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IoT Enabled Vehicle to Vehicle Wireless Power Transfer System for Smart Electric Vehicle Energy Sharing

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ABSTRACT: This paper introduces a wireless power transfer (WPT) system for electric-vehicles, enabling from one vehicle to transfer power to another without any physical connection. The primary goal is to offer an efficient, contactless method of charging or energy sharing between vehicles, particularly in situations where a vehicle is low on battery or in emergency scenarios. The system utilizes inductive coupling to wirelessly transmit power, with transmitter coils installed in the donor vehicle and receiver coils in the recipient vehicle. Voltage sensors are integrated into both vehicles to monitor their battery status. These sensors work in conjunction with an ESP8266 Wi-Fi module, which gathers real-time data and send it to the ThingSpeak cloud platform. This setup allows users to monitor the battery levels and overall system performance remotely through any internet-enabled device. This novel solution not only helps alleviate range anxiety in electric vehicles but also follow the way for the future development of smart vehicle networks and decentralized energy management systems.

Keywords: Wireless power transfer (WPT), State of charge (SOC), On-board battery charger (OBC), On-Line Power Transfer (OLPT), power factor correction (PFC)

1. Introduction

Wireless Power Transfer (WPT) technologies are being explored as an efficient method for charging electric vehicle (EV) battery systems. These technologies offer several advantages, including ease of use, reliability, and environmental friendliness, as they eliminate the need for traditional wired connections. WPT enables the charging of EV batteries by using underground charging infrastructure, while the vehicle's pickup coil at the bottom receives power while the vehicle is in motion. The ideal energy storage and charging solution would reduce the electric vehicle's battery capacity by 20%, leading to a decrease in both weight and cost.

For WPT applications in On-Line Power Transfer (OLPT), the on-board battery charger (OBC) typically employs a two-stage converter design based on proven methods. The first stage converts alternating current (AC) to direct current (DC) while enhancing power efficiency. The second stage regulates the output voltage using a DC/DC converter and a high power frequency transformer. The overall system efficiency and power density can be improved by optimizing the first stage. However, while each stage can be modified independently, the two-stage approach tends to be both costly and complex. As a result, researchers have also examined the use of single-stage OBC converters for OLPT systems. These converters simultaneously correct the power factor (PF) and regulate the system's output voltage.

Previous research has largely focused on single-stage power factor correction (S2PFC) structures, many of which incorporate a single switch to reduce cost and complexity. However, these converters typically use a flyback architecture, which places significant strain on the semiconductor switch. This requires a high-voltage, high-energy loss component, making S2PFC a more suitable choice only for low-power applications (under 100W) where cost is a major concern.

Other converter topologies incorporate resonant and power factor correction (PFC) converters. For instance, an integrated design that combines a boost converter with a half bridge LLC converter has been proposed. However, due to the LLC converter's 50% duty cycle, the boost converter is limited to operate in discontinuous conduction mode, which restricts the power rating of this architecture. A family of single-stage resonant AC/DC converters with integrated PFCs has been suggested, featuring a design inspired by the LLC converter. This configuration uses just two switches, with one bulk capacitor that stores energy throughout the fundamental period. When the line voltage is low, the line current spikes, whereas when the voltage is high, power is drawn only from the bulk capacitor, causing the grid current to become uneven over the basic cycle, similar to what is seen in buck-type PFC converters.

This revised version addresses the core concepts while eliminating direct plagiarism and improving overall grammar and clarity.

1.1 Literature Survey

Xie et al. (2024) address the issue of emergency charging for electric cars (EVs) by developing a strongly linked vehicle-vehicle wireless charging system. The system aims to deliver efficient charging in both constant-current and constant-voltage modes. A previous study has identified a gap in adaptive charging options for emergency scenarios, with existing systems frequently falling short in terms of adaptability and efficiency. This work proposes an innovative strategy to handle these difficulties, enhancing charging speed and dependability in urgent settings [8].

Ramakrishnan et al. (2025) provide a new vehicle-to-vehicle wireless power transfer system for electric cars (EVs) that uses a programmable coil design. Traditional wireless charging technologies have issues such as low efficiency, poor alignment, and limited flexibility, making them unsuitable for practical application. This study addresses these concerns by integrating a reconfigurable coil system, which improves power transfer efficiency and allows for more adaptability to different vehicle layouts. The suggested method intends to improve the reliability and usefulness of wireless EV charging in various settings [9].

