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Dynamic Charging of Electric Vehicle Through Electrified Roads

*J. Ravi Kumar [a], K. Sankeerthana [a], Ch. Sravani [b], A. Sai Charan [c], B. Meher Vikas [d], M. Ravi Shankar [e] **

[a,b,c,d,e] *Department of EEE, GMR Institute of Technology, Rajam , AP-532127,India*

A B S T R A C T

Due to the significant fuel emissions and relative benefits of electric vehicles, the majority of automotive industries are currently producing electric vehicles. The EV runs on a battery and the battery has to be charged regularly. There are many different types of charging methods. static wireless charging is becoming more common for recharging electric vehicles. But an EV can't go very far on a single charge. More batteries will be required in order to enhance its range, and charging the vehicle will take a lengthy time. So, to overcome this, EVs are given the option of dynamic wireless charging will enhance their range and reduce the necessity for huge batteries, and speed up charging. Transmitter coils and receiver coils are required for wireless charging through mutual induction. As it passes through transmitter coil, the receiver coil will collect power from it. Vehicle will receive the power. Accordingly, a software application helps us regarding the payment related to the power consumption of the vehicle.

Keywords: dynamic charging, coil topologies, coil design, h-bridge inverter, electrified roads, RFID tags

1. Introduction

PHEVs (plug-in hybrid electric vehicles) and PEVs are seeing a sharp rise in both supply and demand in recent years. For charging a EV we need a battery. There are many charging methods are introduced to charge the vehicles. The most challenging problems are long recharging times and short driving distances between recharges. The current conductive charging method necessitates quick recharges of the car using high-power charging stations or devices. [1]. For EV charging, the concept of wireless power transfer (WPT) technology is put forward in order to reduce physical touch and plugging in frequently, to enhance specific energy, and to facilitate quick charging. WPT has the unique and essential properties for power transmission. WPT is safer than conventional conductive EV charging because it prevents electric shock or arcs. [2]. EV cannot run longer distances with a full charge. In static charging method for increasing the battery capacity we need to place large number of batteries which will unnecessarily increase the weight of the vehicle. But in dynamic charging methods no need of batteries which will reduces the weight of the vehicle. we can run the vehicle while driving which can reduces the charging time. In This Paper We Mainly Focuses on Dynamic Wireless Charging System. The availability of wireless charging may persuade more people to think about switching to electric vehicles. Also, we concentrate primarily on long track DWPT systems and electrified highways for Electric Vehicles to execute dynamic wireless charging at high driving speeds.

2. Related Works

The recent study on this type of models has proposed numerous results to the problem being addressed then.

The coil designs for wireless charging of EVs, addressing their fundamental constructions, guiding ideologies, and distinctive characteristics. There is an introduction to the fundamental topologies, such as the circular rectangular shaped coil (CR), circular shape (C), homogeneous shape coil (H), double-D shaped coil (DD), double-D quadrature shaped coil (DDQ), and bipolar pad (BP). Among them BP is the best which reduces the cost by eliminating one coil and more flexible than other coils. [1]. In this study, a segmented dynamic wireless power transfer with high voltage and power is presented. The sequence of QDDQ is chosen as one segmented energising group, and the maximum output power and voltage can reach 2.5 kW and 500 V. The mutual inductance can be maintained by repeating the QDDQ sequence. The inverters use silicon carbide MOSFET CCS050M12CM2, which ensures high-power operation. To increase power and lessen voltage or current stress on semiconductor devices, parallel inverters are used. [2]

The planning organisation for public infrastructure as well as battery EV customers are the main subjects of this essay. Whole system net energy consumption and total system travel time are two different planners' objectives that are taken into account. Batteries EV drivers respond to each target by selecting their preferred route based on where the planner has placed DWC facilities. With an assumption of a 60-minute re-charging time giving the user 30 miles of initial range, a 100-million-dollar investment in DWC is needed to sufficiently recharge all Battery EV within the network. In order to address significantly larger actual networks in a fair amount of computational time, an effective solution algorithm is used. [3]. The speed limit examined relates to quite low values since the architectural arrangement of the EVSE must find a balance in between the requirement to keep maintenance and installation costs low and consumers' confirmation of the duration of time required to complete a proper recharge. The primary problem with electric vehicles (EVs) is actually their lack of autonomy, which is compounded by the fact that there aren't enough public charging stations scattered throughout, charging takes a long time, batteries have a finite lifespan, and they are expensive. These are all ideas related to the on-board energy source, in the end. In particular, a car trying to join the charging lane has a low battery SOC and needs to recharge [4]

