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Wireless Solar Charging Systems for Electric Vehicles: Technology, Design, and Implementation Challenges

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Abstract

Higher standards for the ease, safety, and dependability of electric vehicle (EV) charging have been proposed in recent years due to the new energy sector's electrical vehicle (EV) rapid development. Inductive coupling is used for wireless power charging. Both stationary and dynamic situations can be used for inductive coupling. Low energy loss and reduced demands on the primary circuit are achieved by rearranging the transformer and changing the high frequency. The primary can transfer enough battery power to the secondary without causing a significant amount of energy loss. Through the air core transformer, electricity is subsequently transferred to the charging battery, which is electrically connected to the secondary circuit. When buses are waiting at a bus station for shuttle bus services, they can be taxed. It can be applied to rental taxi parking as well. As a result, electric buses only require a small amount of battery charge to reach the next stop. This reduces the size of the battery and encourages electric vehicles to save a lot of money. This technology makes charging stations more efficient by allowing for planned stops and predetermined itineraries, which shortens the charging time. Dynamic charging will encourage the usage of electric cars and cut down on the use of petroleum fuel. With extended charging times and even while the electric car is moving, delays at traffic lights may now be accommodated. Rain and snow are examples of bad weather conditions that have no effect on an electric vehicle's ability to charge.

Keywords: Inductive charging, wires, switches, solar energy, charging stations, electric vehicle

INTRODUCTION

The need to tackle climate change, reduce greenhouse gas emissions, and lessen the environmental effects of burning fossil fuels is driving a radical transformation in the global transportation sector towards electric mobility. With its cleaner, quieter, and more environmentally friendly transportation options, electric vehicles (EVs) have become a viable substitute for traditional internal combustion engine vehicles. However, several obstacles stand in the way of the general adoption of EVs, including their short driving range, slow charging speeds, and insufficient infrastructure for charging. To fully realize the potential of electric mobility and hasten the shift to a low-carbon transportation future, several issues must be resolved.

In recent years, there has been growing interest in the development of innovative charging solutions that offer convenience, efficiency, and sustainability for electric vehicles. One such solution is the integration of solar power and wireless charging technology to create a Solar Wireless Electric Charging System for Cars. This novel approach harnesses the abundant energy of the sun and eliminates the need for physical cables, providing a seamless and eco-friendly charging

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experience for EV owners. By leveraging renewable energy sources and wireless communication technology, solar wireless charging systems have the potential to revolutionize the EV charging infrastructure, making electric mobility more accessible, convenient, and environment friendly.

Both plug-in electric vehicles and high-power applications using electric vehicles can use wireless charging systems when they are stationary. When compared to plug-in charging infrastructure, wireless charging methods are more straightforward, dependable, and easy to use. The main problem of WCS is that it can only be used when the car is parked or in stationary conditions like car parks, traffic signals, garages etc. Issues with electromagnetic compatibility, low power transmission, big construction, limited range, and high performance are the primary obstacles that stationary wireless charging must overcome.

Dynamic mode of operation is used to improve the range and sufficient volume of battery storage. Thus, even when the car is moving, battery storage devices can be charged using this technique. This allows for a greater range of transportation because the cars only require a small amount of battery storage. Coil misalignment and a wide air gap are the two main issues that the dynamic WCS must deal with in this situation. The power transmission efficiency is calculated using the coil alignment and air gap distance between the source and receiver. The air gap distance grows for large passenger vehicles and spans from 150 to 300 mm for compact vehicles.

The proposed Solar Wireless Electric Charging System for Cars combines two key technologies: photovoltaic (PV) solar panels and wireless power transfer (WPT) systems. The system comprises solar panels installed on carports, parking lots, or other suitable locations, which convert sunlight into electrical energy. This solar energy is then transferred wirelessly to the electric vehicle using electromagnetic induction or resonant coupling. The vehicle is equipped with a receiver coil and power electronics that capture the transmitted energy and convert it back into electrical power to charge the vehicle's battery. By integrating solar power generation with wireless charging capabilities, the proposed system offers a sustainable, efficient, and user-friendly solution for powering electric vehicles.