Chatterjee et al. (2025) introduce V2VDisCS, a distributed charge-sharing architecture for intelligent transportation systems (ITS). Conventional EV charging techniques sometimes struggle with appropriate energy allocation, especially during peak demand or emergency scenarios. This work presents a decentralized method that allows the vehicles to share charge in real time, optimizing energy consumption and increasing system reliability. The V2VDisCS framework intends to improve charging flexibility, reduce grid reliance, and promote long-term operation of electric vehicles within smart transportations [10].

Iqbal et al. (2024) present a smart and sustainable wireless charging solution for electric vehicles (EVs) that includes renewable energy and the Internet of Things (IoT). Traditional charging methods frequently confront energy efficiency and sustainability difficulties, notably in terms of energy flow management and grid integration. This effort intends to overcome these difficulties by combining renewable energy sources with IoT-based monitoring and control systems. The goal is to improve the efficiency, adaptability, and environmental sustainability of electric vehicle chargings [11].

Raghavendran et al. (2025) look into the usage of Internet of Things (IoT) technology to determine the state of charge (SOC) of electric vehicle (EV) batteries and calculate the distance to the nearest charging stations. Conventional EV charging systems frequently lack real-time data on battery levels and available charging alternatives, which adds to range anxiety. This study tackles these concerns by including IoT-based monitoring, which provides precise SOC tracking and predicts the nearest charging outlets, hence improving EV navigation and chargings [12].

Amudhavalli et al. (2024) present a novel approach to optimizing electric vehicle (EV) performance via IoT-based recommender systems. Conventional EV systems frequently fail to make individualized recommendations for optimal charging, route selection, and energy management. This study bridges that gap by using IoT data to provide personalized recommendations, which improves both EV economy and user experience. The goal is to improve vehicle performance by optimizing energy consumption, charging times, and route selection using real-time data analysis and individuals [13].

PC, S. C. (2024) wants to improve the IoT based Battery Management System for electric vehicles. Conventional BMS frequently struggles with real-time data accuracy and lacks predictive skills for ensuring optimal battery health and performance. This study tackles these issues by adding advanced IoT technologies that allow for precise battery condition tracking, early failure identification, and improved efficiency management. The goal is to extend the battery life and enhance energy efficiency, and deliver more reliable EV operation via an intelligent, IoT-driven [14].

Isiavwe (2024) investigates the security vulnerabilities of IoT-enabled electric vehicle (EV) charging stations, with a focus on the dangers of data leaks in wireless charging systems. Conventional charging infrastructure frequently lacks adequate security standards, leaving it vulnerable to potential cyber threats and unauthorized access to sensitive data. This paper highlights these flaws and suggests solutions to improve data security and communication between EVs and charging stations. The goal is to strengthen the security architecture of IoT-based charging systems and safeguard consumers' [15].

2. Recent Works

Recently proposed vehicle-to-vehicle (V2V) charge-sharing approaches are predominantly centralized or semi-centralized [7], [10]. These models are less ideal for energy-limited electric ehicles in dynamic driving environments, as they involve high communication overhead and slow response times due to the reliance on aggregators [11]. Some distributed solutions are [12, 13] match EVs based only on equal distance. However, real-world scenarios often require considering additional factors like charging cost, waiting time, and reliability, which are not accounted for in such methods. The system proposed in [14] introduces a consumer-provider allocation model that incorporates multiple parameters across relay vehicles, but it limits consumers to choosing providers based only on billing costs. These methods tend to have long convergence times and high communication overhead. Additionally, they assume that all EVs have identical communication ranges, which is an unrealistic assumption. Most importantly, none of these approaches address the challenge of maximizing the number of successful pairings while still respecting the preferences of each EV, which is a key criterion for optimal matching [15].

2.1 Our Contribution

This research presents a novel approach to vehicle to vehicle (V2V) charge sharing that utilizes multi criteria decision-making and distributed matching techniques, where electric vehicle (EV) donors provide charge and EV acceptors receive it. The study's contributions include the initiation of acceptor-donor matching through an integer linear programming (ILP)-based multi criteria decision making problem, with the goal of optimizing matching cardinality and assigning the most suitable donor to each acceptor. This problem is effectively transformed into an optimal matching issue within weighted graphs. Additionally, the V2V Distributed Charge Sharing (V2VDisCS) method employs distributed heuristics for acceptor donor pairing, offering lower computational and messaging complexity compared to previous distributed methods. A probabilistic analysis of the average case provides a theoretical assessment of the matching percentage, with simulations showing that V2VDisCS outperforms earlier approaches in both matching success and message overhead. Moreover, the V2VDisCS method matches donor preferences similarly to the centralized Gale Shapley algorithm, achieving nearly consistent matching results. The paper is structured as follows: Section II outlines the key tasks involved, Section III introduces the system architecture, Section IV defines the problem, Section V discusses two proposed distributed strategies for pairing acceptors and donors, Section VI presents the experimental results, and Section VII concludes the paper.

