Journal of Information & Optimization Sciences
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 45 (2024), No. 3, pp. 829–838
DOI : 10.47974/JIOS-1594

Solar wireless electric vehicle charging system

Raj Kumar
Mohammad Farooq
Shalabh Kumar Mishra †
Sandeep Sharma
Ashima Airan
Department of Electrical and Electronics Engineering
Bharati Vidyapeeth's College of Engineering
New Delhi
India

Ashu Soni *
Department of Electronics and Communication Engineering
Bharati Vidyapeeth's College of Engineering
New Delhi
India

Abstract

Electric vehicles (EVs) are increasingly prevalent on roads today. These vehicles have demonstrated their effectiveness to minimize travel costs through transitioning from traditional fuel sources to electricity, that is notably more cost-efficient, alongside the associated environmental benefits. The primary aim is to implement a charging system that accommodates extended vehicle usage by applying higher charging rates for prolonged periods. Presently, the prevailing charging infrastructure for EVs involves conductive methods where the vehicle connects to a charging station; however, this process typically takes longer. Advancements in technology are introducing wireless charging solutions. Inductive EV charging, a wireless alternative, eliminates the need for physical wires. This innovative approach proposes charging electric vehicles while they are in motion, eliminating the necessity for vehicles to stop for refueling. Notably, this charging mechanism operates on solar energy, obviating the requirement for an exterior source of power. The system-design encompasses the utilization of various components such as batteries, transformers, solar

† *E-mail:* **shalabhmishra14@gmail.com**
* *E-mail:* **soniashu.14@gmail.com (Corresponding Author)**

panels, copper coils, regulator circuits, ATmega328p controllers, AC to DC converters, and the LCD.

Subject Classification: *Primary 93A30, Secondary 49K15.*

Keywords: *Wireless power transmission, Electric vehicle, ATmega328p controller, Dynamic wireless charging.*

1. Introduction

The proliferation of EVs is driven by their superior environmental advantages for consumers. Nonetheless, two significant challenges persist with electric vehicles: Extended charging durations, typically ranging from sixty to 180 minutes. Insufficient power infrastructure for charging stations, especially in the rural and remote locations. Charging systems for EVs are broadly categorized as static or dynamic based on vehicle movement and as wireless or wired based on the charging cable employed. In this situation, a wireless dynamic charging system is employed, enabling charging while the vehicle is in motion without a physical connection [2]. Leveraging solar energy as the primary input eliminates the need for an external power source. The charge controller facilitates solar panel-powered battery operation, storing DC electricity for subsequent use. To transmit this DC power, an AC conversion step is essential, accomplished via a transformer. The transformer converts power to AC, regulated by circuitry, subsequently empowering copper coils for wireless energy transmission [3]. Moreover, a copper-made coil is positioned beneath the electric vehicle. As the vehicle moves across these coils, energy is transmitted from the transmitter coil to the EV coil. Notably, the energy induced in this coil remains in DC form, necessitating reconversion to DC for charging the EV battery. This is achieved through circuitry for AC-to-DC transition. An ATmega microcontroller facilitates input voltage measurement, displaying results on the screen of LCD. This technology exemplifies the integration of a wireless solar-powered charging system tailored for EVs, showcasing its potential application and functionality.

2. Objective

The primary objective of proposed system is to create an infrastructure that harnesses renewable sources, thereby mitigating pollution, curbing greenhouse gas emissions, and establishing a more effective charging mechanism. Solar energy serves as the primary means to charge electric vehicles [4]. To expedite charging without necessitating stops, a wireless charging system is employed, significantly reducing charging times. This approach not only enhances convenience but also delivers cost-saving advantages. Additionally, the system contributes to diminishing noise pollution.

3. Block Diagram

The schematic diagram presented in Figure 1 illustrates the systematic procedure involved in wirelessly charging an electric vehicle through the utilization of solar energy. In this setup, the energy accumulated by the solar panels is stored within a battery unit. Subsequently, this stored energy is directed towards an inverter, which converts it from its stored form (DC) into alternating current (AC) voltage. The converted AC voltage undergoes a step-up process facilitated by a transformer, elevating its voltage level for efficient transmission. Once transmitted wirelessly, the received voltage is then reconverted back into direct current (DC) voltage. This converted DC voltage serves a dual purpose: it is routed together the ATmega micro controller and the car's battery for the purpose of charging the vehicle. The ATmega controller, integrated within the system, interfaces with a 16x2 liquid crystal display (LCD) unit. This display is utilized to showcase and present crucial information, particularly the input voltage of the electric vehicle's battery. This provision of real-time information regarding the input voltage ensures monitoring and management of the charging process, enabling users to track and gauge the status of their