The primary objective of this research is to design, develop, and evaluate a prototype Solar Wireless Electric Charging System tailored for electric cars. The study aims to assess the feasibility, efficiency, and practicality of the proposed system under real-world conditions, considering factors such as energy harvesting capability, charging efficiency, user experience, and environmental impact. Additionally, the research will explore potential challenges and limitations associated with the implementation of solar wireless charging technology and propose strategies for optimization and improvement.

LITERATURE SURVEY

A review of EV fast-charging methods and their effects on battery systems, including heat management and related constraints, was given by Ryan Collin. Furthermore, the study offered potential new methods and prospects for systems-level research and power electronic converter topologies to enhance the fast-charging state-of-the-art [1].

Johansen looked at AC fast-charging to reduce the overall cost of rolling out electric vehicles while reducing range anxiety. The advantage of AC charging is that it enables cars to be charged using a cheap AC charging station that supplies electricity straight from the electrical grid. Standard AC cord setups offer charge rates of up to 43kW in Europe and 52kW in the US. The more costly DC chargers have the same power level as this one. Therefore, fast-charging infrastructure can be significantly expanded using AC fast-changing technology [2].

Forecasting the global market for hybrid, plug-in, and electric vehicles (HEVs) as well as their effects on the battery industry (lead acid, nickel metal, and lithium-ion batteries) is the primary objective of the Pillot study [3]. Hanni dahl gave a presentation on Norway's continuing battery electric vehicle (BEV) revolution, emphasizing the policies put in place to encourage a move away from the traditional motor vehicle. The coordination of various policy initiatives, BEV infrastructure, and EV technological advancements was investigated [4].

In many places, government-funded credits or rebates at the time of purchase, together with other benefits for EV users, have somewhat offset the increased cost of batteries, which raised the purchase price of EVs. These include free downtown parking, free access to toll lanes or carpool lanes, and free battery charging stations. Until recently, "range anxiety" was a marketing hurdle. Battery prices are falling, range has more than tripled, and even more advancements are in the works. The power source presents EVs with yet another opportunity. While EVs don't need oil to function, internal combustion engines do. Clean energy is quickly becoming more affordable [5].

Magnetic resonance technology, or wireless power transfer (WPT), has the potential to free people from obnoxious cords. In actuality, the WPT uses the same fundamental theory known as inductive power transfer that has been established for at least 30 years. WPT technology has advanced quickly in the last many years. With a grid to load efficiency above 90%, the transfer distance rises from a few millimeters to several hundred millimeters at kilowatt power level. The developments make the WPT highly appealing for both stationary and dynamic electric vehicle (EV) charging applications. The WPT technologies relevant to EV wireless charging were evaluated in this research. The challenges of charging time, range, and cost can be readily overcome by implementing WPT in EVs. The widespread adoption of EVs has rendered battery technology obsolete. It is believed that state-of-the-art accomplishments would inspire researchers to advance both the growth of EV and the continued development of WPT [6–8].

For many years, electrical transportation has been in use. Electric locomotives have been well-developed in railway systems for a long time. On a fixed track, a train travels. Using pantograph slides to extract electric power from a conductor rail is simple. However, the high degree of flexibility in electric vehicles (EVs) makes it difficult to obtain power in a comparable manner.