The calculation of mutual inductance is suggested using a quick and versatile method. The output power is significantly influenced by mutual inductance. The surface-integral in the conventional analytical calculation method might be simplified to be the total of these coefficient and the amplitude of magnetic flux density based on the concept of mutual inductance calculation-coefficients, thereby reducing the mutual inductance calculation difficulties. The issues with the typical FEM, such as the lengthy simulation times and high memory requirements, can also be resolved when the suggested technique is used to build and optimise the receiver. The suggested approach can be used to calculate the receiver's maximum lateral displacement as well as quickly compare various receiver structures. It also offers theoretical assistance for the design of receiver structures [5].In a dynamic charging application, this study demonstrates the viability of modelling the Litz wire using an analogous layer, which can drastically cut down on computation time by up to 20 times every iteration. The entire design process is thus quicker and more precise. In this example, we show how to create a dynamic charger for a remote-control automobile. They were able to reach AC efficiencies of 95.2% with no misalignment and 47.36% and 83.36% for 30% and 50%, respectively, of misalignment. We were able to determine how the DD coils were affected by the zero-power point [6]

In this study, a novel magnetic coupler is proposed. Segmented transmitters, which are turned on or off depending on the location of the overhead receiver coil, are created by alternately laying unipolar and bipolar coils. LCC compensations are used, which reduce costs by having inputs connected in parallel to a single inverter. To accomplish constant voltage charging and constant current charging, a reconfigurable resonant circuit is created on the receiver side. Additionally, an optimization design is constructed using the finite-element analysis programme Maxwell to select the optimal turns for the receiver coil in order to further enhance output quality. The proposed DWPT system is tested using a laboratory prototype with a charging current of 4A and a voltage of 96V operating at a frequency of 85 kHz. According to the experimental findings, output voltage and current can be maintained consistently and steadily with only a 2% variation, and 90.37% of the system is efficient overall.[7]. For the dynamic WPT system, this research proposed a novel circuit and its control scheme. The advantage of employing multiple parallel LCC RPCNs on the primary side is that all of the sub compensation network may be stimulated by a single inverter, and the power between various networks may be distributed automatically based only on the mutual inductance values. An auxiliary LCC network is recommended to control the primary coil's constant current in order to significantly reduce EMI and reduce system power loss. One of the key advantages of the proposed system is that the primary side only requires a single power converter, which lowers component prices [8]

The charging station must operate at a low efficiency throughout this stage of the transportation process in order to follow the suggested control strategy without experiencing significant energy losses. Similar to a transformer, an inductive power transfer (IPT) system transmits energy from a main coil to a secondary coil over an air gap, even if they are not actually attached. During dynamic inductive charging, variations in the coils' self-inductance are brought on by the motion of the EV. To maximize the transmitted energy while retaining high system efficiency, the compensation component, frequencies, and load resistance should also be optimized in accordance to the inductance values [9].Electric vehicles (EVs) may be charged while they are in motion owing to dynamic wireless transmission of power (DWPT). Yet high prices and problems with efficiency prevent DWPT from being widely used. the improvement. The chosen 3.7-kVA pad has a perfect pad length of 1.75 m, a statistically projected value of 96% for pad performance, and a GA per meter price of $1004. Pareto fronts display the variety of optimum designs. The suggested system's drawbacks include pulsating power at the Tx and Rx, complex control and synchronization techniques, and an overreliance on the electronic power module. The proposed approach is evaluated on a 3.7-kVA DWPT system that operates at a low power to reduce the cost of experimental validation [10]

The OLEV (office for low emission vehicle) on-road dynamic wireless charging solution for electric vehicles is presented. The wireless dynamic charging idea and fast charging with a power capability of up to 100 kW are discussed. The general system architecture is provided, along with a thorough explanation of the system's power supply and vehicle infrastructure. The experimental verification for transmission effectiveness and other crucial factors in vehicle and infrastructure technologies is explained [11].A wireless power transfer system for electric roads can result in considerable energy savings due to the reduction in battery capacity. The reduced tractive power demand brought on by the vehicle's smaller battery size has not been taken into account in this work. Another crucial topic for additional research is the mass-decompounding effect brought on by the vehicle's smaller battery and how that affects the viability of the dynamic wireless power transfer system. [12]

