEW
### 2.1. Coils

A coil is an electrical component that consists of a wire wound around a core. This wire is usually manufactured from an electrically conductive material, such as copper or aluminium, while the core can be made of different materials such as air, plastic, or magnetic materials like iron or ferrite. A field of magnetic energy is created around a coil when an electric current passes through it [11], [12]. The magnetic field's intensity is dependent on the coil's current flow and the number of wire turns. This magnetic field can be utilized to produce a voltage in a nearby conductor, or to generate mechanical force in an electromagnetic motor. Coils have a broad range of applications, including their use as inductors in electronic circuits, transformers for power distribution, and motors for various industrial and household applications [13]. They are also used in scientific instruments such as magnetic resonance imaging (MRI) machines and particle accelerators. Various properties of a coil such as its inductance, resistance, and capacitance can be calculated based on its physical dimensions and the materials used by the (1)-(3) [17]. These properties can be utilized to design and optimize coils for specific applications, such as maximizing the efficiency of a transformer.

$$L = \frac{N^2 \times \mu \times A}{l} \quad (1)$$

Where N is the number of rounds in the coil and L is the inductance value in Henry, A is the cross-sectional surface of the center, l is the length of the center, and μ is the permeability of the central material [14]-[16].

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

Where C is the capacitance in farads and L is the inductance in henry.

$$C = \frac{\pi \times \varepsilon \times A}{l} \quad (3)$$

Where A is the cross-sectional surface of the center, l is its length, and ε is the material's permittivity [17].

### 2.2. Electric vehicle battery

An EV battery is a replenish able battery that is utilized to power an EV such as an electric car, electric bike, or electric scooter. Lithium-ion, nickel-metal hydride, and lead-acid batteries are just a few of the battery chemistries that are available for EV batteries. Due to its elevated density of energy and prolonged longevity, lithium-ion is the most popular chemistry utilized in contemporary electric vehicles. The performance of an EV battery is typically characterized by its capacity, voltage, and energy density. Capacity refers to the amount of electric charge that the battery can store, usually measured in kilowatt-hours (kWh) [18]. Voltage refers to the electric potential difference between the positive and negative terminals of the battery, which determines the amount of current that can be supplied to the electric motor. Energy density refers to the amount of energy that can be stored per unit volume or mass of the battery. All these parameters can be specified from structure and mass with the help of (4) to (8) [18].

$$Capacity\ (C) = Energy * \frac{Energy(E)}{Voltage\ (V)} \tag{4}$$

$$Energy\ density\ (ED) = \frac{Energy(E)}{Volume\ (V)} \tag{5}$$

$$Specific\ energy\ (SE) = \frac{Energy(E)}{Mass\ (M)} \tag{6}$$

$$State\ of\ Charge\ (SoC) = \left(\frac{Current\ Capacity}{Total\ Capacity}\right) \times 100\% \tag{7}$$

$$Coulombic\ efficiency = \left(\frac{Discharge\ Capacity}{Charge\ Capacity}\right) \times 100\% \tag{8}$$

Where E represents the amount of power held within the battery, V represents its voltage, I represent the current running through it, M represents the battery's mass, and state of charge (SoC) represents the degree of charge.

## 3. METHODOLOGY

The paper focuses on charging car efficiently, so different models are examined and compared based on mathematical, simulation and economic feasibility. The multi-coil system is simulated in one way that is parallel to series [19]. The power from the grid transfer supply to local loads and charge battery in the dark time. Due to less feasibility and heavy load demand in day time the solar maintain the required power of wireless charger.

The power from grid is firstly inverted and then bucked down with the use of maximum power point tracking or MPPT controller connected with pulse width modulation or PWM, and the power from solar is boosted up by the help of PWM taking duty cycle from MPPT. When the battery is fully charged or no car is charging that is parking is free then at day time the solar give power to the grid using three level inverters [20]-[23]. This full system is displayed in Figure 2.

This power from buck/boost converter is then filtered to remove harmonics and improve power quality using passive filter [24]-[26]. The voltage and current needed to be of very high frequency to charge car wireless to manage this. High frequency inverter shown by Figure 3 is used in which PWM inserts the frequency of 50 kHz which is then resonated and passed through transmitting coil.