Methodology

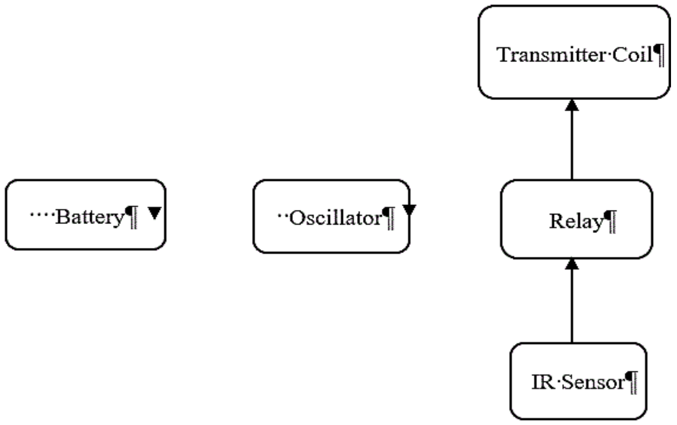
The distance of the pickup from the primary track was 7.6 cm. The attained efficiency was around 60% due to limited semiconductor technology. Auckland University academics have been studying the inductive power supply of moving items for the past 15 years. Their recent achievement in designing pads for the stationary charging of EV is worth noting. For distances of around 200 mm, a 766 mm × 578 mm pad was found to deliver 5 kW of power with over 90% efficiency. The achieved lateral and longitudinal misalignment tolerance is 250 and 150 mm, respectively. The conceptualization of the WPT also benefits from the information acquired by the Korea Advanced Institute of Science and Technology's (KAIST) online electric vehicle (OLEV) project [9–11]. Three generations of OLEV systems have been developed: the first is a light golf cart, the second is a bus, and the third is an SUV. It is noteworthy that the second and third were able to transfer 60 kW of electricity for the buses and 20 kW for the SUVs with 70% and 83% efficiency, respectively; the permitted vertical distance and lateral misalignment were up to 160 mm and 200 mm, respectively. Since the 2007 Science report was published, the WPT has garnered increasing public attention in the United States.

Using MIT technological advances, the Wi Tricity Corporation unveiled the WiT-3300 prototyping kit, which produces 3.3 kW with 90% efficiency over a 180 mm gap. At Oak Ridge National Laboratory (ORNL) in the United States, a wireless battery charging prototypes for electric vehicles was recently created. The tested efficiency for 3 kW power supplies is close to 90% [12].

Block Diagram

Station

The block diagram of the charging system shown in the Figure 1a.



Car Section

The working mechanism in the car shown in the block diagram of Figure 1b.

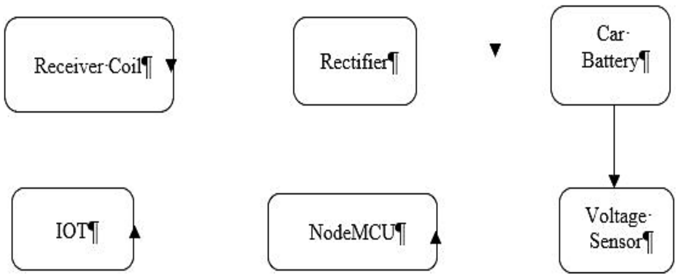


Figure 1. Block Diagram of the system a) station b) car section.

Transmitter Circuit

Figure 2 illustrates the Wireless Power Transferring transmitter circuit, which is constructed around a 5-volt series voltage regulator 7805, a timer IC 555, a multipurpose NPN transistor BC547, an N-channel MOSFET IRF540N, and an LC tuned a wiring system.

