Development of Smart Electric Vehicle On-Road Charging System

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Abstract: Electric vehicles (EVs) are transforming transportation with environmental and energy sustainability benefits. However, range anxiety, charging downtime, and infrastructure limitations remain barriers to widespread adoption. Smart on-road charging systems, including dynamic wireless power transfer (DWPT) and conductive in-motion charging, present a promising solution that enables EVs to charge while driving. This paper presents the hardware prototype of smart electric vehicle on road charging system. The technology has the potential to reduce battery size, increase vehicle range, and enhance user convenience, thereby accelerating EV adoption and supporting intelligent transportation infrastructure. Dynamic charging systems seek to charge an EV while it is in service and is moving. It based on magnetic coupled resonant power transmission in which the transmitting coil of this charging system can selectively turn ON/OFF for charging vehicles while driving. Due to this energy is not wasted as transmission coil is energized when vehicle came in contact with receiver coil. The magnetic flux, a voltage is induced in the receiver coil when comes in line with transmitting coil. Control system functions of a wireless charging system of an electric vehicle.

Index Terms - Smart Electric Vehicle, Transmitter coil, receiver coil, On road charging system, hardware prototype

INTRODUCTION

Electric vehicles (EVs) are one of the promising solutions to improve economic efficiency and reduce the carbon footprint in the transportation sector. Earlier research is focused on the plug-in and conductive solutions for charging the EVs and addressed the challenges of integrating this technology into electricity networks. Plug-in EVs have limited travel range and require large and heavy batteries. Therefore, conductive charging strategies require long waiting time that limits the applicability of EVs compared to gasoline-powered vehicles. More recent research efforts introduced wireless or inductive charging solutions that enable in-motion charging of the EVs which makes EV more favorable for the daily use of many drivers [1]. Earlier publications addressed the quantified potential benefits and challenges of wireless charging [2]-[4], the power electronic interfaces utilized for this technology [5]-[8], WCS placement [4], and battery sizing of the EVs with wireless charging technology [9]. The main advantages of wireless charging technology include increasing the travel range, reducing the battery size and mitigating the prolonged waiting time for charging. Such advantages enhance the economic and environmental benefits as well as the adoption rates of EVs in the transportation networks.

Wireless charging – also referred to as in-motion charging is different from the conventional charging technologies as it enables charging the EV battery while driving in the transportation network. Therefore, the electricity demand for wirelessly charging the EVs is determined by the traffic volume in the transportation network and the decisions made for charging the EVs as they travel over the charging stations [10]. Therefore, unlike the conventional plug in charging solutions, wireless charging technology underlines the interdependence between the traffic routing and the EVs" charging strategies. The EV routing determines the electricity demand at different WCS, which in turn, would affect the electricity charging prices at these stations. Therefore, as the number of EVs with wireless charging capabilities increase, the characteristics of the demand imposed by the wireless charging of EV the day-ahead operation of the electricity network. In this paper, the proposed decentralized approach addresses the interaction between the electricity and transportation networks by capturing the imposed wireless charging demand which is further determined by the traffic flow pattern and the price of electricity.

Stationary wireless charging makes the charging process safer and more convenient. However, in terms of charging time, frequency, the operation of the vehicle, and charging station allocation, stationary charging is not significantly different from conventional plug-in conductive charging. In contrast, dynamic and quasi-dynamic wireless charging enables the EVs battery to be charged while in operation. This capability has raised new operations and infrastructural design issues that had never been raised for conventional plug-in EVs. These issues are the focus of this paper. Note that in this paper, references to "wireless charging EV" indicate dynamic and quasi-dynamic wireless charging EVs, if not specified.). It should also be stated that although the term wireless charging EV suggests a single vehicle unit, it should be understood as a system comprised of EVs and the charging infrastructure. Further terminological and categorical distinctions are discussed in subsequent sections.

voltage regulator IC units. A fixed three-terminal voltage regulator has an unregulated dc input voltage, Vi, applied to one input terminal, a regulated dc output voltage, Vo, from a second terminal, with the third terminal connected to ground.

NEED OF THE STUDY

The sensors mounted on the vehicle are interfaced with microcontroller. The microcontroller processes the data fed by the sensors. If there is an obstacle in the range of the vehicle at certain distance from the vehicle, the vehicle first drops its speed adjusting to the proximity of the obstacle. As the distance between the obstacle and the vehicle goes on increasing the speed goes on dropping.