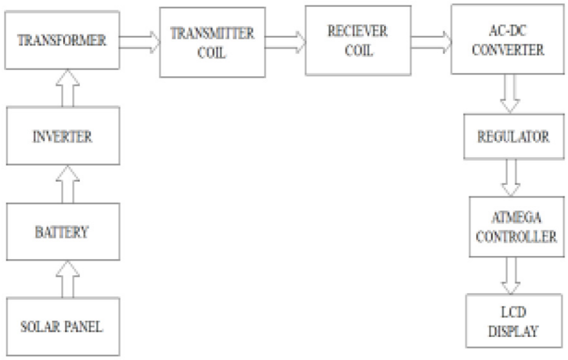

Figure 1

Wireless Charging System

vehicle's battery charge. The block diagram elucidates the sequential stages of wirelessly transferring solar-derived energy to an electric vehicle. This process involves energy storage, conversion from DC to AC voltage, amplification, wireless transmission, reconversion from AC to DC voltage, and subsequent utilization for both monitoring and charging the vehicle's battery via an ATmega controller equipped with an LCD display.

4. Proposed System Analysis

In the proposed system, there are primarily two circuits. One circuit that links the inverter, transformer, and solar panel. Figure 2 illustrates the vehicle connection with the LCD and copper coils that depicts the voltage for the charging of the EVs.

The solar panel provides 12 volts DC and then this DC is converted into 220 volts AC by using an inverter for the purpose of transmission to the copper coils. Inverters play a pivotal role in scenarios where access to AC power from the grid is limited or unavailable. These circuits are integral for converting DC power into AC power, particularly in situations where higher voltages are required from lower-voltage DC power supplies or batteries. The development of an inverter circuit of 12V DC to 220V AC using IC CD4047 is a significant step in this regard. The CD4047 IC operates as a switching pulse oscillator, while an n-channel power

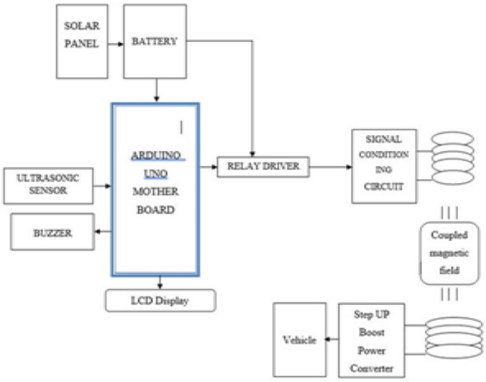

Figure 2

Vehicle connection with other circuits

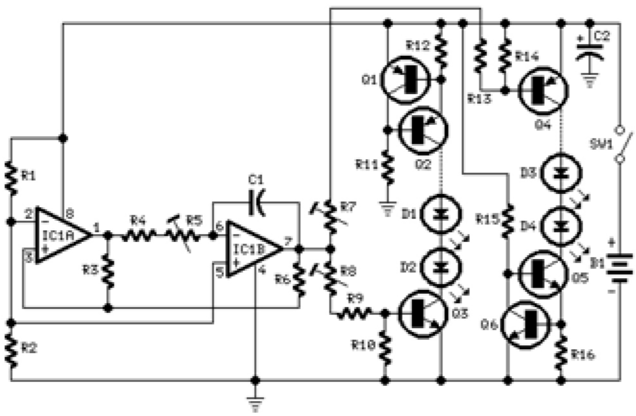

Figure 3

Circuit diagram of Vehicle charging system

MOSFET IRFZ44n serves as the switch. This IC operates efficiently within a range of 5, 10, 15, and 20 volts, offering versatility in various applications. The versatility of the 4047 IC extends across a spectrum of uses, including pulse wave and sine wave generation, as well as the transition of DC signals to AC signals. The output of this inverter is 220VAC, which is then directed to two transformers with step-down capabilities, converting it to 12V output to supply the copper coils. Figure 3 shows the circuit diagram for vehicle charging system.