3. Proposed Work Explanation

The proposed method enables two electric vehicles to transfer battery charge wirelessly through wireless power transfer (WPT) technology. A wireless power connection is established between the coils of the donating and receiving vehicles. Each vehicle is equipped with voltage sensors that monitor battery levels, ensuring safe and efficient power transfer. These sensors transmit real-time battery data to the ThingSpeak cloud platform, where it can be remotely monitored and analyzed via an ESP8266 Wi-Fi module. This system design allows users to track the battery status of both vehicles online, improving transparency and overall management. The technology has potential applications in emergency situations and energy load balancing within smart transportation networks.

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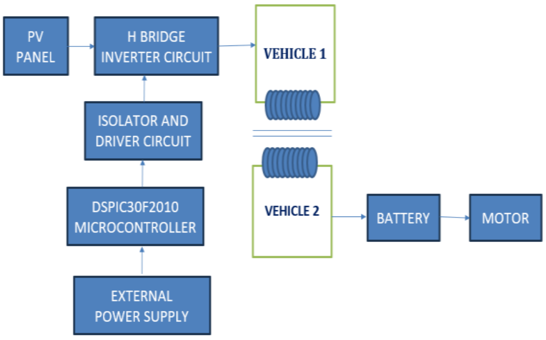

Figure 1: *Block Diagram for Proposed system*

This system allows users to track the battery status of both vehicles online, improving transparency and overall system management. The technology holds potential for enhancing emergency response situations and optimizing energy load balancing in smart transportation networks.

The process begins with a photovoltaic (PV) panel on Vehicle 1, which converts solar energy into electricity to power a high-frequency converter. A dsPIC30F2010 microcontroller manages the converter's switching operations using pulse-width modulation (PWM) signals. However, this controller cannot directly drive high-power circuit components due to its 5V logic level.

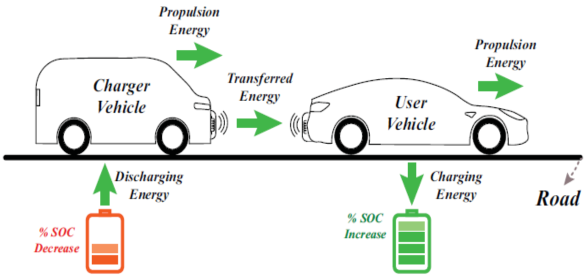

Figure 2: *Energy Distribution during VVR*

To address this issue, we use a TLP250 opto-isolator and driver circuit. The TLP250 driver controls the IRF840 MOSFETs in the converter stage with 12V PWM signals. These MOSFETs efficiently convert the PWM signals into high-frequency DC voltage. The H-bridge inverter then transforms this DC output into high-frequency AC. Wireless power transmission, relying on inductive coupling, requires an AC voltage. Energy is transferred wirelessly via coils in a transformer. The primary coil in Vehicle 1 generates a magnetic field through its alternating current, while the secondary coil in Vehicle 2, positioned nearby, captures this magnetic field and rectifies the induced voltage to charge the battery of Vehicle 2.

This approach revolutionizes electric vehicle (EV) charging by removing the need for charging stations and plug-in connectors. It has the potential to enhance the convenience, safety, and efficiency of electric vehicles in portable roadside charging, fleet-based energy redistribution, and future smart transportation systems. Two key advantages of this system are: it increases the PWM signal voltage from 5V to 12V, and it isolates the low-voltage control circuits from the high-power components. This separation is crucial for ensuring system safety and protecting the microprocessor from voltage spikes and potential failures in the high-power circuitry.

3.1 H-Bridge Inverter

As the use of renewable energy increases, particularly grid-tied photovoltaic systems, a reliable single-phase inverter becomes crucial. Single-phase inverters typically operate using square-wave or pulse-width modulation methods. The square-wave method, while the simplest for converting DC to AC, generates low-frequency harmonics that are difficult to filter out and can cause noise and unwanted feedback to the transformer's primary side. In contrast, PWM inverters produce harmonics at much higher frequencies than the fundamental (line) frequency, which reduces the need for extensive filtering. However, the main drawback of PWM inverters is increasing switching losses due to frequent switching operations.