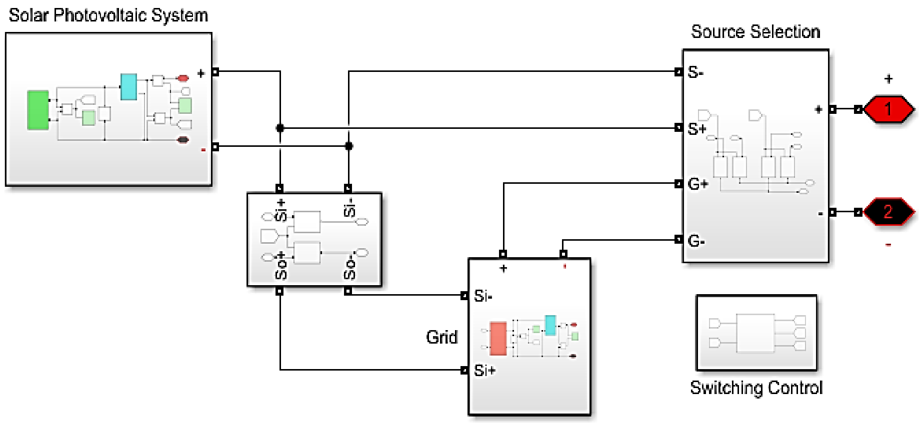



Figure 2. ON-grid system

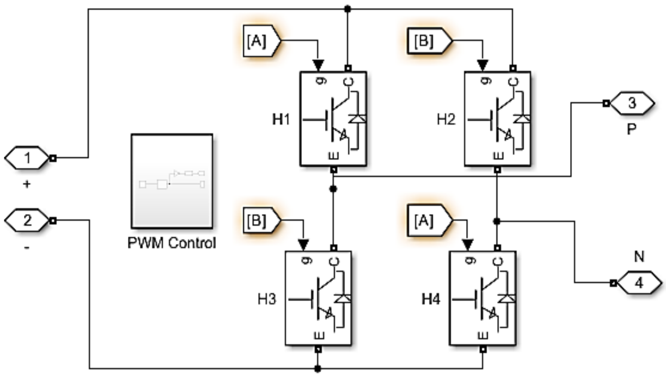



Figure 3. High frequency inverter

## 4. SIMULATION MODELAND RESULTS

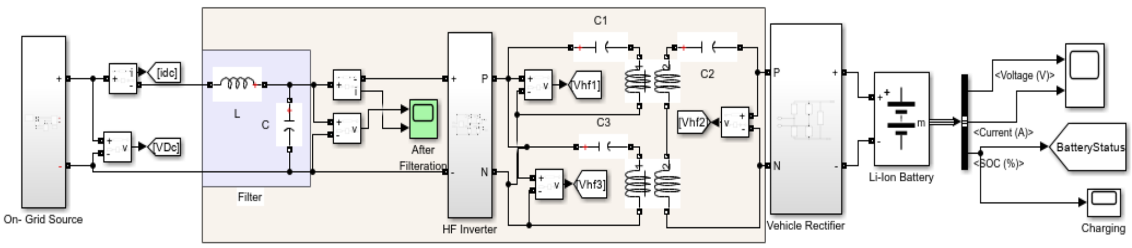
Sincemulti-coil wireless charge has very high voltage distortion so, it's time to simulate with filter. Figure 4(a) (see in appendix) is the model of simulation. DC V & I can be seen in Figure 4(b) i.e., the incoming V & I from source. Since, filter circuit is used so deflection in Figure 4(c) after filtration can be observed. Figure 4(d) and Figure 4(e) displays the V & I across transmitting coil ($T_x$) and receiving coil ($R_x$) and Figure 4(f) is showing the V & I across the battery, Figure 4(g) shows the status of battery. Input filter capacitors and output filter capacitors are the two primary kinds of filter capacitors employed in charging battery circuits. Capacitors are employed to rectify and frequently filter the alternating current across the steps-down transformer, resulting in a controlled DC voltage that is then passed via voltage-regulating chips for charging the battery.

## 5. CONCLUSION

In this paper different cases are proposed and MATLAB based simulation is performed to conquer the effect of charging electrical vehicle's battery wirelessly. Different setups of coil have been prepared to check the effect and all setups are tested with and without filter circuit. After performing different cases of charging battery of electrical vehicle this can be verified from the results of simulation that the best case is "on-grid multi-coil (parallel to series) wireless charger with filter" where charging voltage of 310 Volts and charging current of 31Amperes observed. Passive filter integration for MCWPT can greatly enhance power quality and encourage the transportation industry to adopt clean energy. This research aids in the creation of long-term remedies to the problems related to the infrastructure needed for charging electric vehicles.