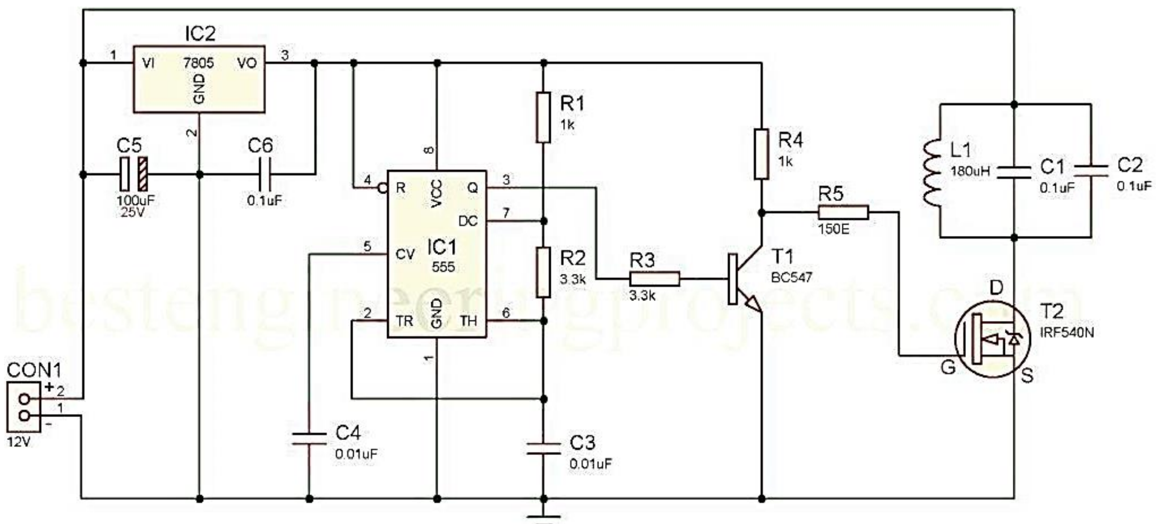


Figure 2. Transmitter circuit of wireless power transfer.

Let us first talk about what tuned circuit is? In the above circuit, we had used tuned collector oscillator (L_1 with $C_1$and C_2). A parallel L-C circuit in the collector circuit serves as the load for a tuned collector oscillator, which essentially controls the oscillation frequency [13, 14]. The base circuit is inductively connected to the output voltage generated by the tuned circuit. Transmitter circuit of Wireless Power Transfer shown in Figure 2.

Since the timer IC 555 is being used to generate pulses, it is set up in a stable multivibrator mode. The MOSFET T2 is driven by the general-purpose transistor T1's base, which is connected to the IC 555's output (pin 3). The L-C tuned circuit, which further transmits an oscillating magnetic field, is switched by the MOSFET T2.

As seen in the image, the series voltage regulator IC2 provides the operating voltage for the entire circuit (+5V) from +12V. Receiver circuit of Wireless Power Transfer and Flow Chart of the proposed system shown in Figure 3 and Figure 4.

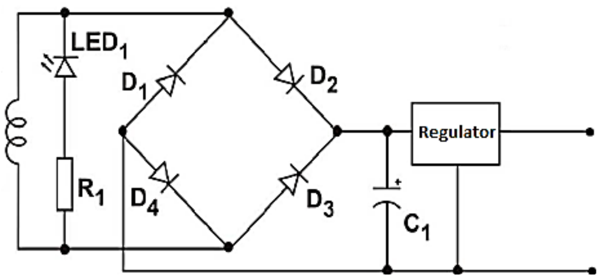


Figure 3. Receiver circuit of wireless power transfer.

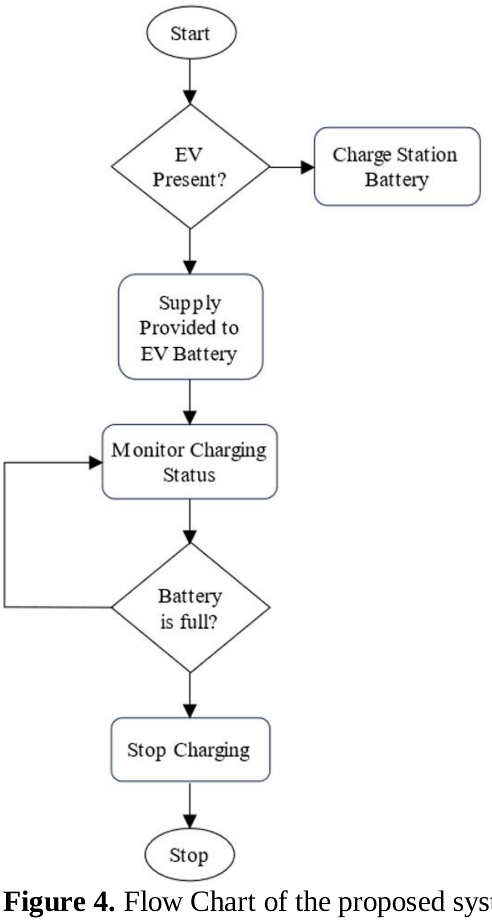


Figure 4. Flow Chart of the proposed system.