The wireless power system works effectively at 12V through these coils, which are crucial in enabling efficient power transfer. The transmitting coil, positioned within the road, extends along the entire lane designated for charging, while the receiving coil is situated at the base of the vehicle. When these coils interact, wireless energy transfer takes place, initiating the charging process for the vehicle. Charging continues seamlessly as long as the vehicle remains in motion over the coils. Once fully charged, the vehicle can exit the coil-equipped lane, allowing for the lanes without coils to be used freely. The prototype road constructed for this purpose comprises a wooden material measuring 60cm in length and 25cm in breadth. Six coils with a diameter of 8.5 cm are strategically positioned on the plank, while a single coil with a diameter of 9.5 cm is located at the base of the cart. The circuit diagram involving the LCD display incorporates a regulator and an ATmega controller, which are interconnected to the LCD. A program is embedded within the ATmega controller to showcase the applied voltage to the vehicle, thereby providing visibility into the charging process. The bridge rectifier, integral to the system, converts the 220V AC into 12V DC voltage, which is regulated and supplied to the vehicle and the 7805 voltage controller IC. This regulated 5V voltage is crucial for the operation of the ATmega328p microcontroller, ensuring its functionality. The ATmega, powered by the vehicle, exhibits the charging voltage on the LCD display, representing the battery's input voltage. Optimal charging efficiency is achieved when the vehicle receives a 12-volt input voltage, ensuring effective battery charging. While the vehicle is in motion, it takes approximately 30 minutes to 1 hour to achieve a substantial charge. Once the vehicle is fully charged, it can depart from the charging lane. Charging time is dependent on the energy capacity (Ah) of the battery divided by the current (A) supplied. Typically, for an efficient charge, maintaining the vehicle's input voltage at 12 volts is recommended. Charging time varies, but a moving vehicle in the charging lane can achieve a substantial charge within 30 minutes to 1 hour, facilitating its departure when fully replenished.

$$\text{Time to charge} = \frac{\text{Energy } (Ah)}{\text{Current } (A)}$$

The car's input voltage is to be 12 volts to get highest efficiency. So, if the vehicle is in moving condition, voltage requirement to charge the vehicle would be 12 volts for almost 30 min to 1 hour. When the vehicle is fully charged it can change the lane.

5. Hardware Findings

Figure 4 depicts the hardware of proposed system. In this experiment, the expected output voltage for the LCD display in our setup was anticipated to be 12 volts.

However, during the experimental phase, our measurements yielded a recorded voltage of 9.45 volts. This displayed voltage on the LCD indicates the transferred voltage supplied to the vehicle for charging purposes. It's important to note that both the voltage and the charging duration fluctuate in correlation with the speed of the vehicle. Although in our experimentation, the vehicle was manually propelled, the actual transfer of power is contingent upon the vehicle's speed during real-world applications. In our scenario, the EV transmission coil maintained a voltage of 12V, while the receiving coil registered a voltage of 9.45V.

The expected output voltage for the LCD display in our setup was anticipated to be 12 volts. However, during the experimental phase, our

Figure 4

Hardware of the proposed circuit

measurements yielded a recorded voltage of 9.45 volts. This displayed voltage on the LCD indicates the transferred voltage supplied to the vehicle for charging purposes. It's important to note that both the voltage and the charging duration fluctuate in correlation with the speed of the vehicle. Although in our experimentation, the vehicle was manually propelled, the actual transfer of power is contingent upon the vehicle's speed during real-world applications. In our scenario, the transmission coil maintained a voltage of 12V, while the receiving coil registered a voltage of 9.45V.

Further measurements were conducted at various terminals to ensure accuracy and assess the efficiency of the system. At the step-down transformer stage, our readings indicated an output voltage of 11.75 volts. Moving along the system, at the output of the inverter, we recorded a voltage of 210V.

These voltage measurements at different stages of the setup were crucial in evaluating the performance and efficacy of the system. While the anticipated voltage output for the LCD display was 12 volts, the actual measured value of 9.45 volts prompts a closer examination of the system's components and the efficiency of energy transfer. Similarly, variations observed in voltage outputs at different stages of the system, such as the step-down transformer and the inverter output, provide insights into the performance and potential areas for optimization within the system's architecture.

Throughout our experimentation, it became evident that both the voltage and the charging duration were subject to alterations corresponding to the speed at which the vehicle was manually propelled. In practical scenarios, the velocity at which the vehicle moves significantly influences the efficacy of power transmission. While the transmitting coil maintained a voltage of 12V, the measured voltage at the receiving coil stood at 9.45V. This difference in voltage was meticulously verified by conducting measurements at each terminal involved in the charging process.