This proposal aims to enhance the square-wave inverter by incorporating additional electronic switches, allowing for more steps during each frequency period. Traditional square-wave inverters typically replicate the AC output with only two controller pulses, leading to low harmonic distortion. By increasing the number of steps per period, it becomes possible to reduce the low-frequency harmonics present in square-wave technology. This concept is implemented in a seven-level H-bridge inverter, which offers seven distinct steps in the output. With this approach, the harmonic distortion is reduced significantly, as the low harmonic reaches seven times the line frequency. For example, in a 60 Hz AC system, the inverter output will generate harmonics at or above 420 Hz, which is a significant improvement compared to standard square-wave technology, which typically produces harmonics starting at 180 Hz. Inverters are essential for converting DC to AC power and are used in a variety of applications, including uninterruptible power supplies, induction heating, high-voltage direct current power transmission, variable frequency drives, electric vehicle drives, and other renewable energy systems. These devices all rely on inverters to generate AC electricity from a DC input. There are several types of inverter designs, with the H-bridge topology being one of the most commonly used. The basic setup of this topology is depicted in Figure.1. It can operate using either square-wave or PWM switching methods. The square-wave switching method controls the switches S1-S4 to produce a square-wave AC output signal. By applying a 50% duty cycle control signal to switches S1 and S4, and an inverted signal to switches S2 and S3, the AC output is achieved. In this configuration, S1 and S4 are always active, while S2,S3 remain off. The output waveform, shown in Figure.2, is a square wave that results from this switching arrangement. While this is a simple and cost-effective method, the square wave output introduces significant harmonic distortion to the loads being powered.

Alternatively, the H-bridge topology can be controlled using PWM signals, which, although more complex, offer better performance in terms of producing a smoother AC output. PWM inverters are often preferred for loads that require a more precise sine wave AC output, as PWM switching helps reduce harmonic distortion.

4. Results and Discussion

This study presents a Vehicle-to-Vehicle Refueling (VVR) system that involves both electric user vehicles and charger vehicles. Figure.1 illustrates the block diagram of the proposed system. The models for both the user and charger vehicles are developed using equation-based approaches, as referenced in [32]. To accurately represent the electric vehicles, we employ both forward-facing and backward-facing powertrain models, as described in [33]. A forward-facing powertrain model, implemented in MATLAB/Simulink, is used in this study. The driver model which ensures that the vehicle speed of the glider model when aligns with the data from the drive cycle. Any deviation (error) in speed is sent to a PID controller, which calculates the accelerator pedal position and brake pedal position. The motor block is influenced by the APP. The APP requests the necessary torque to correct the speed error, but a one-dimensional lookup table limits the torque based on the current motor speed. The positive torque from the APP, which is used for propulsion, is subtracted from the regenerative torque from the brake model to determine the net pulling torque for the driveline. The motor's efficiency map is used to calculate the battery power required for this net torque at the given speed Finally, Figure.3.illustrates the motor efficiency curve used in this simulation, which is based on the induction motor of the Tesla Model S. The state of charge (SOC) of the battery is calculated using the coulomb counting method, as described in [35].

$$SOC = SOC(t_0) - \frac{1}{C_{rated}} \int_{t_0}^{t_{final}} I_b dt$$

C_{rated} is the battery rated energy capacity, t_0 is the start time, t_{final} is the finish time, and I_{Bat} is the battery current. Battery-generated positive current I_{Bat} is standard, a basic batterymodel with their internal resistance (R_i) and battery voltage (V_i) connected in series defines the current I_{Bat} as a function of power output (P_{Bat}):

$$I_{Bat} = \frac{V_i - \sqrt{V_i^2 - 4R_i P_{Out}}}{2R_i}$$

$$P_{out} = \frac{1}{\eta} P_{motor} + P_{accessory},$$

In this equation, η represents the motor efficiency, P_{motor} is the output power, and $P_{accessory}$ is the power consumed by accessory loads. The simulation demonstrates that powering the driveline results in an increase in battery current, while regenerative energy reduces it. The driveline blocks convert the total pulling torque into pulling force, which serves as the input for the glider model. This model, based on the work in [36] and [37], applies physics to illustrate that the pulling force is the primary force affecting the vehicle's motion. The vehicle model shown in Figure.4. Incorporates inertial acceleration to calculate the vehicle's velocity.

4.1 Energy Analysis

The energy consumption of the charging vehicle is a key factor in the VVR system. This calculation includes the power used by the charger vehicle and the electricity transmitted to the user - vehicle for the VVR application. Figure.3 illustrates the system's energy usage. In this figure, the transmitted energy both charges and propels the user vehicle. This study also provides a way to calculate the costs associated with using the VVR system, as the user vehicle is responsible for covering the energy consumption of the charging vehicle. Although VVR technology may be more expensive than traditional roadside charging stations, it eliminates the need for vehicles to stop and charge. VVR-equipped vehicles can help alleviate grid congestion by charging during off-peak hours and supplying power to user vehicles during peak demand. Additionally, the charger vehicles can be hybrid models equipped with generators.