This is done with the help of ultrasonic range finders which continuously feed the distance between obstacle to the microcontroller which automatically adjusts the speed.
When a particular point approaches where the car is too close to the obstacle and is about to collide the braking system is automatically activated which brakes the vehicle thus preventing head on collision.
Three cases can be considered to understand the concept of the project.

1) There road is empty:
   When the road is empty the vehicle will be moving with full speed as you can see in the figure above. The adaptive cruise control system won't be working this time.
2) When the car approaches another car or an obstacle:
   When the car approaches another car or obstacle and the obstacle is still at a sufficient distance from the car, the speed of the car goes on dropping as it approaches another car. This is nothing but adapting the speed of the car with respect to another car, the core concept of adaptive cruise control.
3) When the car is about to collide: When the car is about to collide, the car automatically applies the brake even if the throttle is pressed by the drives. This prevents the head-on collision between the cars.

RESEARCH METHODOLOGY

If wired charging system is built at various charging stations. Wired charging station having more disadvantages such as space required is more, socket are different types, a small substation required, converter circuit is installed at every charging station, range of wire is limited and also time required for charging is more. This all problems is solved by wireless electrical vehicle charging system. The traditional wired or plug-in charging systems are not user and environment friendly. To reduce the charging time, a large number of batteries can be used or the drained batteries can be swapped with the charged batteries when needed. There is energy waste due to line loss when the coil is conducted for long time. Its service life will be decreased because of continuous working.
The implementation of this project involves designing and fabrication of smart system and also 4-wheel drive electric vehicle on which the concept can be demonstrated. The methodology implemented in the project is as follows. p-ISSN: 2395-0072 by the sensors. If there is an obstacle in the range of the vehicle at certain distance from the vehicle, the vehicle first drops its speed adjusting to the proximity of the obstacle. As the distance between the obstacle and the vehicle goes on increasing the speed goes on dropping. This is done with the help of ultrasonic range finders which continuously feed the distance between obstacle to the microcontroller which automatically adjusts the speed.
1) The designing of smart adaptive speed control system: To bring about of concept of adaptive speed control with smart collision detection and avoidance system, an obstacle sensor is interfaced with the microcontroller.
2) The vehicle chassis fabrication: To demonstrate this concept, electric 4 wheel driven vehicle is fabricated. Initially the chassis of the vehicle is fabricated. The chassis is fabricated initially as it forms the structural component of the vehicle and houses all the other parts of the vehicle. The chassis should be strong enough to transfer all the load to ground as well have adequate amount of space for mounting all the other components.
3) The Drive train: After the chassis is fabricated, 4-wheel electric drive train is fabricated and installed on the system. The power of the motor is given to the wheels using the drive train. In this project the proposed drive train is Sprocket Chain Drive and Gear drive. The electric drive train is implemented and assembled in this phase to make completely functional electric car. The drive train should be suitably chosen so that it should be a proper balance between the speed and power.
4) The Solar Power System: The drive train is powered using batteries which are driven using solar energy. In this phase the solar power system is developed which is responsible for making the car solar powered.
5) The smart accident detection and notification system: In this phase the GPS based accident detection and notification system is implemented which will detect the vehicle using the MEMS sensors present on the vehicle and automatically trigger an notification to the hospitals and family members along with the live tracking of the car.
6) When a particular point approaches where the car is too close to the obstacle and is about to collide the braking system is automatically activated which brakes the vehicle thus preventing head on collision.

BLOCK DIAGRAM

The block diagram consists of the Arduino uno, IR sensor, transmitter coil, receiver coil, AC to DC converter, relay, battery, DC motor, LED as shown in fig.1.