The analysis of the energy given to the EV and the power stored in the battery shows that both energies are strongly related to the vehicle speed, considering that up to 40 kW is fed to the coil and the extra power is utilized to charge the battery. In reality, the energy storage increases by 2.05% while the electric vehicle (EV) under consideration in this study is travelling at 92 km/h, whereas it increases by 3.80% at 83 km/h. However, taking into account the reduced speed restriction (60 km/h), the stored energy is 7.25 percent, which is the highest in the highway segment. [13]. To provide continuous power transfer of about 10 kW to Vehicle components, the On Ground Demonstration array has been designed. The GAs (Ground assemblies) has been made to overlap one another in order to transfer electricity continuously.

When a receiver is not coupled, the transmitting resonator is intended to draw less current from the power source. The input voltage and lateral misalignment have the biggest effects on the output. WPT is not much impacted by movement speed. Coils that cross each other continuously transfer energy [14] .A new system called long-track EV-DWPT has been implemented. It employs the LCC-S source-side constant current topology. The system's charging efficiency gradually diminishes as the transmitting coil length increases. Only US and RL have an impact on efficiency, while US, b, and RL have an impact simply on charging power. both the output power and charging efficiency must be greater than 10W and 85%, respectively. dynamic wireless charging focusses on the vehicle's peak speed, which mostly affects the length of the power transmission coil. [15].

3. Methodology

a) BOT Design

The Components Used for Designing Bot Are Motors, Chassis, Wheels2*7, Motor Driver, Arduino Uno, Bluetooth Module, Battery. A computer programme that acts as an agent for a user, another programme, or to replicate human activity is known as a robot, often referred to as an internet bot. Here the bot is used in the place of electric vehicle. Receiver coil is placed in the bot. The number of turns in receiver coil are 7 and the distance between the coils are 200mm.Code was dumped in the Arduino for the control of the bot to move forward or backward conditions. Motors are used to drive the bot and battery is used for supply power to the bot. whenever the bot is entered into the track the bot will charge due to the mutual induction between the receiver coil and transmitter coil and the bot will move forward through dynamic wireless charging system. For charging a bot it needs less power, so less input voltage is required.

b) Coil Topologies:

The coils in DWC are made of a copper core surrounded by a layer of insulation. This insulation helps to reduce the amount of heat generated during the charging process. The coils in DWC systems are designed to be able to handle high levels of energy, so that the system can charge an EV quickly and efficiently. Their design must meet a number of criteria, including affordability, effective power transfer and coupling with misalignment. For different shaped coils we get different amount of power will be transferred. For CRP (circular rectangular pad), mainly improves the flux area and the flux leakage in edge can be reduced and the transmission distance is low and charging zone is less. For circular pads (CP), medium amount of power will be transferred and same as rectangular pad coil. HP (horizontal pad) coils the pad weight will be more and charging zone is medium. Because to the parallel field pattern along the ferrite bars, a DD-flux coil's path can be made to be taller and narrower. When the receiver pad is centrally oriented, this architecture behaves poorly in terms of interoperability, just as the CP topology. The DDQP architecture was created to generate both a parallel and perpendicular magnetic field in order to solve this interoperability issue. According to research, the coils width, length, spacing between them, number of turns, and pitch are the design factors that have the biggest impact on how they couple. In contrast to the DDQP topology, the BPP(Bi-polar) pad is a high flexibility architecture that was developed to create parallel and perpendicular fields where the two coils are partially overlapping. The BPP architecture can operate in three different modes: single coil mode, DD mode, and CRP mode, depending on the various current direction activities. So, the multi-mode secondary pad design, which has a lot of potential for wireless EV charging, can effectively be suitable for the BPP topology. Several sorts of topologies could be taken into account in the primary and secondary pad designs depending on certain applications and requirements. The transmission coil and the receiving coil of the DDP-DDQP system, which are five times larger than those of the conventional CP-CP system, can be used to increase the charging zone. So here we used DDQP shaped coils for better power transfer.