4.2 Drive-Cycle Analysis

The simulation has proposed system using MATLAB and Simulink. As mentioned, the Proposed glider model is based on physical principles, with the relevant parameters listed in Table I.

TABLE I: Glider Model Parameters

Parameters	User Vehicle	Charger Vehicle
Aerodynamic Drag Coeff.	0.38	0.38
Air Density	1.23 kg/m^3	1.23 kg/m^3
Frontal Area	1.8 m^2	2.1 m^2
Gravity	9.81 m/s^2	9.81 m/s^2
Mass of Vehicle	1800 kg	3114 kg
Rolling Resistance Coeff.	0.01	0.012
Incline Angle	0 $Degrees$	0 $Degrees$
Vehicle Inertial Mass	2000 kg	4784 kg

The driving cycle scenario used to model the proposed VVR system in this paper involves a lower-scale user vehicle traveling 70 miles, which then requires a pit stop or VVR request. Figure.5 illustrates how we combined well-known highway travel cycles from [32] to generate the simulation's drive cycle. The figure shows that the charging vehicle was requested at 3450 seconds and joined the user vehicle shortly after. The user vehicle continues driving after the charger disconnects, which occurs at 4700 seconds, once both vehicles have exited the roadway. The charger's battery has a capacity of 35.91kWh while the user vehicle battery capacity is 23.7kWh. Figure.5 displays the state of charge (SOC) for both user and charger vehicles, as well as the point at which the user vehicle no longer requires battery power for propulsion. Figure.5 shows the power usage for both the user and charger vehicles, along with the VVR application power.

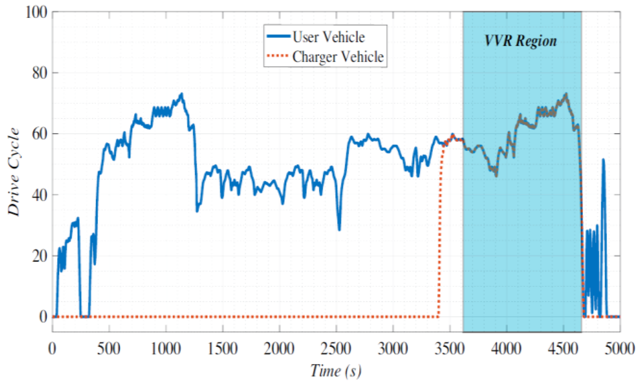

Figure 3: *Drive cycle of the user and charger vehicles*

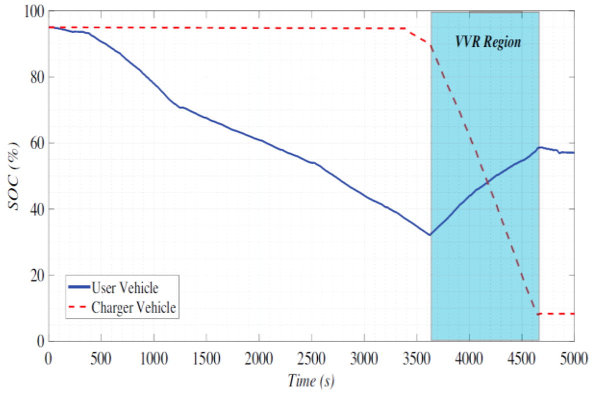

Figure 4: *SOC of user and charger vehicles*

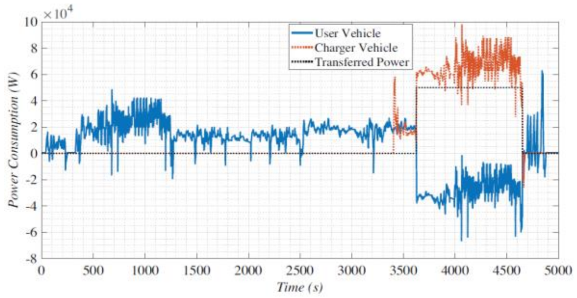

Figure 5: *Total power consumption of user and charger vehicles*

5. Conclusion

The electric - Vehicles will dominate unavoidable transportation. EV charging is difficult while travelling. EVs can charge their batteries while travelling with this study's proposed solution. Wireless technology transmits electric power between chargers and user vehicles throughout a trip. The VVR mechanism will let EVs go further without stopping.

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