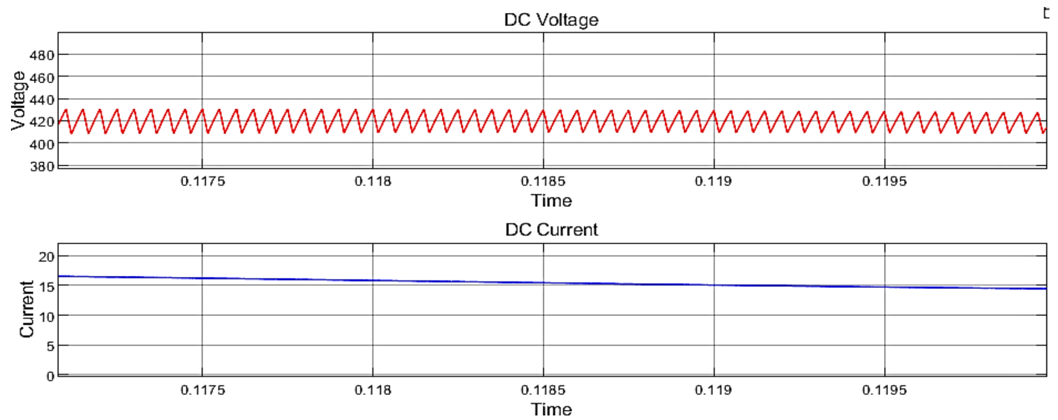
According to simulation we have 40.5 kwh battery so charging time power generated = 310*31=9.61 kW, assuming 80% charging efficiency the actual power delivered = 9.61*0.8=7.69 kW, charging time = 36.24 Kwh/7.69=4.71 hr. Furthermore, case of multi-coil like parallel to parallel, series to parallel and series to series will be needed to be compared for efficient transfer of power. Thanks to Tesla's invention of the magnetic resonant coupling, power can be transmitted and delivered through the air using two circuits, including a transmitter & receiver system. The real world did not employ this strategy for approximately a century. Nonetheless, a variety of cordless charging techniques are now accessible to eliminate the necessity for wires on a wide range of devices, including wearable technology, and cars.

## APPENDIX

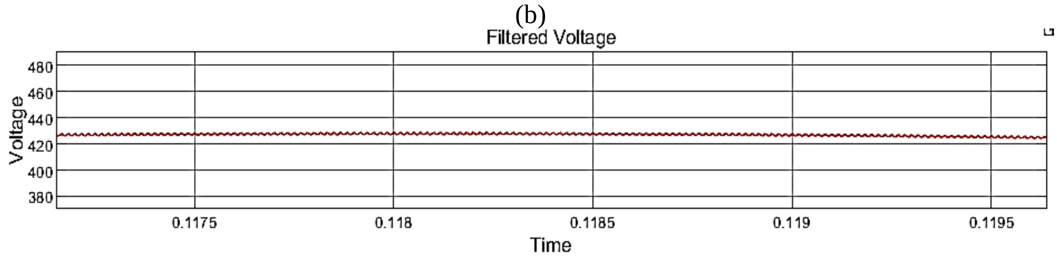



(a)

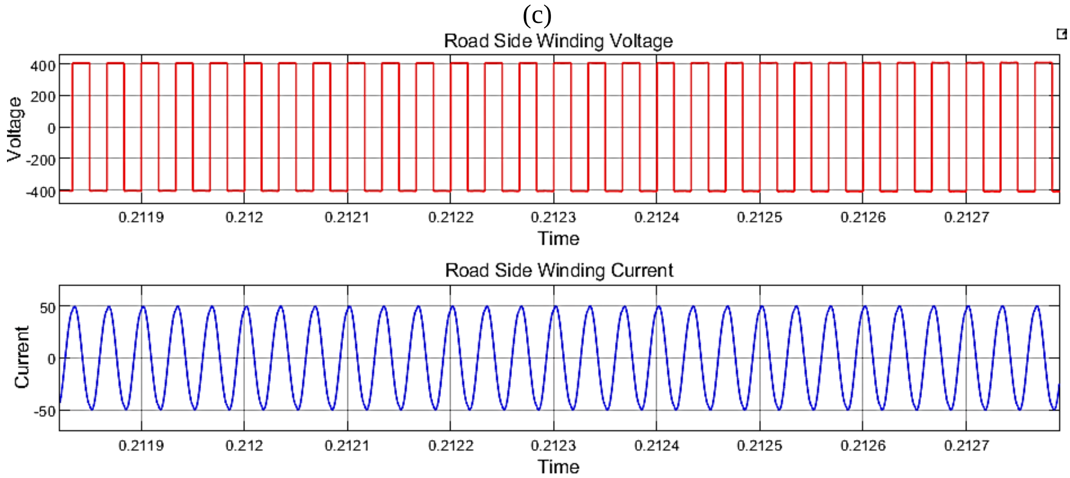
Figure 4. Simulation model and results: (a) simulation model of multi-coil power transfer with filter circuit