	CRP	CP	HP	DDP	DDQP	BPP
Transferrable power	Medium	Medium	Low	High	High	High
Pad weight	Low	Low	High	Low	Medium	Medium
Transmission distance	Low	Low	Medium	Medium	High	High
Charging zone	Small	Small	Medium	Medium	Large	Large

Table 1: Comparison of Various Coil Topologies

c) Coil Design, **H-Bridge Inverter**:

Transmitter coil and receiver coil are components of a wireless charging system used in electric vehicles. One of the coils is on the EV, and the other is either mounted in parking lots or imbedded in the road. The distance between the transmitter and receiver coils is typically a few inches. The two coils must be aligned properly to enhance the efficiency of the wireless charging system. The number of turns in receiver coil is 7 and transmitter coil is 7 and the distance between the coils are 200mm. To provide adequate magnetic coupling for high-power applications, the receiver and transmitter coils are each designed at 500 mm*500 mm. The transmitter coil is placed above the ground which means on ground system where the power can be transferred efficiently without any disturbances. When linked to a source of AC power, The receiver coil transforms the alternating magnetic field that back into energy to operate the vehicle while the transmitter coil produces an alternating magnetic field. A voltage source inverter is used to provide power to the primary winding of the systems using adjusting capacitors during unidirectional operation. A magnetic field is produced by the induced current, and it generates the secondary voltage when paired with the secondary coil. This voltage is rectified and processed before being used to charge the EV battery using a unidirectional DC-DC converter. To manage the flow of power to and from the EV battery in a bidirectional situation, a second inverter must be added to the secondary winding in place of the rectifier and DC-DC converter. There are other suggested inverter topologies, however we choose to employ the voltage source H-bridge (VSHB) inverters. The VSHB inverter converts higher frequency AC power from DC electricity. A VSHB inverter has four semiconductor power switches. Power MOSFETs are popular in WPT applications because of their high switching frequency, positive temperature coefficient, and positive breakdown voltage aspects.

The main component of WPT is coil design.

- It includes an inductor, capacitor, and resistor.

- WPT is based on the magnetic resonance concept provides magnetic resonance offers improved thermal management and multiple device charging.
- For resonance purpose capacitor is used to reduce reactance

Inductor:

The inductance of a coil depends on various parameters such are:

No of turns of transmitter coil- 5

Area of cross section – 12.566

No of turns in receiver coil – 15

Length of the coil – 0.7m

Distance between the two coils – 20cm

Here circular pad topology is used

Inductance of the primary coil

$L_1 = \frac{N1^2 \mu A}{l} = 0.563$ mH

Inductance of the secondary coil

$L_2 = \frac{N2^2 \mu A}{l} = 5.07$ mH

Mutual inductance

$M = \frac{N1N2\mu A}{l} = 1.691$ mH

K is the coupling factor

The coil should be worked under resonance

K = 0.3 [due to air as a medium]

Resonant technology allows wireless power transmission over a long distance with great flexibility and positioning.