RESULTS & DISCUSSIONS

The charging performance of the wireless charging station with a solar panel largely depends on factors such as solar panel capacity, sunlight availability, and device compatibility. Adequate solar panel capacity ensures a sufficient power supply for charging multiple devices simultaneously. However, if sunlight availability is limited or inconsistent, charging performance may be affected. It is crucial to consider these factors during the design and installation of the charging station to optimize its performance. Environmental Sustainability: Integrating a solar panel into the wireless charging station promotes sustainability by harnessing renewable energy. By absorbing sunlight and turning it into electrical energy, the solar panel lessens dependency on conventional power sources. This setup decreases carbon emissions and contributes to a greener environment, aligning with the global efforts to combat climate change. Energy Efficiency: The wireless charging station's solar panel enables the utilization of clean and renewable energy, minimizing energy waste and increasing overall efficiency. By directly converting sunlight into electricity, the system maximizes the use of available resources, reducing dependence on conventional energy grids. Cost reductions and a more sustainable power source are possible outcomes of this effectiveness. Result photos shown in Figures 5 (a,b,c).

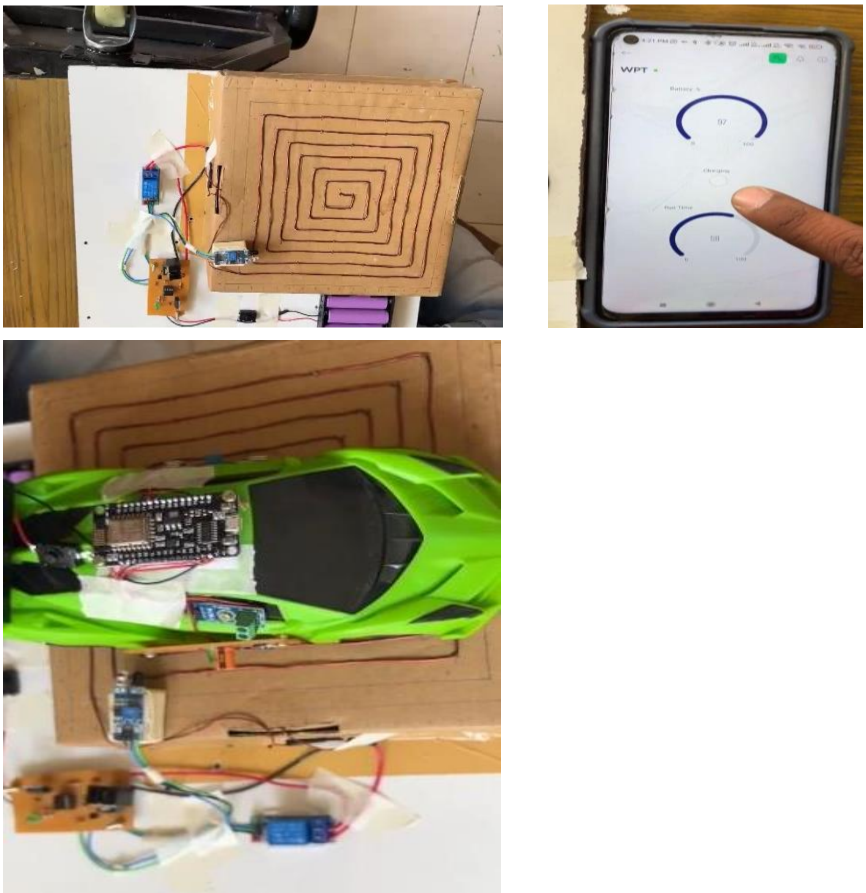


Figure 5. Result Photos.