6. Application

As EVs and solar power are proliferating, wireless charging emerges as the simplest and quickest method to charge electric vehicles, while dynamic charging allows for on-the-go charging while driving. The flexibility in EV charging power facilitated by dynamic charging enables synchronization with solar energy generation. An optimal Gaussian EV charging profile, peaking at 1200 hours and lower than the maximum installed solar panel power, aligns with the Gaussian pattern of solar energy generation over a 24-hour period. Electric vehicles have proven to be highly useful in regions or zones where traditional fuel-based vehicles face restrictions or prohibitions. In environments or zones with stringent emission regulations or limitations on conventional vehicle use. The Electric Vehicles (EVs) find diverse applications across various sectors. In the consumer realm, they encompass electric cars, motorcycles, scooters, and bicycles, catering to personal commutation needs. Moreover, within commercial sectors, electric vans and trucks are gaining traction, serving as efficient and eco-friendly options for transport and delivery services. In urban areas, electric buses and trains are increasingly prevalent, offering sustainable alternatives for public transportation, mitigating emissions, and reducing noise pollution. These applications collectively contribute to a cleaner, more sustainable future in transportation across both consumer and industrial domains.

7. Conclusion and Future Scope

Electric Vehicles (EVs) signify a pivotal milestone in sustainable transportation, driving a crucial shift towards reducing carbon emissions and lessening dependence on fossil fuels for a cleaner environment. Ongoing advancements in battery technology, charging infrastructure, and manufacturing processes promise a bright future for EVs, enhancing their performance, range, and accessibility.

Looking forward, the potential for EVs is multifaceted, including the development of more efficient batteries enabling extended driving ranges and faster charging times. Expansion of charging infrastructure, featuring rapid chargers and wireless technology, is vital for widespread adoption. Integration of renewable energy sources like solar power for EV charging and progress in autonomous driving and vehicle-to-grid (V2G) systems are poised to reshape our relationship with EVs, seamlessly integrating them into smart grids and optimizing energy use. This trajectory suggests a future where EVs dominate, shaping a cleaner, more sustainable transportation ecosystem.

References

[1] C. C. Mi, G. Buja, S. Y. Choi, and C. T. Rim, "Modern Advances in Wireless Power Transfer Systems for Roadway Powered Electric Vehicles" in *IEEE Transactions on Industrial Electronics*, Oct. (2016).

[2] X. Zhang, Z. Yuan, Q. Yang, Y. Li, J. Zhu, and Y. Li "Coil Design and Efficiency Analysis for Dynamic Wireless Charging System for Electric Vehicles" by in *IEEE Transactions on Magnetics*, July (2016).

[3] K. Kumar, S. Gupta, and S. Nema "A Review of Dynamic Charging of Electric Vehicles" by in the 2021 7th International Conference on Electrical Energy Systems (ICEES).

[4] A. Shufian, M. M. Rahman, K. Ahmed, R. Islam, M. Hasan, and T. Islam "Design and Implementation of Solar Power Wireless Battery Charger" in the 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT).

[5] G. Ombach "Design Considerations for Wireless Charging System for Electric and Plug-in Hybrid Vehicles" in the IET Hybrid and Electric Vehicles Conference 2013 (HEVC 2013).

[6] Z. Danping, L. Juan, C. Yuchun, L. Yuhang, and C. Zhongjian "Research on Electric Energy Metering and Charging System for Dynamic Wireless Charging of Electric Vehicle" in the 2019 4th International Conference on Intelligent Transportation Engineering (ICITE).

[7] J. Zhang, H. Yan, N. Ding, J. Zhang, T. Li, and S. Su "Electric Vehicle Charging Network Development Characteristics and Policy Sugges-

tions" in the 2018 International Symposium on Computer, Consumer and Control (IS3C).

[8] C. H. Lee, G. Jung, K. A. Hosani, B. Song, D. -k. Seo, and D. Cho "Wireless Power Transfer System for an Autonomous Electric Vehicle" in the 2020 IEEE Wireless Power Transfer Conference (WPTC).

[9] C. C. Mi, G. Buja, S. Y. Choi, and C. T. Rim, "Modern Advances in Wireless Power Transfer Systems for Roadway Powered Electric Vehicles," in *IEEE Transactions on Industrial Electronics*, vol. 63, no. 10, pp. 6533-6545, Oct. (2016).

[10] X. Zhang, Z. Yuan, Q. Yang, Y. Li, J. Zhu, and Y. Li, "Coil Design and Efficiency Analysis for Dynamic Wireless Charging System for Electric Vehicles," in *IEEE Transactions on Magnetics*, vol. 52, no. 7, pp. 1-4, July (2016).

Received March, 2024