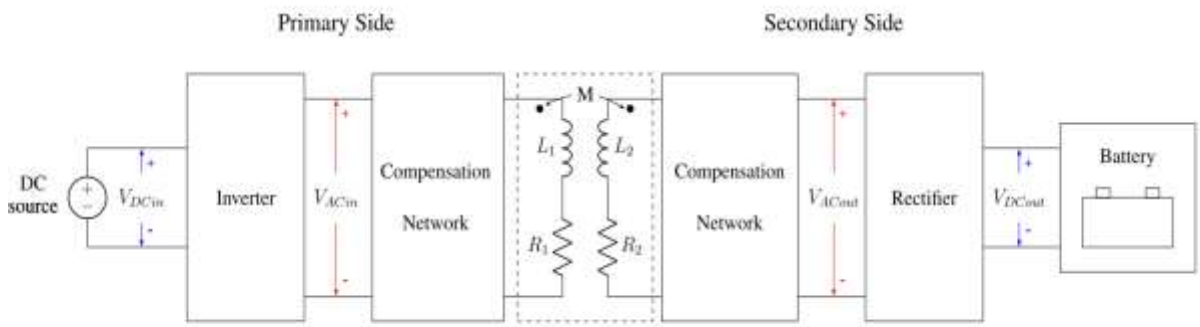

Fig1: Design of a wireless electric vehicle charger with power converters

3.4. Electrified Roads:

Electrified roads are roads that are equipped with an electric power source, usually a rail or cable, to power electric vehicles. Electrified roads enable electric vehicles to travel longer distances without having to be recharged, eliminating the need for large batteries and making long-distance travel more efficient. on roads transmitter coils are placed. The distance between the transmitter coils is 1.5 cm and overlapping of these coils can produce power efficiently. When cars are travelling on rails at a speed restriction of 60 km/h, the two-second rule must be taken into account; the minimum safe distance is 33.33 m. Since EVs typically do not travel at a steady pace, the speed variance has a significant impact on the charging time. Roads can be electrified in two ways: with a single transmitter track or with segmented units. The drawback of single track is that there is only one power source for the entire system, which means that if any fault develops, it would disrupt the entire system. The coupling coefficient is low because the secondary and primary coils of different lengths, which lowers the efficiency of energy transmission and could be dangerous due to the emission of electromagnetic fields outside the linked zone. The WPT system contains a number of coils underneath the roadway track in segment tracks (units) that may be linked to the main supply of power along a certain length. Here long track segmented rails for the road are used. If there is a full or partial electric road, the fuel usage won't change significantly as long as there is adequate electricity available at the segments to charge the batteries.

Fig: Electric lane

RFID Tags:

"Short frequency identification," or RFID, refers to the use of radio frequency technology to quickly identify goods with the use of smart barcodes that are affixed to them. RFID computer software receives data from the tag through radio waves, which are subsequently transmitted to the reader.

When the vehicle gets charged then the Amount for the power consumption units by the vehicle was calculated and charged for the vehicle. The RFID Readers mounted at the toll booth will read the pre-paid RFID tags attached to the vehicles' car windows and automatically deduct the appropriate amount. The toll gate system was built at the end to collect the money from the passenger. The whole process is explained through the flowchart given below.

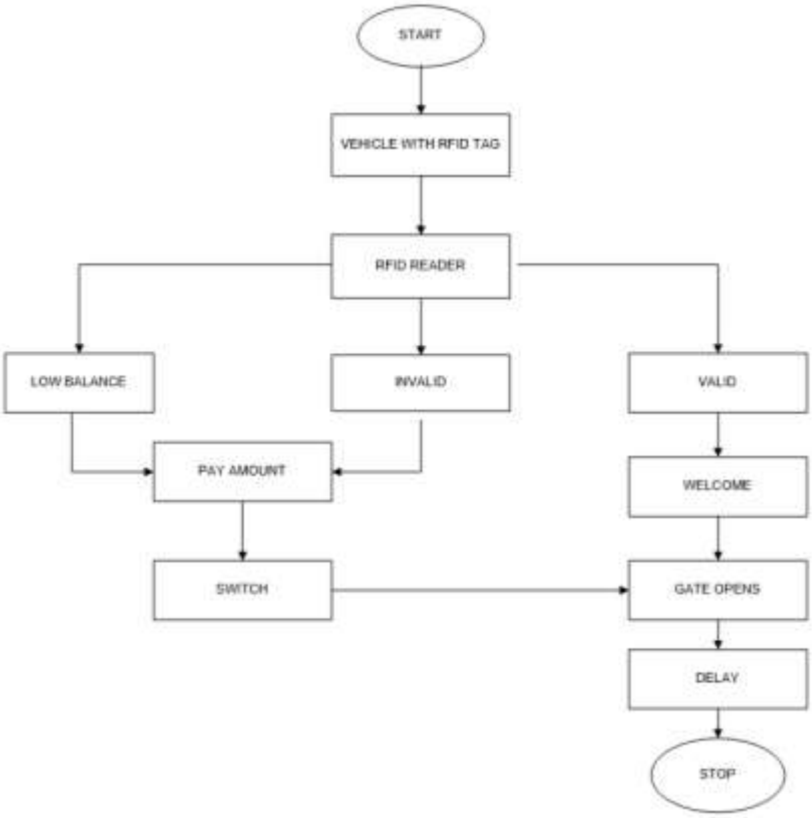

Fig2: FLOWCHART OF RFID

Results and Conclusion

Conclusion:

This research gives an overview of dynamic wireless EV charging through electrified roadways. The switching pattern is DDQ. It is made clear how and where to connect DD coils and Q-shaped coils. H-bridge inverter is used for high frequency power supply. RFID tags are used to collect the amount for charging time and power consumed. This charging system is only used small power applications. For heavy vehicles like buses, trucks large amount of power is requiring so Solar panels are arranged in place of coils on track to charge the vehicle dynamically is our future investigation.

Results:

For different shaped coils we get different amount of power, the output power is mainly depending on the input voltage. overlapping of coils produce power more efficiently. The distance between the coils can also affect the power produced and charging time. The power transfer is different for change in the number of turns of the coil. The charging time will be less if the power will transfer to the vehicle without any power loss. If the speed is high, it is difficult to transfer the power properly.

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