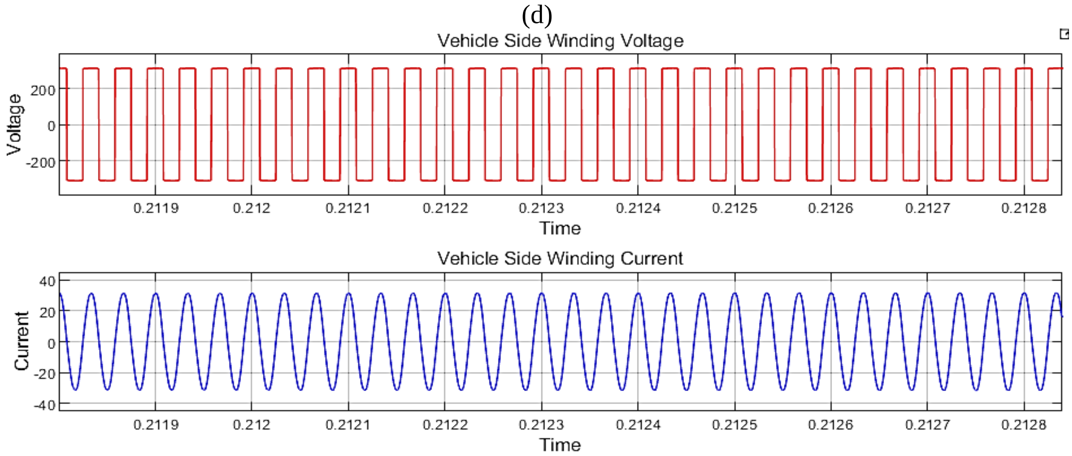

(b)




(c)

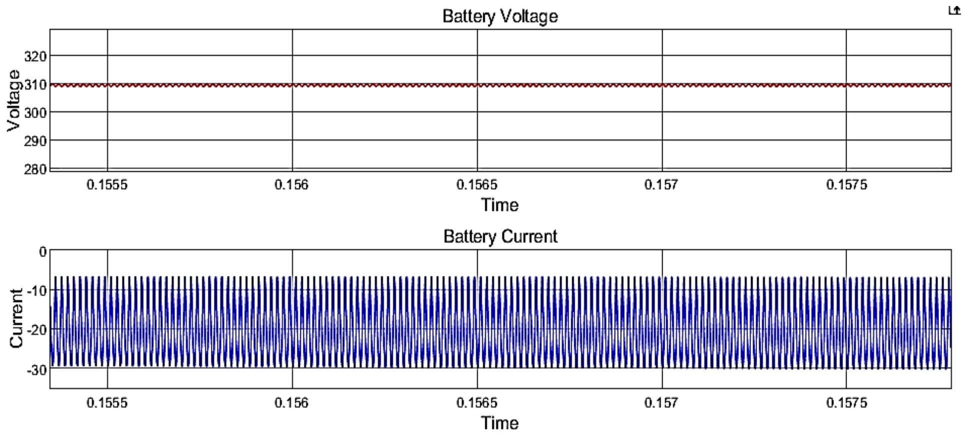



(d)

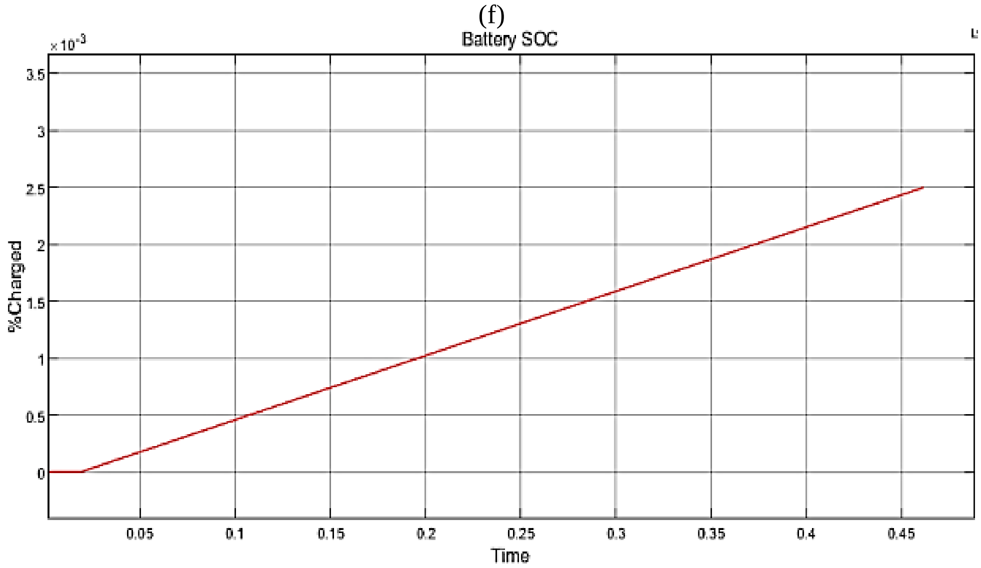



(e)

Figure 4. Simulation model and results: (b) V & I from DC-DC converter, (c) filtered voltage, (d) V & I across transmitting coil, and (e) V & I across receiving coil (continued)




(f)




(g)

Figure 4. Simulation model and results: (f) V & I for charging battery, and (g) status of battery charging (continued)

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