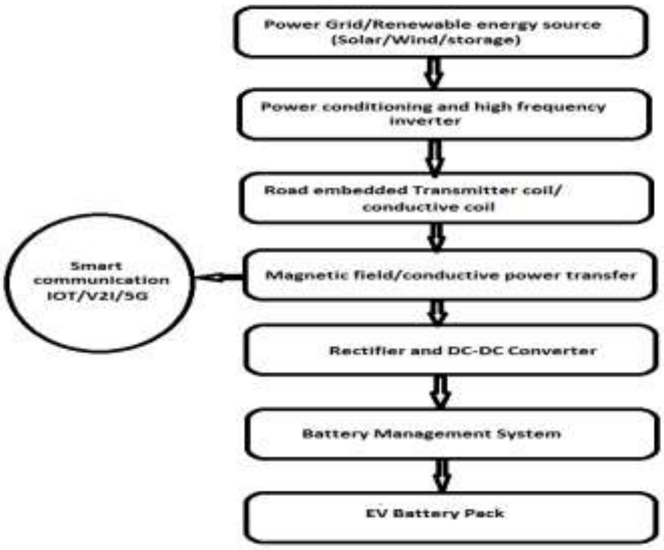

Fig. 1: Block Diagram of Electric vehicle on road charging system

Arduino uno is the main component of the project as it controls and monitor the parameters, IR sensor will detect the presences of the vehicle and sends the signal to Arduino uno. Depending upon the vehicle position, relay is turned on to energize the transmitter coil. The receiver coil present in the vehicle gets energized by the transmitter coil by mutual coupling, the energy produced is given to AC to DC converter, and the converter is connected to the battery. The battery gives power to the motor to run.

WIRELESS CHARGING ARCHITECTURE AND HARDWARE RESULTS

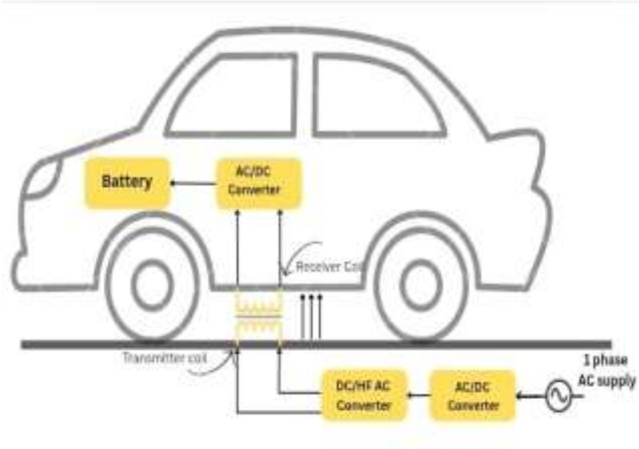

Fig. 2: Diagram of smart on road EV charging system

Wireless charging system architecture consisting of AC supply which is used as the source to fed the transmission coil as shown in fig.2. From the principle of resonant coupling, the reception coil is coupled. The output is given to AC-DC converter to obtain rectified DC to charge the battery which is connected to load. The coils in the project which is used to transmit power wirelessly are called magnetic resonators. This creates magnetic field in the region around a transmission coil, tune a reception coil to the same resonant frequency as the source, it will couple resonating anywhere within that region, converting oscillating magnetic field into an electrical current within the reception coil this response is called coupled magnetic response. The power can be fed to the load for charging a battery. Block diagram of wireless charging system.

The hardware of above architecture is built in prototype as shown in fig.3

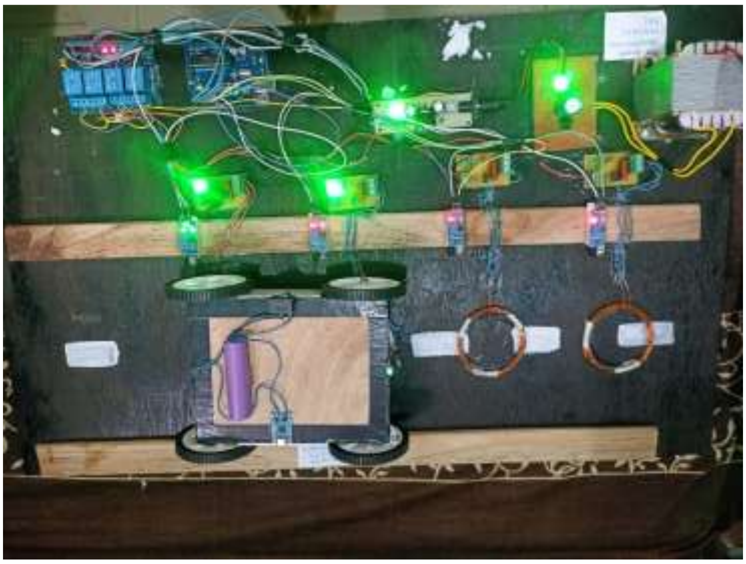

Fig. 3: Hardware prototype of smart EV on road charging system

The fig. 3 shows a Smart EV On-Road Wireless Charging System prototype.