Future Scope

The future scope of the "Solar Wireless Electric Charging System for Cars" presents a promising landscape of innovation and sustainability. As technological advancements continue to unfold, there are several exciting avenues for further development and application of this groundbreaking technology. One avenue is the integration of solar wireless charging systems with emerging trends in autonomous vehicle technology. By seamlessly integrating charging capabilities into self-driving cars, these systems can enable autonomous vehicles to recharge their batteries wirelessly, reducing the need for manual intervention and enhancing the efficiency of transportation networks.

Additionally, there is a great deal of opportunity for dynamic energy management and optimization when solar wireless charging devices are integrated with smart grid technology. By leveraging real-time data on energy demand, generation, and storage, these systems can intelligently allocate and distribute renewable energy resources, maximizing efficiency and minimizing grid congestion. A more resilient and sustainable energy infrastructure may result from this integration, which has the potential to completely transform how we distribute and use energy.

Moreover, the deployment of solar wireless charging infrastructure in urban areas presents an opportunity to address the growing demand for electric vehicle charging facilities. By integrating charging stations into existing infrastructure, such as parking lots, streetlights, and public transportation hubs, cities can promote sustainable transportation options and reduce reliance on fossil fuels. Additionally, off-grid applications of solar wireless charging systems, such as providing reliable power sources for remote communities and emergency response vehicles, offer solutions to energy access challenges in underserved or isolated areas.

Looking ahead, the future scope of solar wireless electric charging systems extends beyond automotive applications to encompass a wide range of industries and sectors. From fleet electrification and vehicle-to-grid integration to consumer electronics charging and smart home applications, the possibilities are endless. As researchers, engineers, and policymakers continue to collaborate and innovate, solar wireless charging systems have the potential to play a pivotal role in shaping the future of transportation, energy, and sustainability on a global scale.

Applications

Solar wireless electric charging systems for cars have a multitude of potential applications across various domains. One significant application lies in urban transportation infrastructure, where the deployment of these systems can revolutionize the way electric vehicles (EVs) are charged and powered. By integrating solar panels and wireless charging technology into parking lots, streetlights, and public transportation hubs, cities can create a comprehensive network of charging stations that provide convenient and sustainable charging options for EV owners. In addition to encouraging the broad use of EVs, this infrastructure helps to lower greenhouse gas emissions and enhance urban air quality.

Beyond urban transportation, solar wireless charging systems have applications in fleet electrification, particularly in commercial sectors such as taxi services, delivery companies, and public transportation agencies. By providing cost-effective and efficient charging solutions, these systems can accelerate the transition from conventional fuel-powered vehicles to electric fleets, thereby reducing operating costs, minimizing environmental impact, and enhancing the sustainability of transportation operations.

Additionally, off-grid settings with little to no access to conventional electrical infrastructure may be found to be used for solar wireless charging devices.

In remote communities, outdoor events, and emergency response scenarios, these systems can serve as reliable and renewable energy sources, powering electric vehicles, portable devices, and essential equipment without the need for grid connectivity. This application of solar wireless charging technology contributes to improving energy access, resilience, and sustainability in underserved or isolated areas.

CONCLUSION

This project provided an overview of fast-changing technologies, described the problems with fast-charging, such as its effects on battery systems in terms of restrictions and heat management, offered remedies, and suggested new research directions for future developments. The world will not be able to survive on petroleum-based transportation in the coming decades; therefore, cutting-edge technologies are required to transition to sustainable electric transportation. One of the major issues with EVs is their slow battery charging periods. Recharge timings must be equivalent to fill-up times to be widely accepted by consumers.

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