It consists of a transmitter section embedded in the road and a receiver section mounted on the vehicle. The transmitter includes inductive coils, a power supply, driver circuits, sensors, an Arduino microcontroller, and relay modules to control coil activation. The receiver section has a coil, rectifier circuit, battery, and indicator LED. When the vehicle moves over the coils, sensors detect its presence and activate the corresponding coil. Power is transferred wirelessly through electromagnetic induction, converted to DC, and used to charge the battery dynamically while the vehicle is in motion.

CONCLUSION

The developed model of the Smart Electric Vehicle On-Road Charging System successfully demonstrates an efficient and innovative approach to wireless power transfer for electric vehicles. The system integrates key components such as transmitter and receiver coils, control circuitry, sensors, and a microcontroller to enable automatic detection and charging of the vehicle while in motion. The use of inductive coupling ensures contactless energy transfer, reducing wear and improving safety compared to conventional plug-in methods. The prototype highlights the feasibility of dynamic charging infrastructure, which can significantly reduce dependency on large onboard batteries and minimize charging downtime. Additionally, the implementation of sensors and switching mechanisms ensures that power is delivered only when the vehicle is properly aligned, improving energy efficiency.

Overall, this project provides a promising solution for future smart transportation systems, contributing to sustainable mobility and reduced carbon emissions. Further improvements in efficiency, alignment accuracy, and large-scale implementation can make this technology viable for real-world applications.

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REFERENCES

1. T. Imura, Y. Lin and Y. Hori, “Basic Experimental Study on Dynamic Wireless Power Transfer System for EVs,” *IEEE Transactions on Industrial Electronics*, vol. 60, no. 1, pp. 318–328, Jan. 2013.
2. S. Li and C. C. Mi, “Wireless Power Transfer for Electric Vehicle Applications,” *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 4–17, Mar. 2015.
3. D. C. Yates, M. A. McCulloch, and A. S. Siddiqui, “Dynamic Wireless Charging of Electric Vehicles: Survey of Systems, Operating Limits, and Future Opportunities,” *IEEE Electrification Magazine*, vol. 8, no. 1, pp. 6–19, Mar. 2020.
4. J. Kim, S. Choi, and S. Ahn, “Design and Control of On-Line Electric Vehicle Charging System Using Resonant Inductive Coupling,” *IEEE Trans. Ind. Electron.*, vol. 61, no. 9, pp. 4935–4945, Sep. 2014.
5. H. Imura and Y. Hori, “High-Efficiency Wireless Power Transfer System for Electric Vehicle Charging,” *IEEE Trans. Ind. Electron.*, vol. 57, no. 5, pp. 2202–2208, May 2010.
6. M. Yilmaz and P. T. Krein, “Review of Charging Power Levels and Infrastructure for Plug-In Electric Vehicles,” *IEEE Trans. Power Electron.*, vol. 28, no. 5, pp. 2151–2169, May 2013.
7. N. Tessier, A. Ghosh, and G. Ledwich, “Integration of Dynamic Wireless Charging for Electric Vehicles with Smart Grid Control,” *IEEE Trans. Smart Grid*, vol. 12, no. 3, pp. 2128–2137, May 2021.

8. S. Kwon, Y. J. Park, and J. H. Park, "A Study of Traffic-Adaptive Wireless Charging Road System for Electric Vehicles," *Proc. IEEE Veh. Power Propulsion Conf.*, 2018.
9. Y. Han, S. Kwon, and G. Kim, "Real-Time Control Strategy for Dynamic Charging Wireless Power Transfer System," *IEEE Trans. Veh. Technol.*, vol. 67, no. 6, pp. 4827–4840, Jun. 2018.
10. Z. Xue, W. Liu, C. Liu, and K. T. Chau, "Critical Review of Wireless Charging Technologies for Electric Vehicles," *World Electric Veh. J.*, vol. 16, no. 2, 2025.

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